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DISCLAIMERS

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1995 CLIMATOLOGY REVIEW

G. Spoden[1], G. Randall[2], D. Huggins[3], D. Ruschy[4] and D. Baker[4].

Abstract

The material presented is a review of (a) the hydrologic year (Oct. 1994-Sept. 1995) total precipitation and departures from normal, (b) summary of the 1995 growing season soil water changes measured at two stations, and (c) the long-term temperature (1820-1992) and precipitation (1837-1995) trends based on the unique Eastern Minnesota record.

1995 Hydrologic Year Precipitation

The 1995 growing season provided a sharp contrast in climate conditions across Minnesota. Large sections of southern Minnesota received above normal precipitation through the late spring and into the summer. Conversely, some areas of northern Minnesota reported very low precipitation totals. Warm temperatures and unusually high relative humidity were common statewide throughout the summer.

Spells of heat and high humidity occurred during each of the summer months. Many areas set high temperature records on June 17 and 18. Temperatures in the upper 90s and lower 100s were common. The Twin Cities recorded the longest June spell of 90 degree days in history. The very hot weather combined with sparse May and June precipitation in the North to create agronomic crop stress in the Northwest and heightened forest fire potential in the Northeast. Large forest fires occurred in the Boundary Waters Canoe Area in June. The fires returned again in August. Contrary to problems created in the North, extended periods of high temperatures benefited crops in the South. The hot weather accelerated plant development delayed by a cool spring. Another heat spell in mid-July killed several thousand turkeys, and boosted energy demands to all-time highs. The very warm summer temperatures, and an unusually large number of days with dewpoint temperatures in the 70s, may have indirectly contributed to the outbreak of airborne disease in Mankato and Luverne.

July precipitation was above normal over the entire state, temporarily easing the dryness in the North. With the above normal July precipitation came severe weather. High winds, hail, and some tornadoes caused damage in many Minnesota communities. An extremely heavy rainfall event occurred on July 3 and 4 in west central Minnesota, dropping 10 or more inches of rain on northern Chippewa and southern Swift counties. High water covered roads and washed out fields. Intense windstorms downed millions of trees July 13 and 14, affecting an estimated 200,000 acres of forested land from near Detroit Lakes eastward to the Grand Rapids area.

Heavy rains continued into August, especially in the South. By the end of August, many areas of southern Minnesota reported 125 to 150 % of normal precipitation for the warm season. The very wet conditions in the South led to unusually high lake levels and stream flows. The hydrologic imbalances are most notably apparent in those areas dampened by above normal precipitation throughout the 1990s. This decade's unusually heavy precipitation in southern Minnesota is comparable in magnitude (but not in areal extent) to the abnormally wet conditions found during the mid-1980s in southern and central Minnesota. In Fig. 1 is shown the hydrologic year (October 1994-September 1995) total precipitation and Fig. 2 the departure from the 1961-1990 normal. Along the western border the departures range from 2 to 10 inches above normal. Only in NE Minnesota is found a negative departure.

1995 Soil Water Measurements

The above normal precipitation in much of the state is reflected in the soil water content at both the Southwest Experiment Station (Lamberton) and the Southern Experiment Station (Waseca) as shown in Fig. 3 and 4, respectively. The long-term average of the readily available soil water in a 5-foot column of soil under corn is shown for comparison with the 1995 season. At both stations, the soil water indicates a season of generous precipitation. Only briefly at Waseca in the latter part of July was the soil water below the long-term average.

The soil water levels at the end of the 1995 season indicate a well-above average content for the beginning of the 1996 season. The contents appear to be sufficient to carry the crop for some time without replenishment being required. This may be an important feature of the 1996 season in case the spring precipitation should be below normal.

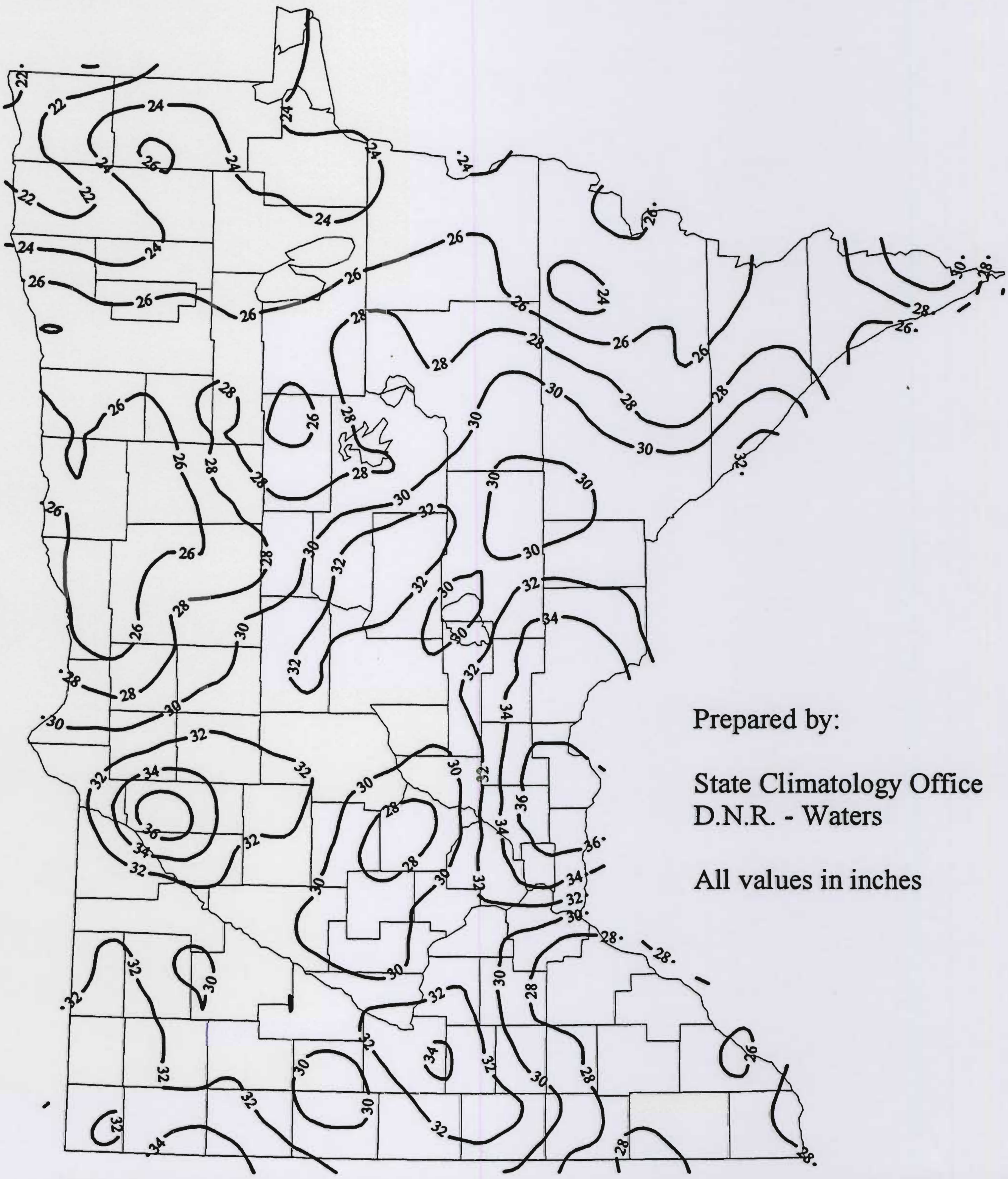
Long-Term Temperature and Precipitation Trends

The final topic in the Climatology Review is the long-term Eastern Minnesota climatic record of temperature, Fig. 5, and precipitation, Fig. 6. These two records consist of the early Fort Snelling record in combination with the Farmington 3NW record at the Akin family farm about 20 miles distant. The annual temperature record shown commenced in 1820. In spite of numerous variations, particularly the 1955-1975 cool period, the temperature has shown an increasing trend since about 1867. The 1955-

[1]State Climatology Office, Dept. Natural Resources
[2]Southern Experiment Station
[3]Southwestern Experiment Station
[4]Dept. Of Soil, Water, and Climate

1975 cool period did lead some observers to believe that the trend was toward a new and world cooling period that would wreak havoc upon world food supplies. However, due to the recovery of the temperature since about 1975 the general consensus concerning our climate has been that a warming trend of equal seriousness is now occurring. It remains to be seen if that trend will continue. Since 1967 the linear trend indicates a mean increase of 2.3°F.

The Eastern Minnesota precipitation record is also based upon the early Fort Snelling record which for precipitation began in 1837. As with the temperature record the current 1961-1990 normal, shown in Fig. 6, is well above the long-term mean. It is also obvious from the smoothed record that above average precipitation has been the "norm" with few exceptions, 1976 and 1988 the major exceptions. There is no reason to believe that the present condition will continue and as a result it is prudent to plan accordingly. That is, to be prepared as best as possible for a time when precipitation totals revert to amounts that are below the current normal.



Data sources: National Weather Service, Soil and Water Conservation Districts, DNR - Forestry, Metro Mosquito Control District, DNR/NWS Backyard Rain Gauge Network, Minnesota Association of Watersheds, Minnesota Power and Light, Deep Portage Conservation District, Metropolitan Waste Control Commission

Fig.1. Hydrologic year (October, 1994 - September, 1995) total precipitation.

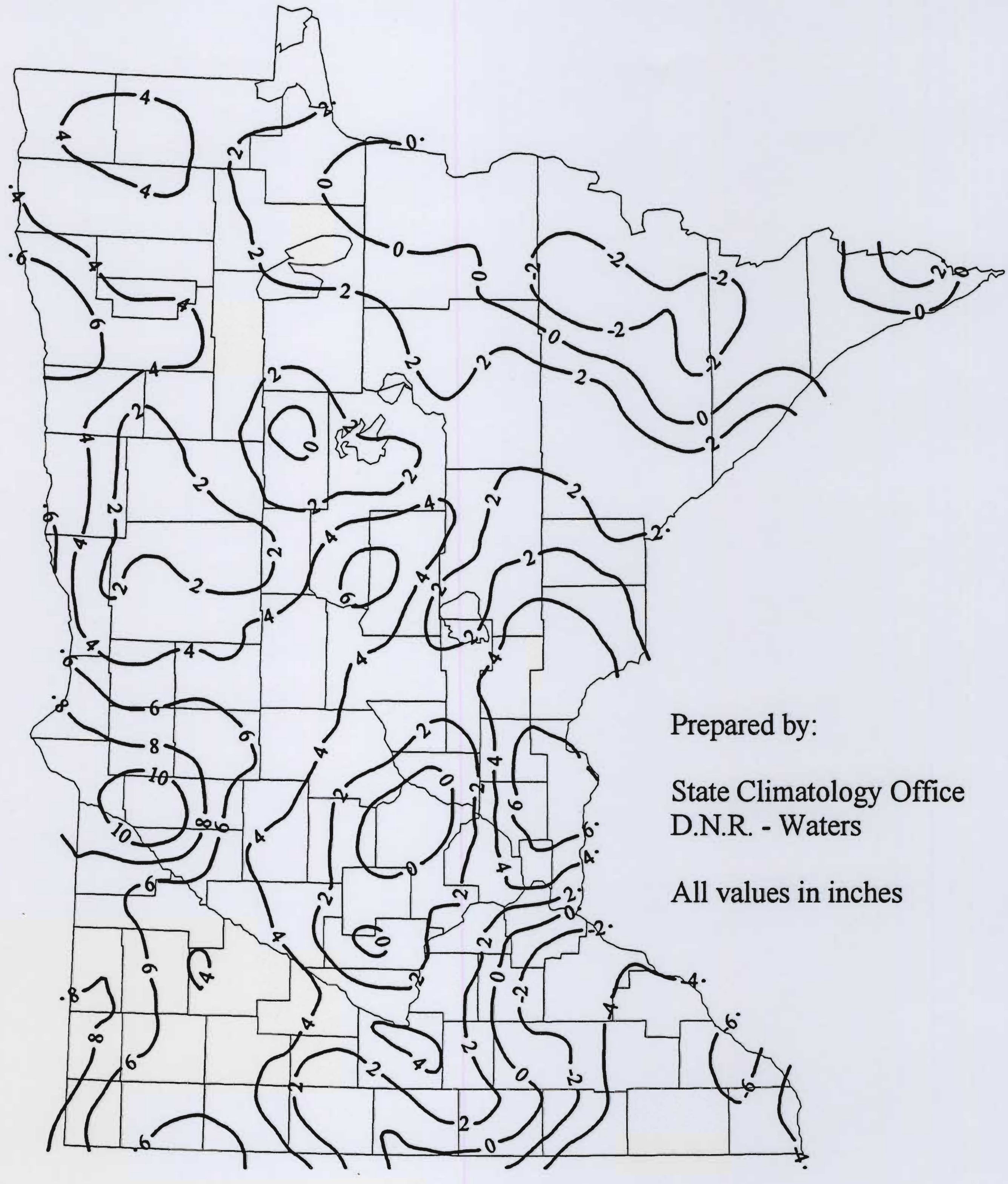


Fig. 2. Hydrologic year (October, 1994 - September, 1995) precipitation departure from normal (1961-1990).

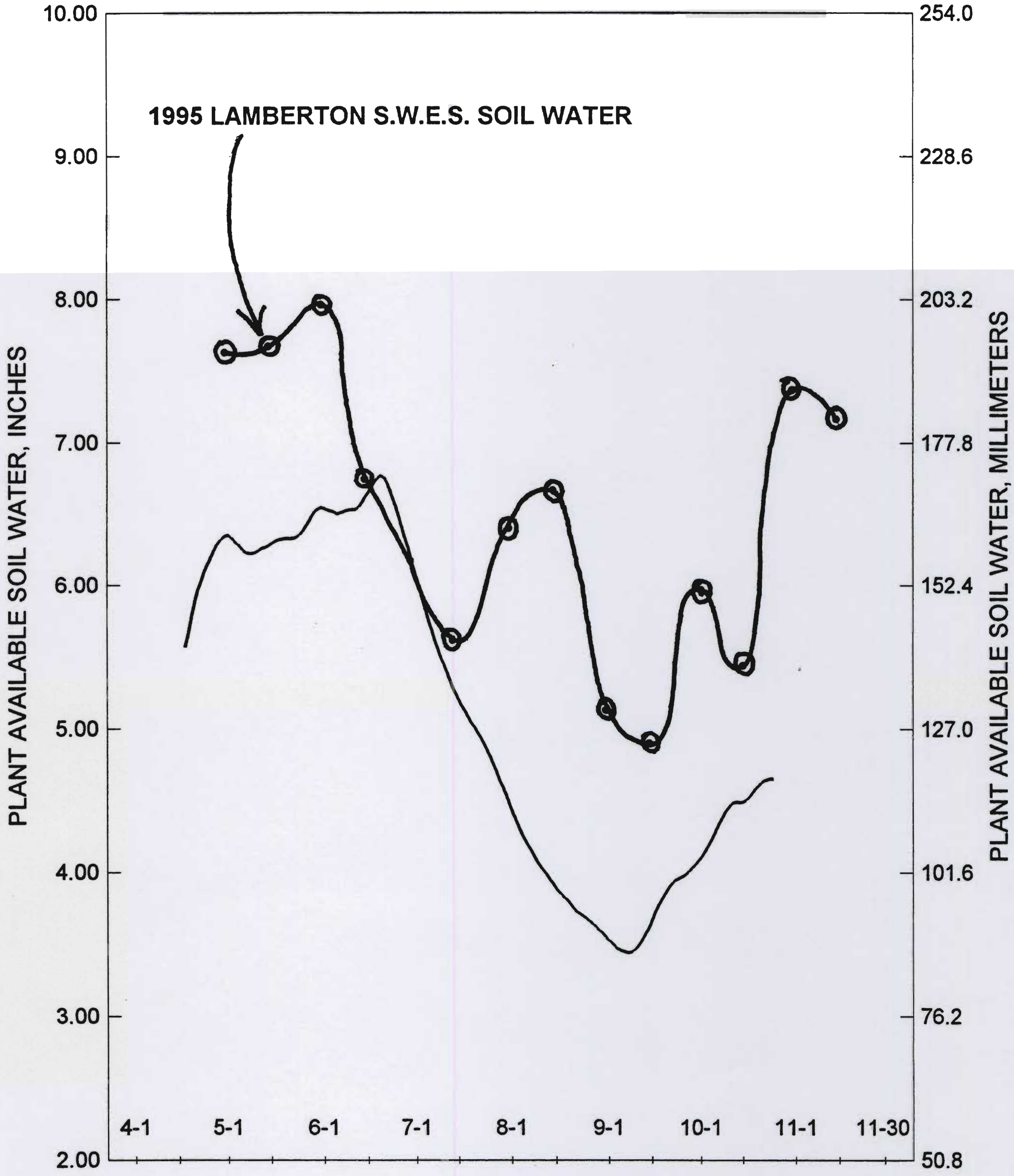


Fig. 3. Total plant available soil water in a 5-foot column of soil under corn at the Lamberton S.W.E.S. in 1995 shown against the 1964-1995 average.

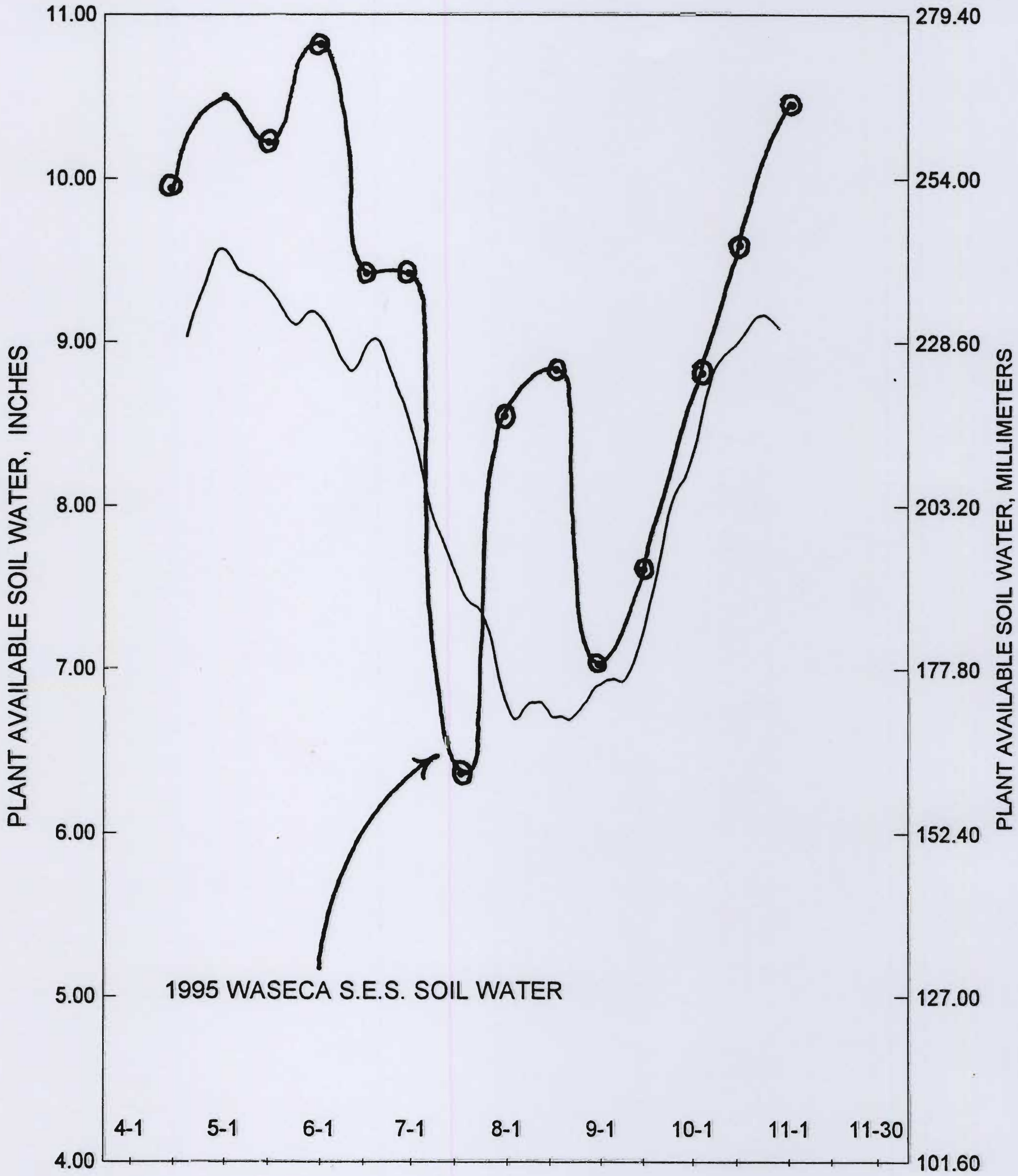


Fig. 4. Total plant available soil water in a 5-foot column of soil under corn at the Waseca S.E.S in 1995 shown against the 1977-1995 average.

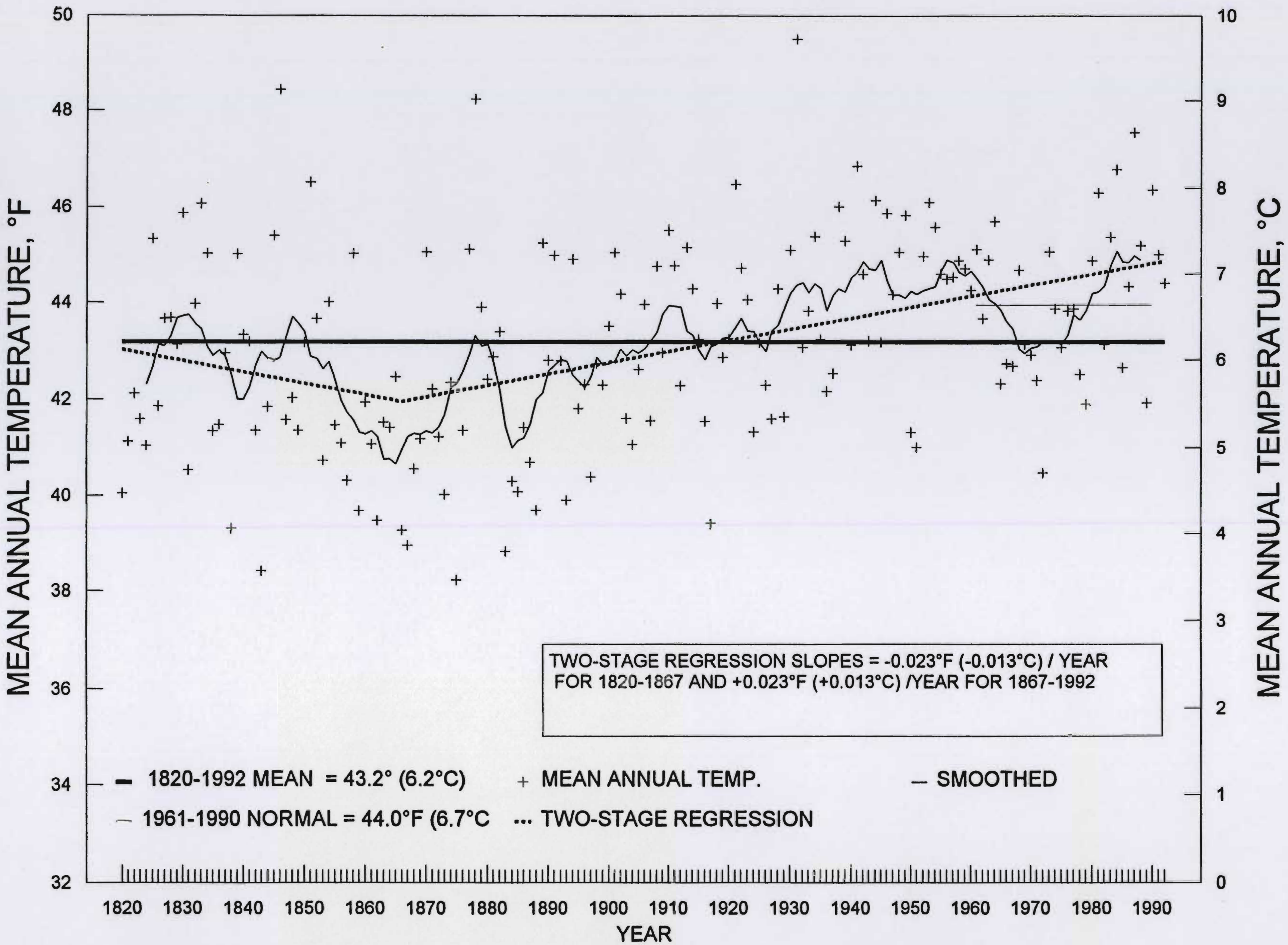


Fig. 5. Eastern Minnesota mean annual temperature for the years 1820-1992.

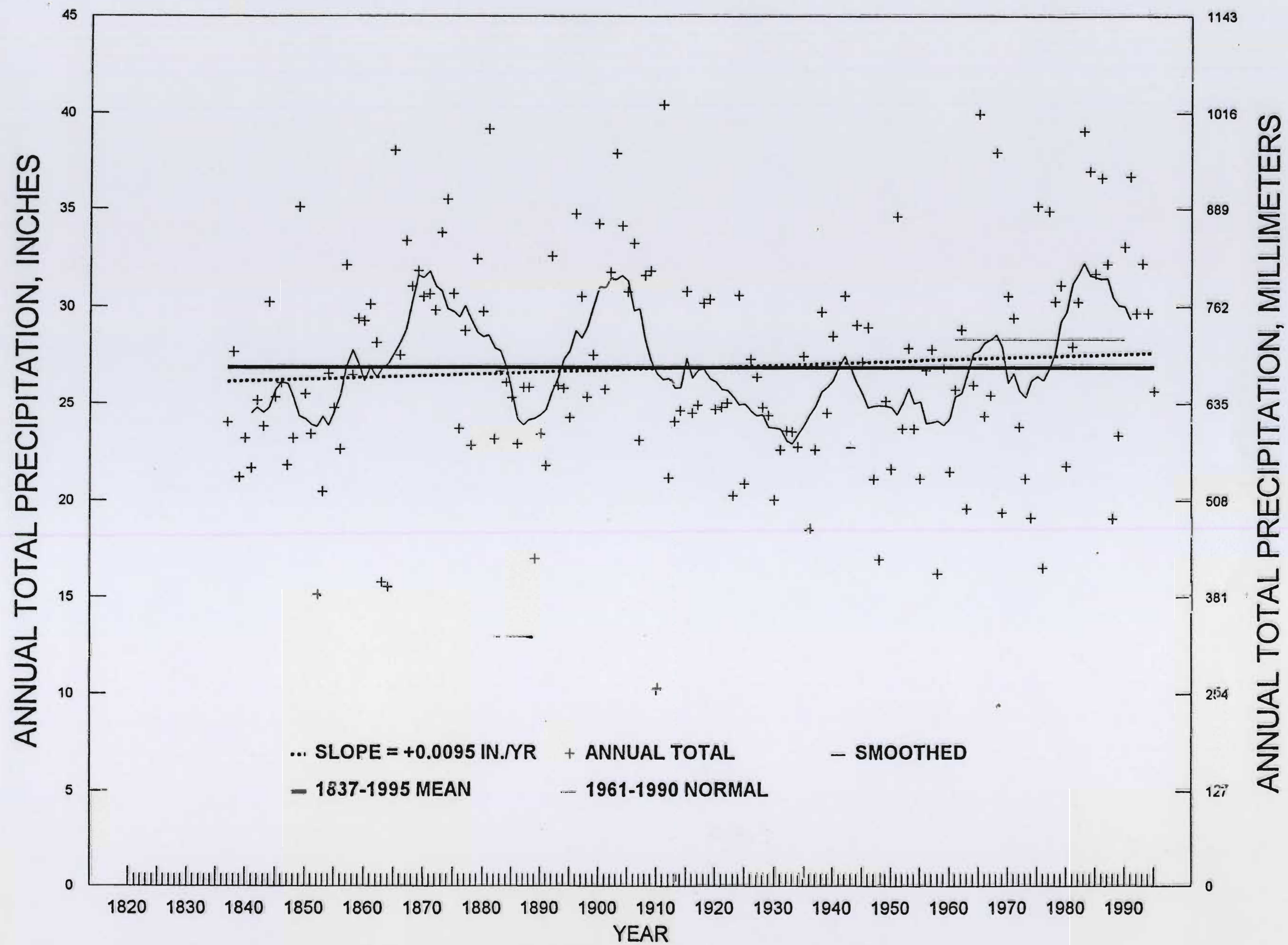


Fig. 6. Eastern Minnesota annual precipitation for the years 1837-1995.

POTATO CULTIVAR RESPONSE TO NITROGEN ON AN IRRIGATED SOIL - 1995[1]

Carl J. Rosen, Dave Birong, and Wenshan Wang[2]

Abstract: The first year of a three year field study was conducted at the Sand Plain Research Farm at Becker to determine the effects of nitrogen rate and timing on yield of Norland, Snowden, Goldrush, and Russet Burbank potatoes. For early harvest Norland, increasing nitrogen rate from 125 lb N/A to 285 lb N/A decreased total yield and larger size tubers. Higher rates of N applied at planting tended to increase tuber size; although the trend was inconsistent. For Snowden, increasing N rate from 125 lb N/A to 285 lb N/A decreased total yield. Increasing N rate had no effect on total yield of Goldrush, but tended to decrease tubers in the 3-6 oz category and increase tubers in the greater than 12 oz category. For Russet Burbank, increasing N rate from 125 lb N/A to 285 lb N/A tended to decrease total yield; although this yield decrease was primarily due to lower production of undersized tubers (< 6 oz). Russet Burbank tuber size was optimized at the 245 lb N/A rate. At equivalent total N rates, post-hilling N applications had no effect on tuber yield or quality. The petiole nitrate test on both a dry weight and sap basis was useful for measuring the N status of the crop. For Norland, Snowden and Goldrush, petiole nitrate-N concentrations less than 0.5% on a dry weight basis and 600 ppm on a sap basis in mid-July were associated with the highest yields. For Russet Burbank, highest yields were associated with a petiole nitrate-N concentration of 1.7% on a dry weight basis and 1200 ppm on a sap basis during tuber bulking.

Potatoes are a relatively shallow rooted crop, often supplied with high rates of nitrogen to promote growth and yield. High rates of nitrogen are used because of the potential for increased yield and a high rate of return compared to the cost of nitrogen applied. Because of the higher profit margin with potatoes, there is the temptation to use higher rates of nitrogen as insurance against loss of yield. The shallow root system of potatoes, high nitrogen requirement, and production on sandy soils greatly increase the potential of nitrate contamination of shallow aquifers under irrigated potato production. This environmental concern has prompted research to identify management practices that will minimize nitrate losses to groundwater. Recent studies with Russet Burbank have shown that timing of nitrogen application can have a dramatic effect on nitrogen use efficiency by the potato crop. Delaying most of the nitrogen until after emergence decreased nitrate concentrations in the soil water below the root zone by over 50%. Use of the petiole nitrate sap test to schedule N application after hilling for late season varieties has also shown promise for improving nitrogen use. While great strides have been made in understanding the nitrogen requirement of potatoes and reducing nitrate losses, improvements in N use efficiency can still be made. Areas that need attention are: determining N response of varieties other than Russet Burbank, and fine-tune the sap test calibration for Russet Burbank as well as other potato varieties. Specific objectives of this study were to: 1) evaluate nitrogen rate and time of application on Norland yield and quality, 2) characterize nitrogen response and calibrate the petiole nitrate sap test for Snowden, Goldrush, Russet Burbank, and Norland.

Materials and Methods

The experiment was conducted at the Sand Plain Research Farm in Becker, Minnesota on a Hubbard sandy loam. Selected chemical properties in the 0-6" depth were as follows: pH, 5.5; Bray P, 30 ppm; and NH_4OAc K, 110 ppm. An average of 9 lb nitrate-N was available in the top 2 ft prior to planting. Each variety was tested in separate strips. For Russet Burbank, Snowden, and Goldrush, five of the six N treatments were: 125, 165, 205, 245, and 285 lb N/A. All nitrogen was applied in three split applications: 25 lb N/A at planting and the remainder split equally between emergence and hilling. The sixth treatment was a post-hilling treatment where 160 lb N/A was applied through hilling as described above followed by 80 lb N/A post-hilling (40 lb N/A June 22 and 40 lb N/A July 6). For Norland, twelve N treatments were evaluated. The first five were the same as described above for the other varieties, the remaining seven treatments were designed to evaluate the effect of starter N on yield. Various times of application were evaluated at 165 and 205 lb N/A. Specific timing of N application for each treatment for Norland is shown in Table 1.

For each variety, treatments were replicated 4 times in a randomized complete block design. Spacing was 10" in the row and 36" between rows for all varieties. Each plot was 4 rows wide and 20 feet in length. Norland "B" size and Goldrush "A" size cut seed potatoes were planted by hand on April 24, 1995. Snowden "B" size and Russet Burbank "A" size cut seed potatoes were planted on April 25. Admire was applied in furrow for Colorado potato beetle control. Emergence N was applied on May 23 and hilling N was applied on June 9. Petioles were sampled at two week intervals starting June 19. Norland petioles were collected at three

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[1]Funding for this research was provided by a grant from the Area 2 Potato Research Council.

[2]Extension Soil Scientist, Assistant Scientist, and Visiting Scholar respectively, Dept. of Soil, Water and Climate.

sampling dates and petioles from the other varieties were collected at five sampling dates. Half of the petioles collected were crushed to express the sap for quick nitrate determination using a Cardy meter, and the remainder were dried for conventional nitrate determination. Norland vines were killed July 17 and tubers were harvested July 18. Snowden vines were killed August 16 and tubers harvested August 17. Goldrush vines were killed August 22 and tubers were harvested August 28. Russet Burbank vines were killed September 13 and tubers were harvested September 18. At each harvest, total yield, graded yield, tuber specific gravity, and internal disorders were recorded. Total dry matter and nitrogen content of vines and tubers were also determined to calculate total nitrogen uptake by the crop. Irrigation was provided according to the checkbook method. Rainfall and irrigation on a weekly basis is provided in Figure 1.

Results

Norland: Norland tuber and vine yield is presented in Table 1. In general, increasing nitrogen rate from 125 lb N/A to 285 lb N/A decreased total yield and larger size tubers. Higher rates of N applied at planting tended to increase tuber size; although the trend was inconsistent. Surprisingly, neither N rate nor timing significantly affected vine yield. However, there was a trend for more vines with higher N rate and with reduced N in the starter. Growth cracks were not affected by treatment. Incidence of hollow heart increased with increasing N in the starter. Effects of N rate and timing need to be evaluated on a late harvested Norland crop as well as an early crop to determine if N rate/timing response varies with harvest date. While sap testing or petiole analysis to predict N needs of Norland potatoes is not practical due to the early harvest date, petioles levels of nitrate-N were related to early harvest yield, particularly the day before vine killing on July 17 (Table 2). Yields seemed to be optimized when petiole nitrate was low. Levels of petiole nitrate-N above 0.5% on a dry weight basis or 600 ppm on a sap basis were associated with lower yield. These results suggest that the petiole nitrate test may be a useful tool for timing of harvest. Nitrogen content of Norland tubers ranged from 63 to 81 lb N/A and was not affected by N treatment (Table 3). The N content of vines ranged from 35 to 73 lb N/A and increased with increasing N rate and decreasing amount of N in the starter. Total N content of the vine and tuber ranged from 99 to 155 lb N/A and was generally not affected by N treatment except for a lower N uptake with increasing N in the starter at the 165 lb N/A rate. This trend was not observed at the 205 lb N/A rate. Tuber dry matter increased with decreasing N rate and increasing N in the starter.

Snowden: Snowden tuber and vine yield is presented in Table 4. Increasing N rate from 125 lb N/A to 285 lb N/A decreased total yield. Vine growth increased with increasing N rate. At equivalent N rates, post-hilling N did not significantly affect tuber yield or vine growth. Specific gravity decreased with increasing N rate, while hollow heart incidence was not affected. Petiole nitrate on a dry weight or sap basis increased with increasing N rate at all sampling dates (Table 5). Under the conditions of this experiment, where the Snowden crop was harvested early, highest yields were associated with lower levels of petiole nitrate-N. On July 11, highest yields were associated with less than 0.5% on a dry weight basis and less than 700 ppm on a sap basis. Nitrogen content of Snowden tubers ranged from 86 to 103 lb N/A with no effect due to N treatment (Table 6). The N content of vines ranged from 16 to 52 lb N/A and increased with increasing N rate. Total N content of the vine plus tuber ranged from 119 to 147 lb N/A and increased with increasing N rate. At equivalent N rates, posthilling N applications did not affect N content of the tubers or vines. Tuber dry matter accumulation decreased with increasing fertilizer N.

Goldrush: Goldrush tuber and vine yield is presented in Table 7. Increasing N rate had no effect on total yield, but tended to decrease tubers in the 3-6 oz category and increase tubers in the greater than 12 oz category. Vine growth increased with increasing N rate. Hollow heart incidence was not affected by N rate. Specific gravity decreased with increasing N rate. Post-hilling nitrogen had no effect on total yield, but tended to decrease tubers in the 3-6 oz category. Petiole nitrate on a dry weight or sap basis increased at all sampling dates with increasing N rate (Table 8). Highest yields were associated with lower levels of petiole nitrate-N, which may have been due to early dieback of the vines. On July 11, highest yields were associated with less than 0.5% on a dry weight basis and less than 700 ppm on a sap basis. Nitrogen content of Goldrush tubers ranged from 69 to 103 lb N/A with inconsistent effects due to N treatment (Table 9). The N content of vines ranged from 9 to 24 lb N/A and increased with increasing N rate. The low N accumulation in vines was due to early dieback. Total N content of the vine plus tuber ranged from 93 to 121 lb N/A. Overall, N rate had inconsistent effects on N accumulation by the crop. At equivalent N rates, posthilling N applications did not affect N content of the tubers or vines. Tuber dry matter decreased with increasing fertilizer N.

Russet Burbank: Russet Burbank tuber and vine yield is presented in Table 10. Decreasing N rate from 125 lb N/A to 285 lb N/A tended to increase total yield; although, this yield increase was primarily due to increases in undersized tubers (< 6 oz). Tuber size was optimized at the 245 lb N/A rate. Nitrogen treatments had no effect on specific gravity or hollow heart incidence. Vine yield increased with increasing N rate. At equivalent N rates, post-hilling N had no effect on tuber yield or quality. Overall quality of Russet Burbank tubers from this study was poor with a large portion of undersized tubers being produced.

The high yield of undersized tubers was most likely the result of heat stress causing a second tuber set. Petiole nitrate on a dry weight or sap basis increased at all sampling dates with increasing N rate (Table 11). On July 11, marketable yields were associated with petiole nitrate-N of 1.7% on a dry weight basis and 1200 ppm on a sap basis. Nitrogen content of Russet Burbank tubers ranged from 76 to 100 lb N/A with no effect due to N treatment (Table 12). The N content of vines ranged from 5 to 20 lb N/A and increased with increasing N rate. Total N content of the vine plus tuber ranged from 82 to 118 lb N/A and increased with increasing N rate. At equivalent N rates, posthilling N applications did not affect N content of the tubers but tended to increase N content of the vines. Tuber dry matter accumulation decreased with increasing fertilizer N.

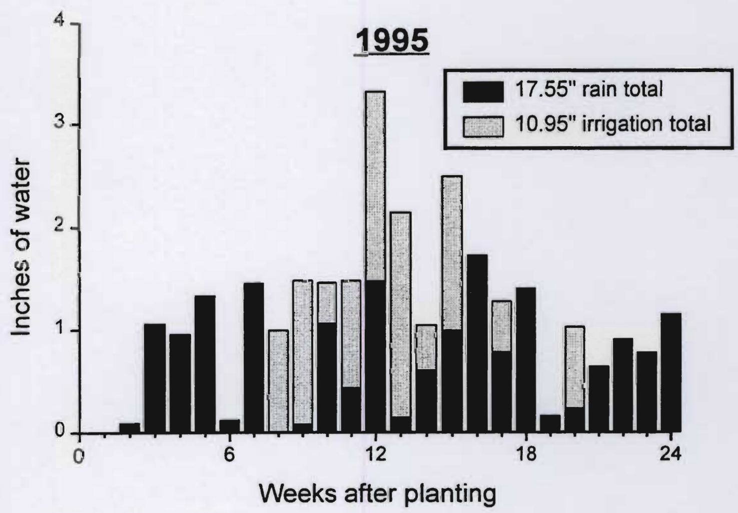

Figure 1. Rainfall and irrigation at Becker, MN during the 1995 growing season.

Table 1. Effect of nitrogen treatments on Norland fresh weight of vines, tubers, and quality. Becker, MN.

Treatment			Fresh weight								Growth Cracks	Hollow Heart
	N total	N timing	Vine	<1½"	1½-1⅞"	1⅞-2¼"	2¼-2½"	2½-3"	>3"	Total		
			Tons/A	cwt/A							% incidence	
1.	125	(25,50,50)[1]	8.12	7.7	14.2	108.5	92.1	92.8	20.4	335.7	3.0	2.0
2.	165	(25,70,70)	8.06	9.3	21.3	116.7	91.7	70.7	20.1	329.8	1.0	3.0
3.	205	(25,90,90)	8.48	9.2	18.8	104.0	75.7	77.4	25.8	310.9	0.0	1.0
4.	245	(25,110,110)	8.29	7.3	17.7	103.2	72.2	81.0	23.9	305.3	3.0	5.0
5.	285	(25,130,130)	8.73	8.6	18.1	94.8	71.9	66.5	26.8	286.7	5.0	1.0
6.	165	(45,60,60)	8.25	10.3	16.5	102.8	83.6	82.5	27.3	323.0	1.3	5.3
7.	165	(65,50,50)	7.40	8.9	16.3	111.5	103.9	83.3	16.2	340.1	3.0	5.0
8.	165	(85,40,40)	7.03	8.9	20.8	130.5	92.6	82.4	14.3	349.5	4.0	9.0
9.	205	(45,80,80)	7.94	12.2	19.6	104.3	84.2	77.8	17.6	315.7	3.0	2.0
10.	205	(65,70,70)	8.48	8.0	19.5	104.6	84.0	73.2	26.4	315.7	1.0	1.0
11.	205	(85,60,60)	7.43	7.7	17.4	109.7	100.5	79.5	22.8	337.6	4.0	6.0
12.	205	(65,90,50)	8.11	8.1	18.0	105.6	91.2	74.6	23.6	321.1	3.0	8.0
Significance			NS	NS	NS	NS	*	NS	NS	++	NS	++
BLSD (0.05)			--	--	--	--	23.6	--	--	48.6	--	7.5
Contrasts												
Lin Rate N (1, 2, 3, 4, 5)			NS	NS	NS	++	**	++	NS	**	NS	NS
Quad Rate N (1, 2, 3, 4, 5)			NS	NS	++	NS	NS	NS	NS	NS	*	NS
Lin Rate N (2, 6, 7, 8)			++	NS	NS	NS	NS	NS	NS	NS	++	++
Quad Rate N (2, 6, 7, 8)			NS	NS	*	*	NS	NS	NS	NS	NS	NS
Lin Rate N (3, 9, 10, 11)			NS	NS	NS	NS	*	NS	NS	NS	NS	NS
Quad Rate N (3, 9, 10, 11)			NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Planting rate (3) vs (12)			NS	NS	NS	NS	NS	NS	NS	NS	NS	*

[1] = Planting, emergence and hilling respectively. NS = Nonsignificant; ++, *, ** = significant at 10%, 5% and 1%, respectively.

Table 2. Effect of nitrogen treatments on Norland nitrate-N concentration in potato petioles (dry weight basis) and nitrate concentration in petiole sap, as determined by various procedures. Becker, MN.

Treatment			June 15		June 28		July 17	
	N total	N timing	dry weight Petiole-N	sap Horiba	dry weight Petiole-N	sap Horiba	dry weight Petiole-N	sap Horiba
			ppm NO_3-N					
1.	125	(25,50,50)[1]	19646	1250	14142	1138	4917	513
2.	165	(25,70,70)	19644	1225	15979	1175	6341	657
3.	205	(25,90,90)	20202	1300	17370	1375	11866	875
4.	245	(25,110,110)	20151	1375	18680	1450	17222	1233
5.	285	(25,130,130)	20218	1350	18937	1425	17515	1278
6.	165	(45,60,60)	19965	1250	16179	1100	6980	748
7.	165	(65,50,50)	18568	1225	14084	1042	3706	340
8.	165	(85,40,40)	17662	1075	9563	808	1327	208
9.	205	(45,80,80)	19746	1300	17602	1350	10944	943
10.	205	(65,70,70)	19996	1375	18110	1275	13651	1125
11.	205	(85,60,60)	19069	1225	15466	1125	4946	590
12.	205	(65,90,50)	19920	1250	17252	1150	8207	778
Significance			NS	++	**	**	**	**
BLSD (0.05)			--	220	2622	193	3659	399
Contrasts								
Lin Rate N (1, 2, 3, 4, 5)			NS	++	**	**	**	**
Quad Rate N (1, 2, 3, 4, 5)			NS	NS	NS	NS	NS	NS
Lin Rate N (2, 6, 7, 8)			NS	++	**	**	**	**
Quad Rate N (2, 6, 7, 8)			NS	NS	*	NS	NS	NS
Lin Rate N (3, 9, 10, 11)			NS	NS	NS	*	**	NS
Quad Rate N (3, 9, 10, 11)			NS	NS	NS	NS	**	*
Planting rate (3) vs (12)			NS	*	NS	*	++	NS

[1] = Planting, emergence and hilling respectively. NS = Nonsignificant; ++, *, ** = significant at 10%, 5% and 1%, respectively.

Table 3. Effect of nitrogen treatments on Norland nitrogen content, concentration and dry matter production. Becker, MN.

Treatment			Nitrogen content			N concentration		Dry matter		
	N total	N timing	Vine	Tuber	Total	Vine	Tuber	Vine	Tuber	Total
			lbs/A			% N		Tons/A		
1.	125	(25,50,50)[1]	48.7	71.6	120.3	2.75	1.47	0.88	2.43	3.31
2.	165	(25,70,70)	55.9	70.9	126.8	3.36	1.58	0.85	2.26	3.11
3.	205	(25,90,90)	57.3	73.8	131.1	3.42	1.64	0.83	2.24	3.07
4.	245	(25,110,110)	59.8	72.6	132.4	3.65	1.68	0.82	2.14	2.96
5.	285	(25,130,130)	69.1	65.6	134.7	3.95	1.66	0.89	1.99	2.88
6.	165	(45,60,60)	59.9	72.0	131.9	3.34	1.63	0.88	2.21	3.09
7.	165	(65,50,50)	44.8	68.9	113.7	2.92	1.45	0.77	2.39	3.16
8.	165	(85,40,40)	35.8	63.0	98.8	2.37	1.19	0.75	2.66	3.41
9.	205	(45,80,80)	55.8	68.1	123.9	3.31	1.63	0.84	2.13	2.97
10.	205	(65,70,70)	73.2	82.1	155.3	3.80	1.82	0.96	2.26	3.22
11.	205	(85,60,60)	48.2	81.2	129.4	3.24	1.57	0.75	2.59	3.34
12.	205	(65,90,50)	62.0	67.7	129.7	3.45	1.62	0.88	2.10	2.98
Significance			*	NS	**	**	*	NS	*	NS
BLSD (0.05)			24.6	--	23.7	0.64	0.38	--	0.51	--
Contrasts										
Lin Rate N (1, 2, 3, 4, 5)			*	NS	NS	**	NS	NS	*	*
Quad Rate N (1, 2, 3, 4, 5)			NS	NS	NS	NS	NS	NS	NS	NS
Lin Rate N (2, 6, 7, 8)			*	NS	**	**	**	NS	*	NS
Quad Rate N (2, 6, 7, 8)			NS	NS	NS	NS	NS	NS	NS	NS
Lin Rate N (3, 9, 10, 11)			NS	NS	NS	NS	NS	NS	++	NS
Quad Rate N (3, 9, 10, 11)			++	NS	NS	NS	NS	NS	NS	NS
Planting rate (3) vs (12)			NS	NS	NS	NS	NS	NS	NS	NS

[1] = Planting, emergence and hilling respectively. NS = Nonsignificant; ++, *, ** = significant at 10%, 5% and 1%, respectively.

Table 4. Effect of nitrogen treatments on Snowden fresh weight of vines, tubers, and quality. Becker, MN.

	Treatment		Fresh weight						Specific	Hollow
			Vine	<1⅞"	1⅞-2½"	2½-3"	>3"	Total	Gravity	Heart-%
	N total	N timing	Tons/A	cwt/A						incidence
1.	125	(25,50,50)[1]	5.40	14.1	209.8	150.2	40.0	414.1	1.0896	5.0
2.	165	(25,70,70)	7.21	17.4	191.3	145.5	29.2	383.4	1.0883	5.0
3.	205	(25,90,90)	7.74	14.4	182.1	158.3	30.6	385.4	1.0875	4.0
4.	245	(25,110,110)	7.80	14.5	172.8	146.1	27.5	360.9	1.0879	2.0
5.	285	(25,130,130)	8.67	17.3	164.9	128.4	38.6	349.2	1.0869	4.0
6.	245	(25,70,70)+80[2]	8.24	16.9	169.4	127.0	34.6	347.9	1.0880	4.0
Significance			**	NS	++	++	NS	**	NS	NS
BLSD (0.05)			1.31	--	37.2	27.3	--	37.6	--	--
Contrasts										
Lin Rate N (1, 2, 3, 4, 5)			**	NS	**	++	NS	**	*	NS
Quad Rate N (1, 2, 3, 4, 5)			NS	NS	NS	++	NS	NS	NS	NS
Post-hilling (4) vs (6)			NS	NS	NS	NS	NS	NS	NS	NS

[1] = Planting, emergence and hilling respectively. [2] = Two post-hilling applications at 40 pounds N/A each.
NS = Nonsignificant; ++, *, ** = significant at 10%, 5% and 1%, respectively.

Table 5. Effect of nitrogen treatments on Snowden nitrate-N concentration in potato petioles (dry weight basis) and nitrate concentration in petiole sap, as determined by various procedures. Becker, MN.

	Treatment		Date					
			June 19		June 29		July 11	
			dry weight Petiole-N	sap Horiba	dry weight Petiole-N	sap Horiba	dry weight Petiole-N	sap Horiba
	N total	N timing	ppm NO_3-N					
1.	125	(25,50,50)[1]	18916	1500	13156	1090	4011	610
2.	165	(25,70,70)	20544	1700	18331	1450	11108	1203
3.	205	(25,90,90)	20780	1675	19144	1425	15536	1375
4.	245	(25,110,110)	20846	1700	20499	1600	17449	1575
5.	285	(25,130,130)	21755	1775	21254	1675	21293	1725
6.	245	(25,70,70)+80[2]	20433	1650	20514	1550	20772	1600
Significance			*	**	**	**	**	**
BLSD (0.05)			1576	108	1808	127	2491	186
Contrasts								
Lin Rate N (1, 2, 3, 4, 5)			**	**	**	**	**	**
Quad Rate N (1, 2, 3, 4, 5)			NS	NS	**	*	*	**
Post-hilling (4) vs (6)			NS	NS	NS	NS	*	NS

[1] = Planting, emergence and hilling respectively. [2] = Two post-hilling applications at 40 pounds N/A each.
NS = Nonsignificant; ++, *, ** = significant at 10%, 5% and 1%, respectively.

Table 5 cont. Effect of nitrogen treatments on Snowden nitrate-N concentration in potato petioles (dry weight basis) and nitrate concentration in petiole sap, as determined by various procedures. Becker, MN.

	Treatment		Date			
			July 25		August 8	
			dry weight Petiole-N	sap Horiba	dry weight Petiole-N	sap Horiba
	N total	N timing	ppm NO_3-N			
1.	125	(25,50,50)[1]	783	305	929	198
2.	165	(25,70,70)	3047	568	1540	285
3.	205	(25,90,90)	4557	630	2781	335
4.	245	(25,110,110)	9328	1110	6109	640
5.	285	(25,130,130)	12842	1375	9805	943
6.	245	(25,70,70)+80[2]	9682	983	6496	655
Significance			**	**	**	**
BLSD (0.05)			1907	233	3320	233
Contrasts						
Lin Rate N (1, 2, 3, 4, 5)			**	**	**	**
Quad Rate N (1, 2, 3, 4, 5)			*	NS	++	*
Post-hilling (4) vs (6)			NS	NS	NS	NS

[1] = Planting, emergence and hilling respectively. [2] = Two post-hilling applications at 40 pounds N/A each.
NS = Nonsignificant; ++, *, ** = significant at 10%, 5% and 1%, respectively.

Table 6. Effect of nitrogen treatments on Snowden nitrogen content, concentration and dry matter production. Becker, MN.

Treatment			Nitrogen content			N concentration		Dry matter		
			Vine	Tuber	Total	Vine	Tuber	Vine	Tuber	Total
	N total	N timing	lbs/A			% N		Tons/A		
1.	125	(25,50,50)[1]	15.9	102.9	118.8	1.59	1.11	0.49	4.64	5.13
2.	165	(25,70,70)	26.3	96.1	122.4	1.92	1.10	0.68	4.39	5.07
3.	205	(25,90,90)	35.2	96.0	131.2	2.17	1.16	0.81	4.10	4.91
4.	245	(25,110,110)	45.1	95.9	141.0	2.71	1.23	0.84	3.88	4.72
5.	285	(25,130,130)	52.2	94.8	147.0	2.86	1.20	0.91	3.94	4.85
6.	245	(25,70,70)+80[2]	45.0	86.4	131.4	2.56	1.11	0.88	3.87	4.75
Significance			**	NS	NS	**	NS	**	++	NS
BLSD (0.05)			9.7	--	--	0.43	--	0.17	0.72	--
Contrasts										
Lin Rate N (1, 2, 3, 4, 5)			**	NS	*	**	NS	**	**	NS
Quad Rate N (1, 2, 3, 4, 5)			NS	NS	NS	NS	NS	NS	NS	NS
Post-hilling (4) vs (6)			NS	NS	NS	NS	NS	NS	NS	NS

[1] = Planting, emergence and hilling respectively. [2] = Two post-hilling applications at 40 pounds N/A each.
NS = Nonsignificant; ++, *, ** = significant at 10%, 5% and 1%, respectively.

Table 7. Effect of nitrogen treatments on Goldrush fresh weight of vines, tubers, and quality. Becker, MN.

Treatment			Fresh weight							Specific	Hollow
			Vine	Knobs	<3 oz	3-6 oz	6-12 oz	>12 oz	Total	Gravity	Heart-%
	N total	N timing	Tons/A	cwt/A							incidence
1.	125	(25,50,50)[1]	2.43	12.7	63.5	134.5	186.3	28.6	425.5	1.0692	4.0
2.	165	(25,70,70)	3.10	14.5	59.8	117.9	179.0	52.3	423.5	1.0688	4.0
3.	205	(25,90,90)	3.83	22.5	42.7	107.7	167.2	47.3	387.5	1.0655	5.0
4.	245	(25,110,110)	3.80	16.5	59.6	104.7	162.1	62.5	405.4	1.0635	3.0
5.	285	(25,130,130)	4.26	20.4	48.6	82.5	185.1	52.6	389.1	1.0650	2.0
6.	245	(25,70,70)+80[2]	3.18	19.3	65.3	86.9	161.0	49.2	381.7	1.0659	3.0
Significance			NS	NS	++	**	NS	NS	NS	**	NS
BLSD (0.05)			--	--	20.2	17.6	--	--	--	0.0030	--
Contrasts											
Lin Rate N (1, 2, 3, 4, 5)			**	NS	NS	**	NS	++	NS	**	NS
Quad Rate N (1, 2, 3, 4, 5)			NS	NS	NS	NS	NS	NS	NS	NS	NS
Post-hilling (4) vs (6)			NS	NS	NS	++	NS	NS	NS	NS	NS

[1] = Planting, emergence and hilling respectively. [2] = Two post-hilling applications at 40 pounds N/A each.
NS = Nonsignificant; ++ and ** = significant at 10% and 1%, respectively.

Table 8. Effect of nitrogen treatments on Goldrush nitrate-N concentration in potato petioles (dry weight basis) and nitrate concentration in petiole sap, as determined by various procedures. Becker, MN.

Treatment			Date					
			June 19		June 29		July 11	
			dry weight Petiole-N	sap Horiba	dry weight Petiole-N	sap Horiba	dry weight Petiole-N	sap Horiba
	N total	N timing	ppm NO_3-N					
1.	125	(25,50,50)[1]	19812	1500	14878	1200	4775	533
2.	165	(25,70,70)	21778	1675	18177	1400	9865	840
3.	205	(25,90,90)	21396	1625	19751	1475	13138	1075
4.	245	(25,110,110)	21446	1675	21392	1600	17016	1375
5.	285	(25,130,130)	22834	1675	21456	1600	18646	1450
6.	245	(25,70,70)+80[2]	21938	1625	20452	1575	17600	1400
Significance			NS	**	**	**	**	**
BLSD (0.05)			--	87	1759	108	2497	82
Contrasts								
Lin Rate N (1, 2, 3, 4, 5)			++	**	**	**	**	**
Quad Rate N (1, 2, 3, 4, 5)			NS	++	*	*	++	**
Post-hilling (4) vs (6)			NS	NS	NS	NS	NS	NS

[1] = Planting, emergence and hilling respectively. [2] = Two post-hilling applications at 40 pounds N/A each.
NS = Nonsignificant; ++, *, ** = significant at 10%, 5% and 1%, respectively.

Table 8 cont. Effect of nitrogen treatments on Goldrush nitrate-N concentration in potato petioles (dry weight basis) and nitrate concentration in petiole sap, as determined by various procedures.

Treatment			Date: July 25, dry weight Petiole-N	July 25, sap Horiba	August 8, dry weight Petiole-N	August 8, sap Horiba
	N total	N timing	ppm NO_3-N			
1.	125	(25,50,50)[1]	1639	268	1297	295
2.	165	(25,70,70)	5368	473	3335	403
3.	205	(25,90,90)	6914	745	4311	545
4.	245	(25,110,110)	11675	1003	7683	673
5.	285	(25,130,130)	14362	1275	9522	918
6.	245	(25,70,70)+80[2]	12046	983	4091	610
Significance			**	**	**	*
BLSD (0.05)			2057	158	3557	330
Contrasts						
Lin Rate N (1, 2, 3, 4, 5)			**	**	**	**
Quad Rate N (1, 2, 3, 4, 5)			NS	NS	NS	NS
Post-hilling (4) vs (6)			NS	NS	*	NS

[1] = Planting, emergence and hilling respectively. [2] = Two post-hilling applications at 40 pounds N/A each.
NS = Nonsignificant; *, ** = significant at 5% and 1%, respectively.

Table 9. Effect of nitrogen treatments on Goldrush nitrogen content, concentration and dry matter production. Becker, MN.

Treatment			Nitrogen content: Vine	Nitrogen content: Tuber	Nitrogen content: Total	N concentration: Vine	N concentration: Tuber	Dry matter: Vine	Dry matter: Tuber	Dry matter: Total
	N total	N timing	lbs/A			% N		Tons/A		
1.	125	(25,50,50)[1]	8.7	84.4	93.1	1.63	1.10	0.27	3.83	4.10
2.	165	(25,70,70)	12.6	94.2	106.8	1.71	1.28	0.37	3.75	4.12
3.	205	(25,90,90)	23.4	97.6	121.0	2.14	1.57	0.53	3.13	3.66
4.	245	(25,110,110)	17.9	103.0	120.9	2.19	1.55	0.41	3.34	3.75
5.	285	(25,130,130)	23.8	68.7	92.5	2.49	1.19	0.43	2.91	3.34
6.	245	(25,70,70)+80[2]	18.9	87.0	105.9	2.34	1.46	0.40	3.00	3.40
Significance			*	NS	NS	*	NS	++	NS	NS
BLSD (0.05)			10.2	--	--	0.56	--	0.20	--	--
Contrasts										
Lin Rate N (1, 2, 3, 4, 5)			**	NS	NS	**	NS	*	*	*
Quad Rate N (1, 2, 3, 4, 5)			NS	++	*	NS	++	++	NS	NS
Post-hilling (4) vs (6)			NS	NS	NS	NS	NS	NS	NS	NS

[1] = Planting, emergence and hilling respectively. [2] = Two post-hilling applications at 40 pounds N/A each.
NS = Nonsignificant; ++, *, ** = significant at 10%, 5% and 1%, respectively.

able 10. Effect of nitrogen treatments on Russet Burbank fresh weight of vines, tubers, and quality. Becker, MN.

Treatment			Fresh weight: Vine	Knobs	<3 oz	3-6 oz	6-12 oz	>12 oz	Total	Specific Gravity	Hollow Heart-%
	N total	N timing	Tons/A	cwt/A							incidence
1.	125	(25,50,50)[1]	1.74	68.9	188.5	174.9	96.9	20.9	550.1	1.0836	10.0
2.	165	(25,70,70)	2.49	70.4	155.3	173.1	114.3	24.9	538.0	1.0848	6.0
3.	205	(25,90,90)	4.44	67.1	159.8	151.1	127.9	24.7	530.6	1.0839	9.0
4.	245	(25,110,110)	4.29	75.9	141.6	149.0	136.3	30.2	533.0	1.0840	11.0
5.	285	(25,130,130)	4.96	74.3	126.8	140.4	125.9	32.0	499.4	1.0829	10.0
6.	245	(25,70,70)+80[2]	4.36	68.7	144.2	144.8	125.6	25.4	508.7	1.0830	14.0
Significance			**	NS	*	*	NS	NS	NS	NS	NS
BLSD (0.05)			0.89	--	37.7	24.1	--	--	--	--	--
Contrasts											
Lin Rate N (1, 2, 3, 4, 5)			**	NS	**	**	++	NS	*	NS	NS
Quad Rate N (1, 2, 3, 4, 5)			++	NS	NS	NS	NS	NS	NS	NS	NS
Post-hilling (4) vs (6)			NS	NS	NS	NS	NS	NS	NS	NS	NS

[1] = Planting, emergence and hilling respectively. [2] = Two post-hilling applications at 40 pounds N/A each.
NS = Nonsignificant; ++, *, ** = significant at 10%, 5% and 1%, respectively.

Table 11. Effect of nitrogen treatments on Russet Burbank nitrate-N concentration in potato petioles (dry weight basis) and nitrate concentration in petiole sap, as determined by various procedures. Becker, MN.

Treatment	N total	N timing	June 19 dry weight Petiole-N	June 19 sap Horiba	June 29 dry weight Petiole-N	June 29 sap Horiba	July 11 dry weight Petiole-N	July 11 sap Horiba
			ppm NO_3-N					
1.	125	(25,50,50)[1]	21275	1600	12811	1125	5131	600
2.	165	(25,70,70)	21737	1675	17132	1400	11103	925
3.	205	(25,90,90)	23516	1700	18274	1400	15322	1150
4.	245	(25,110,110)	22816	1750	18709	1475	17057	1275
5.	285	(25,130,130)	23195	1750	19377	1425	18698	1425
6.	245	(25,70,70)+80[2]	22192	1600	19307	1425	16789	1400
Significance			++	++	**	**	**	**
BLSD (0.05)			1813	150	2251	174	2053	105
Contrasts								
Lin Rate N (1, 2, 3, 4, 5)			**	*	**	**	**	**
Quad Rate N (1, 2, 3, 4, 5)			NS	NS	*	*	**	**
Post-hilling (4) vs (6)			NS	*	NS	NS	NS	*

[1] = Planting, emergence and hilling respectively. [2] = Two post-hilling applications at 40 pounds N/A each.
NS = Nonsignificant; ++, *, ** = significant at 10%, 5% and 1%, respectively.

Table 11 cont. Effect of nitrogen treatments on Russet Burbank nitrate-N concentration in potato petioles (dry weight basis) and nitrate concentration in petiole sap, as determined by various procedures.

Treatment	N total	N timing	July 25 dry weight Petiole-N	July 25 sap Horiba	August 8 dry weight Petiole-N	August 8 sap Horiba
			ppm NO_3-N			
1.	125	(25,50,50)[1]	1483	308	1625	204
2.	165	(25,70,70)	5078	610	1075	258
3.	205	(25,90,90)	8052	855	4058	423
4.	245	(25,110,110)	11492	1075	3786	429
5.	285	(25,130,130)	13971	1325	8560	830
6.	245	(25,70,70)+80[2]	11313	1125	7545	640
Significance			**	**	**	**
BLSD (0.05)			1460	125	3053	210
Contrasts						
Lin Rate N (1, 2, 3, 4, 5)			**	**	**	**
Quad Rate N (1, 2, 3, 4, 5)			NS	NS	++	++
Post-hilling (4) vs (6)			NS	NS	*	++

[1] = Planting, emergence and hilling respectively. [2] = Two post-hilling applications at 40 pounds N/A each.
NS = Nonsignificant; ++, *, ** = significant at 10%, 5% and 1%, respectively.

Table 12. Effect of nitrogen treatments on Russet Burbank nitrogen content, concentration and dry matter production. Becker, MN.

Treatment	N total	N timing	Nitrogen content Vine	Nitrogen content Tuber	Nitrogen content Total	N concentration Vine	N concentration Tuber	Dry matter Vine	Dry matter Tuber	Dry matter Total
			lbs/A			% N		Tons/A		
1.	125	(25,50,50)[1]	5.4	76.3	81.7	0.97	0.76	0.28	5.05	5.33
2.	165	(25,70,70)	7.2	97.6	104.8	1.10	0.91	0.32	5.23	5.55
3.	205	(25,90,90)	14.7	88.6	103.3	1.49	0.91	0.49	4.84	5.33
4.	245	(25,110,110)	11.4	97.0	108.4	1.41	0.98	0.40	4.99	5.39
5.	285	(25,130,130)	20.1	90.3	110.4	1.88	1.06	0.52	4.28	4.80
6.	245	(25,70,70)+80[2]	18.8	100.0	118.8	1.66	1.07	0.55	4.71	5.26
Significance			**	NS	NS	**	NS	**	NS	NS
BLSD (0.05)			6.7	--	--	0.45	--	0.08	--	--
Contrasts										
Lin Rate N (1, 2, 3, 4, 5)			**	NS	++	**	*	**	*	NS
Quad Rate N (1, 2, 3, 4, 5)			NS	NS	NS	NS	NS	NS	NS	NS
Post-hilling (4) vs (6)			*	NS	NS	NS	NS	**	NS	NS

[1] = Planting, emergence and hilling respectively. [2] = Two post-hilling applications at 40 pounds N/A each.
NS = Nonsignificant; ++, *, ** = significant at 10%, 5% and 1%, respectively.

POTATO RESPONSE TO PHOSPHORUS ON HIGH PHOSPHORUS TESTING SANDY SOILS: ON-FARM TRIALS - 1995[1]

Carl Rosen and Dave Birong[2]

Abstract: On farm trials were conducted to evaluate Russet Burbank and Norland potato response to phosphate fertilizer on high P testing irrigated soils. Treatments evaluated included banded applications of phosphate fertilizer at planting as well as foliar and emergence sidedress phosphate treatments. For Norland, phosphate fertilizer treatments had no effect on yield except the P foliar treatment which decreased yield due to foliage burn following application. For Russet Burbank, yields increased with phosphate fertilizer applied at banding up to 100 lb P_2O_5/A. Foliar P applications tended to reduce yields due to burn damage. For both cultivars, increasing phosphate fertilizer increased P concentrations in petiole tissue.

Experiments at the Sand Plain Research Farm at Becker have consistently shown significant potato yield responses to phosphate fertilizer on soils testing less than 25 ppm P. On higher P testing soils (> 25 ppm), potato response has been inconsistent. Because of this inconsistency, growers tend to use high rates of phosphate fertilizer regardless of soil test as insurance against yield loss. This practice has led to a steady increase in soil test P levels over the years. Few studies have been conducted that define the P requirement of irrigated potatoes under grower conditions where soil test P levels have been built up to very high (> 50 ppm) levels. Fine-tuning of phosphate fertilizer recommendations has only been addressed on small plots at the Sand Plain Research Farm. Response on a larger scale under grower conditions is essential to completely understand phosphorus requirements of irrigated potatoes. Determining this response can potentially reduce phosphate fertilizer input without detrimentally affecting yields. The objective of this study was to characterize the response of irrigated Russet Burbank and Norland potatoes to phosphate fertilizer on high P testing soils.

Procedures

Two commercial fields in Clear Lake and Becker were selected for this study. Norland was grown at the Clear Lake site and Russet Burbank was grown at the Becker site. Selected characteristics of each site were as follows:

	Clear Lake	Becker
Potato variety grown	Norland	Russet Burbank
Previous crop	Sweet Corn	Dry Bean
Soil pH (1:1 - soil:water)	5.4	6.0
Bray P1	170 ppm	93 ppm
K - (ammonium acetate)	205 ppm	172 ppm

Specific procedures at each site are as follows:

Clear Lake - A total of nine treatments were evaluated. Five of the nine treatments included: 0, 60, 120, 180, and 240 lb P_2O_5/A. The phosphate fertilizer was banded at planting along with nitrogen, potassium, and sulfur starter. Each fertilizer treatment was custom blended using combinations of urea, triple superphosphate, potassium chloride and ammonium sulfate to supply the various phosphate rates while keeping the other nutrients constant. Rates of N, K, and S at planting were: 25 lb N/A, 160 lb K_2O/A, and 18 lb S/A. Plots were six rows wide and 250 ft in length. An additional two treatments included a sidedress application of 100 lb P_2O_5/A as 0-46-0 at emergence. The final two treatments included 11 lb P_2O_5/A foliar (in 30 gal water) applied as 10-34-0 at the hilling stage. These sidedress and foliar applications were superimposed on 30 ft strips within the 0 and 60 lb P_2O_5/A treatments. Norland "B" size potatoes were planted with a pick planter on April 22, 1995 at a spacing of 9" within the row and 36" between rows. Each treatment was replicated four times. Additional nitrogen was applied at emergence on May 19 at the rate of 111 lb N/A and at hilling on June 6 at the rate of 34 lb N/A. A grower treatment bordering the experiment was also compared to the phosphate treatments. Fertilizer rates for the grower treatment were: 1000 lb 8-10-30 at planting, 56 lb N/A at emergence and 34 lb N/A at hilling. Petiole samples were collected on June 28 for nutrient determination. Vines were killed on July 17. Two, 20 ft rows from the middle of each plot were harvested on July 26. Tubers were graded according to the following size categories: less than 1.5", 1.5-1.875", 1.875-2.25", 2.25-2.5", 2.5-3", and greater than 3".

[1]Funding for this research was provided by a grant from the Area 2 Potato Research Council.
[2]Extension Soil Scientist and Assistant Scientist, respectively, Department of Soil, Water and Climate.

Becker - A total of seven treatments were evaluated. Five of the seven treatments were: 0, 50, 100, 150, and 200 lb P_2O_5/A. A nitrogen, potassium, sulfur starter fertilizer without phosphorus was banded at planting. The starter fertilizer supplied 31 lb N/A, 200 lb K_2O/A, and 21 lb S/A. Russet Burbank "A" size potatoes were planted with a cup planter on April 14, 1995 at a spacing of 11" within the row and 36" between rows. Immediately after planting, the phosphate fertilizer (0-46-0) treatments were applied as a band with a belt type applicator 2" below and 3" to each side of the tuber. Plots were 8 rows wide and 50 ft in length. Each treatment was replicated four times. An additional two treatments included 11 lb P_2O_5/A foliar (with 30 gal water) applied as 10-34-0 at the hilling stage. The foliar applications were superimposed on 4 of the 8 rows within the 0 and 60 lb P_2O_5/A treatments. Additional nitrogen was applied at emergence (May 25) at the rate of 63 lb N/A and hilling (June 9) at the rate of 120 lb N/A. Nitrogen was applied through irrigation on July 1 (40 lb N/A) and July 15 (20 lb N/A). A grower treatment bordering the experiment was also compared to the phosphate treatments. The phosphate rate for the grower treatment was 131 lb P_2O_5/A. All other nutrient rates were the same as in the experiment. Petiole samples were collected on June 27 for nutrient determinations. Vines were killed on September 1. Two, 20 ft rows from the middle of each plot were harvested on September 11. Measurements at harvest included: total tuber yield, graded tuber yield, specific gravity, and incidence of internal tuber disorders.

Results

Clear Lake: Yield of Norland potatoes as affected by phosphate fertilizer is presented in Table 1. Total yield was not significantly affected by phosphate fertilizer treatment. The 2.25-2.5" tubers tended to increase with increasing phosphate fertilizer up to 180 lb P_2O_5/A. The grower treatment resulted in lower total yield than that obtained in the P fertilizer experiment. The low yield in the grower treatment is believed to be due to fertilizer placed too close to the seed piece at planting. The foliar applied P fertilizer resulted in leaf burn and depressed yield. These results suggest that caution be used when applying 10-34-0 as a foliar fertilizer. The sidedress P fertilizer did not significantly affect yield.

Increasing phosphate fertilizer increased P and decreased Zn concentrations of potato petioles collected on June 29 (Table 2). Other elements were not affected by phosphate fertilizer rate. All elements were in a range considered optimum for potato production.

Becker: Yield of Russet Burbank potatoes as affected by phosphate fertilizer is presented in Table 3. Total yield increased with phosphate fertilizer up to 100 lb P_2O_5/A. Foliar P fertilizer at the rate applied, burned the leaves and did not significantly affect yield. Grower yields were similar to those obtained in the P fertilizer trial. Phosphate fertilizer had no effect on specific gravity or hollow heart incidence.

Increasing phosphate fertilizer increased P concentrations in petioles collected June 27 (Table 4). The levels of P in potato petioles were considered to be in the adequate range at the time of sampling. The possibility exists that petiole P concentrations dropped to below sufficiency levels during tuber bulking. Petiole analysis later in the growing season may be needed to diagnose P deficiency. Other elements were not affected by P fertilizer treatment and all except for copper were considered to be in the optimum range. Reasons for the low copper petiole levels cannot be determined from this study.

Table 1. Effect of phosphate treatments on Norland fresh weight of vines, tubers, and quality. Clear Lake, MN.

P_2O_5 Treatment		<1½"	1½-1⅞"	1⅞-2¼"	2¼-2½"	2½-3"	>3"	Total	Growth Cracks	Hollow Heart
		Fresh weight								
		cwt/A							% incidence	
1.	0	10.9	26.1	119.5	73.0	52.7	24.5	306.7	13.0	5.0
2.	0 + Foliar[1]	8.0	19.7	103.9	82.1	43.7	17.4	274.8	14.0	6.0
3.	0 + Sidedress[2]	12.1	24.5	100.1	77.9	49.4	35.0	299.0	12.0	9.0
4.	60	15.2	34.2	136.9	70.9	43.5	11.1	311.8	6.0	4.0
5.	60 + Foliar[1]	11.3	29.1	120.5	73.7	36.1	23.0	293.7	11.0	8.0
6.	60 + Sidedress[2]	13.1	31.8	119.9	73.9	60.3	26.7	325.7	10.0	5.0
7.	120	10.5	24.7	112.3	84.5	48.3	24.1	304.4	17.0	5.0
8.	180	10.2	26.8	132.2	85.3	46.6	16.4	317.5	7.0	3.0
9.	240	12.4	28.0	125.9	80.6	47.4	28.9	323.2	11.0	3.0
10.	Grower	7.9	16.2	68.0	51.1	50.8	30.4	224.4	18.0	8.0
Significance		*	**	**	**	NS	NS	**	*	NS
BLSD (0.05)		5.3	9.5	18.2	13.9	--	--	33.7	7.7	--
Contrasts										
Lin Rate P (1, 4, 7, 8, 9)		NS	NS	NS	*	NS	NS	NS	NS	NS
Quad Rate P (1, 4, 7, 8, 9)		NS	NS	NS	NS	NS	NS	NS	NS	NS
Grower vs (1, 4, 7, 8, 9)		*	**	**	**	NS	NS	**	**	NS

[1] = Applied P as a foliar @ 2.9 gallons 10-34-0/Acre at hilling. [2] = Applied P as a sidedress @ 100 lbs 0-46-0/Acre at hilling. NS = Nonsignificant; ++, *, ** = significant at 10%, 5% and 1%, respectively.

Table 2. Effect of phosphate treatments on elemental composition of Norland petioles. Sampled June 28, 1995 Clear Lake, MN.

P_2O_5 Treatment		dry weight NO_3-N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
			Element								
		- ppm -	%				ppm				
1.	0	17112	0.63	12.1	1.12	0.37	117	229	60	5.2	28
2.	0 + Foliar[1]	18208	0.75	12.2	1.05	0.38	118	259	63	3.0	28
3.	0 + Sidedress[2]	16281	0.72	11.8	1.09	0.35	118	225	57	5.1	28
4.	60	19437	0.58	11.3	0.91	0.33	107	219	58	3.3	25
5.	60 + Foliar[1]	20360	0.62	11.8	0.96	0.35	111	212	58	3.9	27
6.	60 + Sidedress[2]	17734	0.59	11.8	0.90	0.34	107	175	53	5.4	27
7.	120	18650	0.67	12.2	1.00	0.37	128	222	68	3.5	28
8.	180	19811	0.65	11.4	1.05	0.35	118	236	58	5.5	27
9.	240	18423	0.74	12.5	1.13	0.40	115	205	65	4.2	29
10.	Grower	20721	0.74	12.2	0.87	0.32	126	220	75	5.0	27
Significance		NS	*	NS	NS	NS	NS	NS	++	NS	NS
BLSD (0.05)		--	0.13	--	--	--	--	--	17	--	--
Contrasts											
Lin Rate P (1, 4, 7, 8, 9)		NS	*	NS	NS	NS	NS	NS	NS	NS	NS
Quad Rate P (1, 4, 7, 8, 9)		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Grower vs (1, 4, 7, 8, 9)		NS	++	NS	NS	++	NS	NS	*	NS	NS

[1] = Applied P as a foliar @ 2.9 gallons 10-34-0/Acre at hilling. [2] = Applied P as a sidedress @ 100 lbs 0-46-0/Acre at hilling. NS = Nonsignificant; ++, * = significant at 10% and 5%, respectively.

Table 3. Effect of phosphate treatments on Russet Burbank fresh weight of vines, tubers, and quality. Becker, MN.

P_2O_5 Treatment		Fresh weight						Specific	Hollow
		Knobs	<3 oz	3-6 oz	6-12 oz	>12 oz	Total	Gravity	Heart
		cwt/A							% incidence
1.	0	42.7	63.2	130.0	148.4	27.7	412.0	1.0821	0.0
2.	0 + Foliar[1]	40.7	71.2	135.5	133.4	13.0	393.8	1.0801	1.0
3.	50	47.1	63.3	128.7	166.0	26.1	431.2	1.0822	0.0
4.	50 + Foliar[1]	34.6	83.6	139.6	153.0	23.6	434.4	1.0813	3.0
5.	100	45.8	67.6	140.9	171.8	25.2	451.3	1.0813	1.0
6.	150	40.8	70.1	152.6	165.8	20.4	449.7	1.0817	0.0
7.	200	51.0	65.6	138.8	150.7	22.2	428.3	1.0819	0.0
8.	Grower	55.2	72.9	140.2	155.0	28.8	425.1	1.0812	1.0
Significance		NS	NS	NS	NS	NS	++	NS	NS
BLSD (0.05)		--	--	--	--	--	49.1	--	--
Contrasts									
Lin Rate P (1, 3, 5, 6, 7)		NS	NS	NS	NS	NS	NS	NS	NS
Quad Rate P (1, 3, 5, 6, 7)		NS	NS	NS	NS	NS	++	NS	NS
Grower vs (1, 3, 5, 6, 7)		NS	NS	NS	NS	NS	NS	NS	NS

[1] = Applied P as a foliar @ 2.9 gallons 10-34-0/A at hilling. NS = Nonsignificant; ++ = significant at 10%.

Table 4. Effect of phosphate treatments on elemental composition of Russet Burbank petioles. Sampled June 27, 1995. Becker, MN.

P_2O_5 Treatment		Element									
		NO_3-N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
		ppm dw	% dw				ppm dw				
1.	0	18577	0.36	10.3	0.80	0.47	141	160	49	1.9	26
2.	0 + Foliar[1]	17414	0.33	9.7	0.76	0.44	150	196	57	1.4	25
3.	50	16673	0.35	10.1	0.83	0.45	152	175	46	1.9	26
4.	50 + Foliar[1]	19017	0.35	10.5	0.79	0.46	143	189	53	1.3	26
5.	100	18046	0.37	10.1	0.85	0.48	145	161	43	1.8	25
6.	150	16402	0.38	9.8	0.78	0.45	146	159	43	1.5	25
7.	200	17859	0.47	10.6	0.88	0.47	146	148	41	1.1	25
8.	Grower	18670	0.39	9.6	0.70	0.43	134	156	43	1.9	24
Significance		NS	**	NS	NS	NS	NS	NS	NS	NS	NS
BLSD (0.05)		--	0.05	--	--	--	--	--	--	--	--
Contrasts											
Lin Rate P (1, 3, 5, 6, 7)		NS	**	NS	NS	NS	NS	NS	NS	NS	NS
Quad Rate P (1, 3, 5, 6, 7)		NS	**	NS	NS	NS	NS	NS	NS	NS	NS
Grower vs (1, 3, 5, 6, 7)		NS	NS	NS	*	NS	NS	NS	NS	NS	NS

[1] = Applied P as a foliar @ 2.9 gallons 10-34-0/Acre at hilling. NS = Nonsignificant; **, * = significant at 1% and 5%, respectively.

EVALUATION OF ROW SPACING EFFECTS ON YIELD AND QUALITY OF IRRIGATED POTATOES[1]

Carl Rosen, Dave Birong, and Glenn Titrud[2]

Abstract: Preliminary studies were conducted at the Sand Plain Research Farm in Becker to evaluate 30 inch row spacing at two plant populations (15,840 and 18,216 plants/A) on irrigated Russet Burbank potato production. Total yield was significantly greater at 30 inch spacing compared to 36 inch spacing at both plant populations; however, the yield increase was primarily due to an increase in smaller (<6 oz) sized tubers. Higher yield of 6-12 oz tubers was obtained with the lower plant populations regardless of row spacing.

Traditional spacing between rows for potatoes is 36 inches. However, row spacing for many of the rotation crops such as sweet corn, field corn, and soybean is 30 inches. Efficiency in farming operations could be improved if potatoes had the same row spacing as rotation crops since tractors could be used interchangeably. In addition, narrowing the row spacing for potato production may also increase nitrogen use efficiency by reducing the amount of inter-row area subject to nitrate losses. Before a switch to 30 inch row spacing is made, growers need to know how tuber production may be affected. The objective of this study therefore was to determine the effects of 30 inch row spacing on yield and quality of irrigated Russet Burbank potatoes.

Materials and Methods:

The experiment was conducted at the Sand Plain Research Farm at Becker on a Hubbard loamy sand with a previous crop of rye. Selected chemical properties prior to planting (0-6") were: Soil pH (1:1 - soil:water), 6.4; Bray P1, 26 ppm; and NH_4OAc K, 119 ppm. Residual nitrate-N in the top 2 ft was 5 lb/A. Two between row spacings were tested - 30" and 36" at two plant populations - 15,840 and 18,216 plants per acre. These plant populations correspond to 11 and 9.5 inches within row spacing for 36" rows and 13.2 and 11.5 inches within row spacing for the 30" rows. The four treatments were replicated 4 times in a split plot design with between row spacing as the main plots and within row spacing as the subplots. Each plot was 6 rows wide and 40 feet in length. Furrows were opened mechanically and a starter fertilizer of (lbs/A) 25 N, 110 P_2O_5, 200 K_2O, 20 Mg, and 33 S was banded 2 to 3 inches to each side below the furrow. Russet Burbank "A" size cut tubers were planted May 2, 1995 by hand, Admire was applied directly in furrow for insect control and the rows were then mechanically hilled. Nitrogen as ammonium nitrate was applied at the rate of 90 lb N/A at emergence (May 29), and 120 lb N/A at hilling (June 9). Petiole samples were collected on July 6 and then dried and ground for nitrate determination. Vines were killed Sept. 14 and the middle two rows of each plot were harvested on Sept. 21. Measurements at harvest included: total tuber yield, graded yield, tuber specific gravity, and internal disorders. Subsamples of vines (prior to killing) and tubers (at harvest) were collected for moisture and nitrogen determination.

Results:

Yield and quality as affected by row spacing is presented in Table 1. Use of 30 inch row spacing significantly increased total yield compared to 36 inch spacing. This effect, however, was due to an increase in the number of smaller sized tubers (less than 6 oz). Number 1 potatoes (6 to 12 oz) increased with wider spacing within rows (lower plant populations) but were not affected by between row spacing. Spacing had no effect on hollow heart incidence or specific gravity.

Petiole nitrate-N on July 6 was lower for the 30 inch spacing compared to 36 inch spacing with no effect due to plant population (Table 2). The higher tuber yield of the 30 inch spacing may have been a strong sink for N which in turn would have lowered the amount of nitrate-N in the petioles. Because of higher total yield/dry matter production, total N uptake with the 30 inch row spacing was greater than uptake with the 36 inch row spacing (Table 2). These results suggest an improved N use efficiency at the 30 inch row spacing.

Based on one year of data, 30 inch row spacing does not appear to be that useful for processing potatoes where larger sized tubers are required. There may, however, be some merit in using 30 inch spacing for potato seed production or fresh market red potato production where an increase in total yield of smaller sized tubers is desirable. Additional studies are required before a general recommendation regarding row spacing effects can be made.

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[1]Funding for this research was provided by a grant from the Area 2 Potato Research Council.
[2]Extension Soil Scientist and Assistant Scientist, respectively, Dept. of Soil, Water and Climate; Supervisor, Sand Plain Research Farm.

Table 1. Effect of row spacing and plant population on vine yield and yield and quality of Russet Burbank tubers. Becker, MN.

Between Row Spacing	Within Row Spacing	Plants per Acre	Tuber Yield						Vine Yield	Specific Gravity	Hollow Heart
				Tuber Size							
			Knobs	<3 oz	3-6 oz	6-12 oz	>12 oz	Total			
inches	inches		---------------------- cwt/A ------------------						Tons/A		%
30	11.4	18,340	92.1	147.4	178.2	141.5	52.2	611.4	16.15	1.0819	20.0
30	13.2	15,840	84.8	117.8	181.0	168.1	47.5	599.2	15.80	1.0802	18.0
36	9.5	18,340	84.5	98.1	134.9	156.1	47.1	520.7	16.07	1.0809	19.0
36	11.0	15,840	78.5	89.0	127.6	187.2	51.3	533.6	15.42	1.0825	23.0
Significance			NS	**	*	++	NS	**	NS	NS	NS
BLSD (0.05)			--	28.4	47.4	37.3	--	38.1	--	--	--
Spacing			NS	**	**	NS	NS	**	NS	NS	NS
Population			NS	++	NS	*	NS	NS	NS	NS	NS
Space X Pop			NS	NS	NS	NS	NS	NS	NS	NS	NS

NS = nonsignificant; **, *, ++ = significant at 1%, 5% and 10%, respectively.

Table 2. Effect of row spacing and plant population on petiole nitrate-N (sampled July 6) and nitrogen content, concentration and dry matter production of Russet Burbank potatoes at harvest. Becker, MN.

Between Row Spacing	Within Row Spacing	Plants per Acre	Nitrogen content			Nitrogen concentration			Dry matter		
			Vine	Tuber	Total	Petiole	Vine	Tuber	Vine	Tuber	Total
inches	inches		------- lbs/A --------			ppm NO_3-N	--- % N ----		------ Tons/A ------		
30	11.4	18,340	43.9	137.6	181.5	15,309	1.54	1.16	1.43	5.96	7.39
30	13.2	15,840	51.0	150.3	201.3	15,527	1.71	1.24	1.54	6.07	7.61
36	9.5	18,340	39.0	129.3	168.3	16,885	1.53	1.23	1.28	5.28	6.56
36	11.0	15,840	43.1	107.2	150.3	16,558	1.49	0.98	1.43	5.36	6.79
Significance			NS	*	++	NS	NS	NS	NS	*	*
BLSD (0.05)			--	32.5	41.6	--	--	--	--	0.63	0.79
Spacing			NS	*	*	*	NS	NS	NS	**	**
Population			NS	NS	NS	NS	NS	NS	NS	NS	NS
Space X Pop			NS	++	NS	NS	NS	*	NS	NS	NS

NS = nonsignificant; **, *, ++ = significant at 1%, 5% and 10%, respectively.

POTASSIUM MANAGEMENT FOR IRRIGATED POTATOES: EFFECTS OF POTASSIUM RATE, TIMING, AND SOURCE AND INTERPRETATION OF A PETIOLE SAP TEST FOR POTASSIUM - 1995[1]

Wenshan Wang, Carl Rosen, and Dave Birong[2]

ABSTRACT: The second year of a two-year study was conducted at the Sand Plain Research Farm in Becker, MN with the objectives of: 1) evaluating the effects of various K management strategies on potato productivity and quality and 2) calibrating a quick petiole K sap test for determining K status of the crop and predicting K needs. Tuber yield increased significantly with increasing K fertilizer up to 240 lb K_2O/A. Yields decreased with banded applications of 320 lb K_2O/A. Hollow heart incidence was lower with addition of K fertilizer. Increasing K fertilizer decreased tuber specific gravity. At equivalent K application rates, method and timing of K application had no effect on yield or tissue K levels. Tubers removed up to 196 lb K/A in optimally fertilized plots. Without K fertilization, soil test K dropped about 20 ppm by the end of the season. Potassium concentrations in nondiluted sap determined with the Horiba electrode were about 900-1500 ppm lower than those determined with the atomic absorption. Potassium concentrations determined with the Horiba electrode on sap diluted with $Al_2(SO_4)_3$ or deionized water were much closer to those determined with the AA. These results suggest that dilution of the sap is necessary to obtain accurate K concentrations in petiole sap. Petiole K measured by the various methods increased with increasing K fertilizer application. On K fertilized plots, petiole K concentrations on a sap or dry weight basis did not follow a consistent pattern through the growing season.

Potatoes have a relatively high requirement for K. Based on data collected at the Sand Plain Research Farm at Becker, K uptake by the tuber can range from 200 to 270 lbs K/A. Because of this high removal rate, growers tend to apply relatively large quantities of K fertilizer each year. Few studies have been conducted in Minnesota that have calibrated K soil tests with fertilizer response of potato. Many of the recommendations are based on removal rates with little credit given to the K buffering capacity of the soil. Another aspect of K fertilization that needs to be tested is the potential requirement for in-season applications of K. Whether in-season applications of K are beneficial for potatoes under Minnesota conditions is presently unknown. In addition to soil testing, petiole analysis can also be used as a diagnostic tool to monitor K status of the plant. A portable K electrode has been developed that may be useful in monitoring plant K status throughout the season. The advantage of this quick test is any problems can be diagnosed immediately without having to wait for laboratory analysis. The objectives of this study were to: 1) characterize the response of Russet Burbank potatoes to K fertilizer applications on medium testing K soils, 2) evaluate the use of the K sap test for determining K status and predicting K fertilizer needs of potato.

EXPERIMENTAL PROCEDURES

The experiment was conducted in Becker, MN at the Sand Plain Research Farm on a Hubbard loamy sand soil. The previous crop was rye. Selected soil chemical properties prior to planting were as follows (0-6"): pH, 6.1; P (Bray P), 22 ppm; and K (NH_4OAc), 82 ppm. Residual nitrate-N in the top 6 inches of soil was 1.6 lb/A. The cultivar "Russet Burbank" was planted on April 20, 1995. Specific treatments were as follows:

	K_2O Application Rate (lb K_2O/Acre) and Date of Application					
	Planting	Emergence	Hilling	Post-Hilling	Post-Hilling	Total
K_2O Source	April 14	May 19	June 7	June 23	July 6	
1) Control	0	0	0	0	0	0
2) KCl	80	0	0	0	0	80
3) KCl	160	0	0	0	0	160
4) KCl	240	0	0	0	0	240
5) KCl	320	0	0	0	0	320
6) KCl	80[1] + 80	0	0	0	0	160
7) KCl	160[1] + 80	0	0	0	0	240
8) KCl[2] and KNO_3	80	80	80	0	0	240
9) KCl[2] and KNO_3	80	40	40	40	40	240

[1] = Broadcast before plowing. [2] = KCl at planting only.

[1]Funding for this research was provided by a grant from the Area 2 Potato Research Council.

[2]Associate Professor (visiting scholar), Professor, and Assistant Scientist, respectively, Department of Soil, Water, and Climate.

Treatments 1 - 5 were all one time banded applications of KCl at planting. For treatments 6 and 7, broadcast KCl was applied by hand one week before planting in addition to 80 lb K_2O/A banded at planting. Treatments 8 and 9 used both KCl and KNO_3 as potash sources where the KCl was banded at planting and the KNO_3 was applied at various stages after planting. Russet Burbank cut potatoes were planted on April 20 at a spacing of 10" within the row and 36" between rows. All banded fertilizer applications were applied with a belt type applicator along with N, P, Mg, and S fertilizer. The fertilizer was banded three inches to each side and two inches below the seed piece. Phosphate fertilizer was applied as 0-46-0 at the rate of 100 lb P_2O_5/A. All plots also received 300 lbs/Acre Epsom salts in the band at planting to supply Mg and S. Nitrogen management for treatments 1 to 7 was as follows: 30 lbs N/A as urea at planting, 100 lbs N/A as urea at emergence (May 23), 110 lbs N/A as urea at hilling (June 8). For treatments 8 and 9, N rates were adjusted so that a total of 240 lb N/A were applied to all plots. The nine treatments were replicated 4 times in a randomized complete block design. Each plot consisted of 4 rows, 30 feet in length. The middle two rows were used for both harvest and sample collection.

Recently matured potato leaves (4th leaf from the growing terminal) were collected every 10-14 days starting one day before hilling until the middle of August. At least 30 leaves were collected from each plot. Leaflets were removed, half of the petioles were crushed with a Hach press, and the remaining petioles were dried in an oven at 140°F. The expressed sap was immediately frozen until analyses could be performed.

The instrument designed for the K quick test was Horiba/Cardy K flat membrane electrode. In addition to the quick test procedure, K in sap and in dried petioles was determined by Atomic Absorption Spectrophotometer (emission mode).

Specific methods for analyses were as follows:

Sap Horiba - The Horiba hand held electrode was calibrated using two standard solutions, 150 and 2000 ppm K^+(KCl). A few drops of nondiluted (original) sap were placed on the electrode membrane and a direct reading of K^+ was recorded.

$Al_2(SO_4)_3$ Horiba - The Horiba electrode was calibrated using two K^+ standard solutions, 150 and 2000 ppm K^+ (KCl). Each standard solution contained 50 g/L $Al_2(SO_4)_3$. Expressed sap was diluted 10 times with 50 g/L $Al_2(SO_4)_3$ solution. A few drops of diluted solution were placed on the electrode membrane and a direct reading of K^+ concentration was recorded.

Water Horiba - The Horiba electrode was calibrated using two K^+ standard solutions, 150 and 2000 ppm K^+ (KCl). Expressed sap was diluted 10 times with deionized water. A few drops of diluted solution were placed on the electrode membrane and a direct reading of K^+ concentration was recorded.

AA Sap - The sap was diluted 100 times with water. An Atomic Absorption (AA) Spectrophotometer (emission mode) was used to measure the K concentration of the diluted sap solution. This method was considered the standard method to compare the results with those of the electrode quick test.

Dry weight petiole-K - The instrumental set up was the same as for the AA sap test. Dried petioles were ground and 0.2 g of ground tissue was weighed and digested with concentrated sulfuric acid and then diluted 100 times with water. Solution K was determined by AA.

Exchangeable K was determined in soil samples collected on September 18. Samples consisted of 6 cores from an individual plot taken to the depth of 0-6". All samples were air dried prior to analysis. Exchangeable K was extracted with 1M neutral NH_4OAc (2 g soil to 20 ml extractant). Concentrations of K in all soil extracts were determined by AA.

Vines were cut and weighed 8 days prior to harvest. Potatoes were mechanically harvested on September 18. Subsamples of vines and tubers were collected to determine dry matter and K accumulation. Other measurements at harvest included: total tuber and vine yield, graded tuber yield, tuber specific gravity, and hollow heart. Potassium content of tuber and vines was determined using similar procedures described above for dry weight petiole analysis.

RESULTS

Tuber and Vine Yield, Specific Gravity, Hollow Heart. The effect of the various potassium treatments on graded yield, specific gravity, and hollow heart is presented in Table 1. Potato yields increased with banded applications of 0-0-60 up to 240 lb K_2O/A. The 320 lb K_2O/A rate tended to decrease yields presumably due to excessive salts. Particularly noticeable was the drop in 6-12 oz tuber in the 320 lb/A treatment. At equivalent K_2O rates, yields with broadcast plus banding did not differ from those with banding alone. Hollow heart tended to decrease with added potassium fertilizer. Specific gravity was not consistently affected by K fertilizer but tended to be lower as K fertilizer level increased. The treatments with potassium nitrate (13-0-44) had yields comparable to those provided with potassium chloride (0-0-60). Slight effects of potassium nitrate were observed but in general, supplying potassium after planting does not appear to dramatically affect potato yield or quality. Vine yield responses to K fertilizer were similar to those recorded for tuber yield.

Dry Matter and Potassium Accumulation. Dry matter and K accumulation, as well as concentrations of K in vines and tubers at harvest, are presented in Table 2. Potassium fertilizer significantly increased dry matter accumulation in vines and tubers. Maximum dry matter accumulation was attained with 160 lb K_2O/A applied as a band at planting. At equivalent K application rates, method of K application and timing of K application had no effect on dry matter accumulation. Increasing K application increased K concentrations of vines, but had inconsistent effects on K concentrations in tubers. Potassium accumulation in tubers ranged from 125 lb K/A when no K fertilizer was applied to 196 lb K/A when 240 lb K_2O/A was applied as a band at planting. The K content of vines ranged from 12 to 44 lb K/A and generally was related to the K rate applied. At equivalent K application rates, method of K application and timing of K application had no effect on K content of vines or tubers.

Potassium Petiole Analysis. Potassium concentrations in potato petioles expressed on a sap and dry weight basis are presented in Table 3. On all sampling dates, K concentrations on a dry weight or sap basis generally increased with increasing K rate, becoming more pronounced later in the growing season. At equivalent K fertilizer application rates, method of K application and timing of K application had minimal effects on petiole K concentrations expressed either in a sap or dry weight basis. Potassium concentrations in nondiluted sap determined with the Horiba electrode were about 900-1500 ppm lower than those determined with the AA. Sap diluted with $Al_2(SO_4)_3$ solution or deionized water and determined with the Horiba electrode had K concentrations that were much closer to those determined with the AA. These results suggest that dilution of the sap is necessary to obtain accurate K concentrations in petiole sap. The discrepancy between K concentrations measured in nondiluted sap and those measured by AA was greatest as the K concentration in the sap increased. At lower sap K levels (less than 2500 ppm K) the difference between nondiluted sap and diluted sap was not as great. Dry weight petiole K concentrations through the growing season generally decreased in the control plots, but either stayed constant or slightly increased when K fertilizer was applied. Petiole sap K followed similar trends.

Exchangeable Soil Potassium. Potassium fertilizer effects on soil K levels are presented in Table 4. Soil K levels at harvest increased with increasing K fertilizer rate. Levels of K in the control plot decreased on average by 23 ppm by the end of the season. Because of the high rate of K removal by the tuber, applications of at least 200-240 lb K_2O/A are required to maintain soil test K levels.

SUMMARY

Results from this study on a medium K test soil indicate that potato yields increased with increasing K fertilizer up to 240 lb K_2O/A. At equivalent K rates, broadcast and banding potash resulted in yields similar to those obtained with banding alone. There was no yield advantage to applying potassium nitrate during the growing season. High levels of K removal by the tuber suggest that soil K could be depleted over the years without K fertilizer application. Petiole sap K tests using portable K electrodes appear to have promise for determining K status of the crop if sap is diluted.

Table 1. Effect of potash treatments on fresh weight of vines, tubers, and quality. Becker, MN.

Treatment		Fresh weight							Specific	Hollow
		Vines	Knobs	<3 oz	3-6 oz	6-12 oz	>12 oz	Total	Gravity	Heart-%
K_2O source	K_2O timing	Tons/A	cwt/A							incidence
1. Control	(0 K_2O/A)	2.51	29.7	118.2	144.5	101.6	22.7	416.7	1.0821	29.0
2. KCl	(80,0,0)[1]	5.08	48.7	109.3	147.0	149.9	33.5	488.6	1.0814	20.0
3. KCl	(160,0,0)	5.56	54.7	105.7	146.8	163.8	40.5	511.5	1.0836	15.0
4. KCl	(240,0,0)	5.19	52.6	102.6	164.3	180.7	32.0	532.2	1.0800	18.0
5. KCl	(320,0,0)	4.67	41.3	102.4	143.1	150.2	43.3	480.4	1.0812	15.0
6. KCl	(80[2]+80,0,0)	5.05	40.3	119.4	157.8	144.7	43.0	505.2	1.0838	17.0
7. KCl	(160[2]+80,0,0)	5.97	53.3	99.7	146.3	184.4	39.6	523.3	1.0821	19.0
8. KCl/KNO_3	(80[3],80,80)	5.38	37.8	86.1	168.2	179.1	55.7	526.9	1.0828	11.0
9. KCl/KNO_3	(80[3],40,40,40,40)[4]	5.07	36.4	109.1	170.1	165.5	40.3	521.4	1.0816	17.0
Significance		++	NS	NS	*	++	NS	*	*	NS
BLSD (0.05)		2.36	--	--	21.6	60.3	--	63.6	0.0025	--
Contrasts										
Linear Rate K_2O (1,2,3,4,5)		*	NS	NS	NS	*	++	*	NS	++
Quadric Rate K_2O (1,2,3,4,5)		**	*	NS	NS	*	NS	**	NS	NS
Cubic Rate K_2O (1,2,3,4,5)		NS	NS	NS	++	NS	NS	NS	NS	NS
Band vs Broadcast (3,4 vs 6,7)		NS	NS	NS	NS	NS	NS	NS	NS	NS
Planting vs P,E,H[1] (4 vs 8)		NS	NS	NS	NS	NS	*	NS	*	NS

[1] = Planting, emergence and hilling respectively. [2] = Broadcast before plowing. [3] = KCl (0-0-60) at planting and KNO_3 (13-0-44) at emergence and hilling. [4] = Two post-hilling applications at 40 lbs K_2O/A as KNO_3 (13-0-44). NS = Nonsignificant; ++, *, ** = significant at 10%, 5% and 1%, respectively.

Table 2. Effect of potash on potassium content, concentration, and dry matter production. Becker, MN

Treatment		K content			K concentration		Dry matter		
K_2O source	K_2O timing	Vines	Tubers	Total	Vines	Tubers	Vines	Tubers	Total
		lbs/A			% K		Tons/A		
1. Control	(0 K_2O/A)	12.4	124.9	137.3	1.21	1.80	0.43	4.07	4.50
2. KCl	(80,0,0)[1]	27.1	159.0	186.1	1.97	1.59	0.53	4.94	5.47
3. KCl	(160,0,0)	39.9	193.3	232.2	2.69	1.71	0.64	5.57	6.21
4. KCl	(240,0,0)	44.0	196.4	240.4	3.87	2.00	0.54	4.92	5.46
5. KCl	(320,0,0)	42.7	149.3	192.0	4.12	1.76	0.49	4.22	4.71
6. KCl	(80[2]+80,0,0)	35.5	180.1	215.6	2.61	1.83	0.58	4.91	5.49
7. KCl	(160[2]+80,0,0)	41.0	182.9	224.0	3.26	1.81	0.57	5.05	5.62
8. KCl/KNO_3	(80[3],80,80)	36.9	169.3	206.2	3.03	1.77	0.58	4.75	5.33
9. KCl/KNO_3	(80[3],40,40,40,40)[4]	39.5	186.8	226.3	3.23	1.84	0.56	5.09	5.65
Significance		++	++	**	**	++	NS	NS	++
BLSD (0.05)		26.0	59.97	61.62	1.09	0.34	--	--	1.32
Contrasts									
Linear Rate K_2O (1,2,3,4,5)		**	++	**	**	*	NS	NS	NS
Quadric Rate K_2O (1,2,3,4,5)		NS	**	**	NS	NS	*	**	**
Cubic Rate K_2O (1,2,3,4,5)		NS	NS	NS	NS	++	NS	NS	NS
Band vs Broadcast (3,4 vs 6,7)		NS	NS	NS	NS	NS	NS	NS	NS
Planting vs P,E,H[1] (4 vs 8)		NS	NS	NS	NS	++	NS	NS	NS

[1] = Planting, emergence and hilling respectively. [2] = Broadcast before plowing. [3] = KCl (0-0-60) at planting and KNO_3 (13-0-44) at emergence and hilling. [4] = Two post-hilling applications at 40 lbs K_2O/A as KNO_3 (13-0-44). NS = Nonsignificant; ++, *, ** = significant at 10%, 5% and 1%, respectively.

Table 3. Effect of potash treatments on potassium concentration in potato petioles (dry weight basis) and potassium concentration in petiole sap, as determined by various procedures. Becker, MN.

Treatment		Date: June 15				
K_2O source	K_2O timing	dry weight Petiole-K	sap Horiba	water Horiba	$Al_2(SO_4)_3$ Horiba	sap AA
		--% K --	ppm K			
1. Control	(0 K_2O/A)	5.56	3125	3675	3600	3625
2. KCl	(80,0,0)[1]	6.92	3575	4425	4300	4321
3. KCl	(160,0,0)	7.55	3850	4625	4600	4488
4. KCl	(240,0,0)	8.28	3875	4475	4700	4596
5. KCl	(320,0,0)	8.22	3900	4825	4800	4654
6. KCl	(80[2]+80,0,0)	7.87	3900	4550	4725	4613
7. KCl	(160[2]+80,0,0)	7.63	3750	4650	4650	4486
8. KCL/KNO_3	(80[3],80,80)	8.61	3850	4850	4900	4677
9. KCl/KNO_3	(80[3],40,40,40,40)[4]	7.75	3700	4625	4500	4314
Significance		**	**	**	**	**
BLSD (0.05)		0.72	226	402	454	423
Contrasts						
Linear Rate K_2O	(1,2,3,4,5)	**	**	**	**	**
Quadric Rate K_2O	(1,2,3,4,5)	**	**	*	*	*
Cubic Rate K_2O	(1,2,3,4,5)	NS	NS	NS	NS	NS
Band vs broadcast	(3,4 vs 6,7)	NS	NS	NS	NS	NS
Planting vs P,E,H[1]	(4 vs 8)	NS	NS	NS	NS	NS

[1] = Planting, emergence and hilling respectively. [2] = Broadcast before plowing. [3] = KCl (0-0-60) at planting and KNO_3 (13-0-44) at emergence and hilling. [4] = Two post-hilling applications at 40 lbs K_2O/A as KNO_3 (13-0-44). NS = Nonsignificant; *, ** = significant at 5% and 1%, respectively.

Table 3 cont. Effect of potash treatments on potassium concentration in potato petioles (dry weight basis) and potassium concentration in petiole sap, as determined by various procedures. Becker, MN.

Treatment		Date: June 26				
K_2O source	K_2O timing	dry weight Petiole-K	sap Horiba	water Horiba	$Al_2(SO_4)_3$ Horiba	sap AA
		--% K --	ppm K			
1. Control	(0 K_2O/A)	6.85	2875	3200	3225	3183
2. KCl	(80,0,0)[1]	9.27	3225	3600	3625	3619
3. KCl	(160,0,0)	9.87	3450	3975	4000	3990
4. KCl	(240,0,0)	9.67	3675	4050	4150	4162
5. KCl	(320,0,0)	10.20	3700	4400	4250	4283
6. KCl	(80[2]+80,0,0)	10.17	3550	4100	4050	4112
7. KCl	(160[2]+80,0,0)	10.01	3450	3950	4025	3979
8. KCL/KNO_3	(80[3],80,80)	9.93	3725	4400	4475	4491
9. KCl/KNO_3	(80[3],40,40,40,40)[4]	9.45	3575	4150	4150	4238
Significance		**	**	**	**	**
BLSD (0.05)		1.33	198	404	370	341
Contrasts						
Linear Rate K_2O	(1,2,3,4,5)	**	**	**	**	**
Quadric Rate K_2O	(1,2,3,4,5)	*	*	NS	NS	++
Cubic Rate K_2O	(1,2,3,4,5)	++	NS	NS	NS	NS
Band vs broadcast	(3,4 vs 6,7)	NS	NS	NS	NS	NS
Planting vs P,E,H[1]	(4 vs 8)	NS	NS	++	++	++

[1] = Planting, emergence and hilling respectively. [2] = Broadcast before plowing. [3] = KCl (0-0-60) at planting and KNO_3 (13-0-44) at emergence and hilling. [4] = Two post-hilling applications at 40 lbs K_2O/A as KNO_3 (13-0-44). NS = Nonsignificant; ++, *, ** = significant at 10%, 5% and 1%, respectively.

Table 3 cont. Effect of potash treatments on potassium concentration in potato petioles (dry weight basis) and potassium concentration in petiole sap, as determined by various procedures. Becker, MN.

Treatment		July 10: dry weight Petiole-K	July 10: sap Horiba	July 10: water Horiba	July 10: $Al_2(SO_4)_3$ Horiba	July 10: sap AA
K_2O source	K_2O timing	--% K --	ppm K			
1. Control	(0 K_2O/A)	5.73	3100	3700	3625	3525
2. KCl	(80,0,0)[1]	7.18	3450	4375	4050	3913
3. KCl	(160,0,0)	8.25	3825	4825	4825	4485
4. KCl	(240,0,0)	8.89	4050	4975	5025	4730
5. KCl	(320,0,0)	9.41	4175	5175	5325	5002
6. KCl	(80[2]+80,0,0)	8.19	3700	4575	4700	4411
7. KCl	(160[2]+80,0,0)	8.25	3650	4575	4575	4340
8. KCL/KNO_3	(80[3],80,80)	9.09	3900	5050	5225	4901
9. KCl/KNO_3	(80[3],40,40,40,40)[4]	8.41	3950	5050	5125	4906
Significance		**	**	**	**	**
BLSD (0.05)		0.93	224	500	354	374
Contrasts						
Linear Rate K_2O (1,2,3,4,5)		**	**	**	**	**
Quadric Rate K_2O (1,2,3,4,5)		++	++	++	NS	NS
Cubic Rate K_2O (1,2,3,4,5)		NS	NS	NS	NS	NS
Band vs broadcast (3,4 vs 6,7)		NS	*	++	*	NS
Planting vs P,E,H[1] (4 vs 8)		NS	NS	NS	NS	NS

[1] = Planting, emergence and hilling respectively. [2] = Broadcast before plowing. [3] = KCl (0-0-60) at planting and KNO_3 (13-0-44) at emergence and hilling. [4] = Two post-hilling applications at 40 lbs K_2O/A as KNO_3 (13-0-44). NS = Nonsignificant; ++, *, ** = significant at 10%, 5% and 1%, respectively.

Table 3 cont. Effect of potash treatments on potassium concentration in potato petioles (dry weight basis) and potassium concentration in petiole sap, as determined by various procedures. Becker, MN.

Treatment		July 28: dry weight Petiole-K	July 28: sap Horiba	July 28: water Horiba	July 28: $Al_2(SO_4)_3$ Horiba	July 28: sap AA
K_2O source	K_2O timing	--% K --	ppm K			
1. Control	(0 K_2O/A)	5.08	2800	3000	3100	2965
2. KCl	(80,0,0)[1]	6.89	3400	3950	4100	3811
3. KCl	(160,0,0)	8.46	3825	4725	4875	4626
4. KCl	(240,0,0)	9.25	3725	4675	4675	4532
5. KCl	(320,0,0)	9.35	3775	4700	4750	4544
6. KCl	(80[2]+80,0,0)	7.96	3625	4400	4450	4248
7. KCl	(160[2]+80,0,0)	7.77	3650	4425	4500	4306
8. KCL/KNO_3	(80[3],80,80)	8.86	3750	4825	5025	4790
9. KCl/KNO_3	(80[3],40,40,40,40)[4]	8.42	3775	4600	4825	4534
Significance		**	**	**	**	**
BLSD (0.05)		1.43	453	505	654	587
Contrasts						
Linear Rate K_2O (1,2,3,4,5)		**	**	**	**	**
Quadric Rate K_2O (1,2,3,4,5)		*	**	**	**	**
Cubic Rate K_2O (1,2,3,4,5)		NS	NS	NS	NS	NS
Band vs broadcast (3,4 vs 6,7)		++	NS	NS	NS	NS
Planting vs P,E,H[1] (4 vs 8)		NS	NS	NS	NS	NS

[1] = Planting, emergence and hilling respectively. [2] = Broadcast before plowing. [3] = KCl (0-0-60) at planting and KNO_3 (13-0-44) at emergence and hilling. [4] = Two post-hilling applications at 40 lbs K_2O/A as KNO_3 (13-0-44). NS = Nonsignificant; ++, *, ** = significant at 10%, 5% and 1%, respectively.

Table 3 cont. Effect of potash treatments on potassium concentration in potato petioles (dry weight basis) and potassium concentration in petiole sap, as determined by various procedures. Becker, MN.

Treatment		Date: August 15				
K_2O source	K_2O timing	dry weight Petiole-K	sap Horiba	water Horiba	$Al_2(SO_4)_3$ Horiba	sap AA
		--% K --	ppm K			
1. Control	(0 K_2O/A)	3.94	2575	2850	2775	2767
2. KCl	(80,0,0)[1]	6.37	3200	3700	3950	3604
3. KCl	(160,0,0)	7.82	3775	4475	4450	4351
4. KCl	(240,0,0)	8.92	3850	4625	4650	4548
5. KCl	(320,0,0)	9.30	3950	5000	5100	5028
6. KCl	(80[2]+80,0,0)	7.59	3450	4075	4075	4061
7. KCl	(160[2]+80,0,0)	7.80	3450	4075	4225	3722
8. KCL/KNO_3	(80[3],80,80)	8.40	4000	4750	4975	4869
9. KCl/KNO_3	(80[3],40,40,40,40)[4]	8.52	3900	4750	4850	4593
Significance		**	**	**	**	**
BLSD (0.05)		1.71	545	739	773	885
Contrasts						
Linear Rate K_2O	(1,2,3,4,5)	**	**	**	**	**
Quadric Rate K_2O	(1,2,3,4,5)	++	*	NS	++	NS
Cubic Rate K_2O	(1,2,3,4,5)	NS	NS	NS	NS	NS
Band vs broadcast	(3,4 vs 6,7)	NS	++	++	NS	++
Planting vs P,E,H[1]	(4 vs 8)	NS	NS	NS	NS	NS

[1] = Planting, emergence and hilling respectively. [2] = Broadcast before plowing. [3] = KCl (0-0-60) at planting and KNO_3 (13-0-44) at emergence and hilling. [4] = Two post-hilling applications at 40 lbs K_2O/A as KNO_3 (13-0-44). NS = Nonsignificant; ++, *, ** = significant at 10%, 5% and 1%, respectively.

Table 4. Effect of potash treatments on soil potassium in the top 1 foot, Sept 18, 1995. Becker, MN.

Treatment		
K_2O source	K_2O timing	--Exchangeable K-- -----0 to 6"-----
		---ppm ---
1. Control	(0 K_2O/A)	59.15
2. KCl	(80,0,0)[1]	65.88
3. KCl	(160,0,0)	74.00
4. KCl	(240,0,0)	92.30
5. KCl	(320,0,0)	92.50
6. KCl	(80[2]+80,0,0)	71.33
7. KCl	(160[2]+80,0,0)	77.75
8. KCl/KNO_3	(80[3],80,80)	67.68
9. KCl/KNO_3	(80[3],40,40,40,40)[4]	76.78
Significance		NS
BLSD (0.05)		--
Contrasts		
Linear Rate K_2O (1,2,3,4,5)		**
Quadric Rate K_2O (1,2,3,4,5)		NS
Cubic Rate K_2O (1,2,3,4,5)		NS
Band vs Broadcast (3,4 vs 6,7)		NS
Planting vs P,E,H[1] (4 vs 8)		++

[1] = Planting, emergence and hilling respectively. [2] = Broadcast before plowing. [3] = KCl (0-0-60) at planting and KNO_3 (13-0-44) at emergence and hilling. [4] = Two post-hilling applications at 40 lbs K_2O/A as KNO_3 (13-0-44). NS = Nonsignificant; ++, ** = significant at 10% and 1%, respectively.

NITRATE LOSSES THROUGH SUBSURFACE TILE DRAINS FOLLOWING CRP, ALFALFA, CONTINUOUS CORN AND CORN/SOYBEAN ROTATIONS

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ABSTRACT

Nitrate losses in tile drainage water have negative implications for both production and enivironmental aspects of agriculture. In 1988, four crop systems: continuous corn, corn-soybean, alfalfa and Conservation Reserve Program (CRP, 50% alfalfa, 50% smooth brome) were established at the Southwest Experiment Station in Lamberton to determine cropping system effects on biomass yields, N uptake, residual soil NO_3^- and NO_3^- and pesticide losses through tile drains. In 1994, the CRP and alfalfa treatments were converted to corn to assess whether converting land from CRP to annual crops could significantly affect water quality. In 1995, the previous CRP and alfalfa treatments were again planted to corn. Crp-corn-CORN yields were significantly greater than alf-corn-CORN and continuous corn rotations. Crop rotation had no effect on tile flow in 1995 and tile flows ranged from 6.92 acre-in to 9.13 acre-in. Tile flows began in March, peaked in April and May and decreased throughout the summer. Crop rotation did effect both nitrate concentration (ppm) and nitrate losses (lb N/A) in tile drainage with greater losses occurring for sb-CORN, and continuous corn treatments as compared to all other treatments. Nitrate concentrations peaked in March in continous corn and soybean-CORN rotations, and peaked in July for crp-corn-CORN, and alf-corn-CORN rotation. Total nitrate losses ranged from 12.55 lb/A in alf-corn-CORN to 22.26 lb/A in soybean-CORN. Nitrate loss was greatest in April and decreased thoughout the summer.

INTRODUCTION

The nitrogen-pesticide movement study was initiated in 1988 to determine the effect of four cropping systems (continuous corn, corn-soybean, alfalfa and CRP) on above ground biomass yield and NO_3-N loss in tile drainage water. The study is located on fifteen drainage plots originally established at the Southwest Experiment Station, Lamberton in 1972. From 1973 to1979 nitrogen rates of 18 to 400 lb N/A were applied to corn. From 1980 to 1985, continuous corn without N and in 1986 and 1987 continuous corn with only 50 lb N/A was grown to reduce the effects of previous N-rate applications. In 1993, phase 2 of the nitrogen-pesticide movement study was initiated to access nitrate losses through tile drains following conversion of CRP and alfalfa to corn.

METHODS AND MATERIALS

In the spring of 1988 four cropping systems were assigned to fifteen drainage plots (45'x50') in a randomized, complete-block design with three replications. The plots are isolated by plastic to a depth of 6'. The four cropping systems included: continuous corn, corn-soybean sequence, continuous alfalfa, and continuous CRP (Conservation Reserve Program). In the fall of 1993, phase 2 of the study was initiated to evaluate the following cropping systems: continuous corn, alfalfa-Corn, crp-Corn, corn-Soybean and soybean-Corn. Starter fertilizer was applied to the continuous corn, alfalfa-Corn, crp-Corn and soybean-Corn plots. These same crops were continued in 1995, and complete plot management details are listed in Table 1. Rates of applied N for corn were determined from soil samples taken in April, a yield goal of 140 bu/A, credits for the previous crop, and University of Minnesota recommendations. Where:
N rate = $(Yg \times 1.2)-STN_{(0\text{-}24in)}-N_{PC}$.

RESULTS

Significant differences in corn yield are observed among crop rotations with crp-corn-CORN and soybean-CORN yields greater than alf-corn-CORN and continuous corn (Table 3). Over-estimation of the N credit (75 lb N/A, credit) from alfalfa grown two years ago could have contributed to lower yields in the alf-corn-CORN rotation. Yields were greater in all four cropping systems in 1994 as compared to 1995 (Table 3).

In contrast to previous years, crop rotation did not significantly effect tile flows which ranged from 6.92 acre-in alf-corn-CORN to 9.13 acre-in in soybean-CORN (Tables 4 and 5). Tile flows were greater in every rotation in 1995 than in 1994. Tile flows began in March, peaked in April and May and declined throughout the summer.

Nitrate concentrations were significantly effected by rotation with greater concentrations in continuous corn and soybean-CORN than in either alf-corn-CORN or crp-corn-CORN (Table 6). Concentrations ranged from 6.52 ppm to 12.26 ppm. Nitrate concentrations were greatest in March, and then declined in continuous corn and soybean-CORN rotations. Crp-corn-CORN and alf-corn-CORN nitrate concentrations were greatest in July. Nitrate leaching from sidedress applications of N is expressed as nitrate concentrations peak in July across all rotations. Nitrate concentrations in 1995 were similar to 1994 results in the continuous corn, corn-SOYBEAN and soybean-CORN rotations. Alf-corn-CORN and crp-corn-CORN nitrate concentrations increased in 1995.

Nitrate loss (lb/A) was greatest in April and decreases throughout the growing season (Table 7). Nitrate losses were significantly greater for continuous corn and soybean-CORN than for alf-corn-CORN, crp-corn-CORN, and cn-SB (Table 7).

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Table 1. Nitrate-Pesticide Movement Plot Management for 1995

Cropping System - Continuous Corn, alfalfa-corn-CORN, crp-corn-CORN

Item	Type	Rate	Date
Seed	Pioneer 3531	30,000/A	5/4/95
Fertilizer	Starter	15-30-20 lb/A ($N-P_2O_5-K_2O$)	5/4/95
	Urea	128 lb N/A - Cont. Corn	6/7/95
		118 lb N/A - crp-Corn	6/7/95
		54 lb N/A - alf-Corn	
Herbicide	Lasso	4 lb/A (ai)	5/3/95
	Bladex	3 lb/A (ai)	
Insecticide	Lorsban	1 lb/A	5/4/95
Primary Tillage	Moldboard Plow	1 pass	Fall 94
Secondary Tillage	Spring Cultivation	1 pass	5/3/95
	Row Cultivation	1 pass	6/7/95

Cropping System - CORN-soybean

Item	Type	Rate	Date
Seed	Pioneer 3531	30,000/A	5/4/95
Fertilizer	Starter	15-30-20 lb/A ($N-P_2O_5-K_2O$)	5/4/95
	Urea	81 lb N/A	6/7/95
Herbicide	Lasso	4 lb/A (ai)	5/3/95
	Bladex	3 lb/A (ai)	
Primary Tillage	None		
Secondary Tillage	Spring Cultivation	1 pass	5/3/95
	Row Cultivation	1 pass	6/7/95

Cropping System - SOYBEAN-corn

Item	Type	Rate	Date
Seed	Parker	150,000/ A	5/17/95
Row Width	30"		
Herbicide	Lasso	4 lb/A (ai)	5/3/95
Primary Tillage	Moldboard Plow	1 pass	Fall 94
Secondary Tillage	Row Cultivation	1 pass	6/7/95

Table 2. Analysis of Variance - 1995 Corn Yields

Source	DF	SS	MS	F	P
Rep	2	442.56	221.28	2.31	0.1284
Rot	3	3640.08	1213.36	12.64	0.0001

Table 3. 1995 cropping system yields

Year	Cont-C	alf-CN	cn-SB	crp-CN	sb-CN	$LSD_{0.05}$
			Yield (bu/A)			
1995	107.80	109.99	37.79	133.92	133.02	11.88*±
1994	164.32	170.40	44.78	177.10	172.19	7.99*±

* Significant difference

± Yield LSD does not include soybean yield

Table 4. Analysis of Variance - Tile Drainage Discharge

	Source	DF	SS	MS	F	P
Tile Flow	Rep	2	0.56	0.28	2.04	0.1404
	Rot	4	1.18	0.29	2.13	0.0908
	Month	5	189.71	37.94	274.78	0.0001
	Rot*Month	20	2.24	0.11	0.81	0.6880
Nitrate Conc.	Rep	2	24.62	12.31	2.85	0.0681
	Rot	4	285.24	71.31	16.53	0.0001
	Month	5	301.27	60.25	13.97	0.0001
	Rot*Month	20	295.71	14.79	3.43	0.0003
Nitrate Loss	Rep	2	5.80	2.90	1.57	0.2191
	Rot	4	23.17	5.79	3.14	0.0233
	Month	5	880.83	176.17	95.38	0.0001
	Rot*Month	20	34.40	1.72	0.93	0.5540

Table 5. Tile Flow as influenced by cropping system

Month	Cont-C	alf-cn-CN	cn-SB	crp-cn-CN	sb-CN	$LSD_{0.05}$
Tile Flow (Acre-in)						
March	0.21	0.16	0.18	0.15	0.36	0.08
April	3.89	3.49	3.94	4.38	4.77	1.23
May	2.56	2.43	2.78	2.90	3.04	0.87
June	0.97	0.82	0.90	0.90	0.91	0.38
July	0.06	0.01	0.03	0.01	0.02	0.01
August	0.07	0.01	0.02	0.01	0.03	0.02
Total(95)	7.76	6.92	7.85	8.35	9.13	0.71
Total (94)	5.00	4.03	5.52	4.55	5.25	0.21

* Significant treatment differences

Table 6. Flow weighted NO_3-N concentration via the tile lines as influenced by cropping system

Month	Cont-C	alf-cn-CN	cn-SB	crp-cn-CN	sb-CN	$LSD_{0.05}$
Flow weighted NO_3-N Conc. (ppm)						
March	18.94	8.17	12.02	3.58	17.30	4.17*
April	12.05	8.59	9.23	8.56	11.66	3.86
May	10.16	7.14	7.49	7.06	9.60	2.16*
June	9.83	7.80	7.45	7.31	8.99	2.25*
July	15.60	9.26	8.72	9.12	6.26	3.04*
August	6.97	3.14	4.75	3.47	3.92	1.34*
Avg(95)	12.26	7.35	8.28	6.52	9.62	1.97*
Avg(94)	11.45	3.10	8.85	1.00	9.79	2.89*

* Significant treatment differences

Table 7. NO_3-N loss via the tile lines as influenced by cropping system

Month	Cont-C	alf-cn-CN	cn-SB	crp-cn-CN	sb-CN	$LSD_{0.05}$
NO_3-N loss (lb/A)						
March	0.90	0.28	0.52	0.13	1.44	0.50*
April	10.56	6.86	8.23	8.98	12.32	4.89
May	5.81	3.92	4.71	4.73	6.59	2.31
June	2.17	1.47	1.52	1.49	1.88	1.05
July	0.20	0.01	0.03	0.01	0.01	0.07*
August	0.19	0.01	0.05	0.01	0.03	0.07*
Total(95)	19.83	12.55	15.06	15.36	22.26	3.44*
Total(94)	13.34	2.88	11.63	1.08	11.53	0.68*

* Significant treatment differences

NITROGEN FERTILITY MANAGEMENT OF CORN

L.D. Klossner, D.R. Huggins and G.L. Malzer[1]

ABSTRACT

The N-Fertility study at the Southwest Experiment Station in Lamberton has two rotations (continuous corn and corn/soybean) five nitrogen rates (0, 40, 80, 120, 160 lb N/A), three nitrogen timings (fall, spring, sidedress) and two nitrogen forms (anhydrous ammonia, urea). The current study is a modification of the continuous corn study initiated in 1960 on tiled Normania loam. The study was modified in 1994 to include additional N rates, a corn/soybean rotation, and anhydrous ammonia. The first year of results that include corn yields in both continuous corn and corn/soybean rotations was in 1995. Corn yields were greater for the corn/soybean rotation (anhydrous ammonia - 114 bu/A, urea - 111 bu/A) than continuous corn (anhydrous ammonia - 111 bu/A, urea - 89 bu/A) averaged across all N treatments. Corn yields with anhydrous ammonia were greater than urea at the lower nitrogen rates of 40 lb N/A, 80 lb N/A but were similar for greater rates of nitrogen. Soil moisture levels were slightly above the 29-year average during the fall of 1994 and spring of 1995, favoring later applications of N. Yields were generally greater with spring and sidedress applied N than with fall applied N, but only at lower N rates. Overall, yields were generally greatest with 120 lb N/A, across all times of application, except for continuous corn anhydrous ammonia applications, where the greatest yields were found with applications of 160 lb N/A.

METHODS AND MATERIALS

The N-Fertility Management study is a modification of the continuous corn study, which was initiated in 1960 at the Southwest Experiment Station on tiled Normania loam. The study is a randomized complete block, split plot design with four replications. Main plots (20'x57.5') consist of crop rotation (continuous corn and corn/soybean). Subplot (20'x28.75') treatments during corn years are timing (fall, spring, sidedress), form (urea, anhydrous ammonia), and N-rate (0,40,80,120,160 lb/A). Soil moisture measurements are made on the first and the fifteenth of each month starting in May and continuing through November. Soil moisture samples are taken to a depth of 5 feet and split into 6 inch increments for the first 2 feet and 1 foot increments for the last 3 feet. Additional management data are shown in Table 2.

RESULTS AND DISCUSSION

Available soil moisture data from the Nitrogen Fertility project is shown in Table 1 and Figure 1. Soil moisture was above normal, compared to the 29 year average, during the fall of 1994 and spring of 1995. High soil moisture levels in the fall and spring (>5 inches of available moisture in the top five feet) usually result in greater yields for spring and sidedress applied N as compared to fall applied N. Overall, yields for the corn/soybean rotation were greater than yields with continuous corn. Corn yields in the anhydrous ammonia treatments in the corn/soybean rotation averaged 114 bu/A across all N timings and rates versus 93 bu/A for the continuous corn anhydrous ammonia treatments. Corn/soybean urea treatments averaged 111 bu/A versus 89 bu/A for continuous corn. Yields with 0 applied N in the corn/soybean rotation were similar to yields in the continuous corn plots with 40 lb N/A. This agrees with current recommendations for a 40 lb/A N credit following soybeans.

Tables 3 and 5 show the analysis of variance data. In the continuous corn rotation (Table 3), nitrogen rate, timing, nitrogen*time, time*form, and nitrogen*time*form were all significant ($p<0.05$). Corn/soybean (Table 5) analysis of variance show significance ($p<0.05$) for nitrogen rate, timing, and timing*form.

Yields with anhydrous ammonia applications were greater on average across all treatments (continuous corn anhyrous ammonia - 93 bu/A, urea - 89 bu/A; corn/soybean anhydrous ammonia - 114 bu/A, urea - 111 bu/A). Anhydrous ammonia treatment yields were only significantly greater than urea applications at the lower nitrogen rates of 40 lb N/A and 80 lb N/A. This occurred in both the continuous corn (Table 4) and corn/soybean (Table 6) rotations.

The effects of N timing were more greatly expressed in the continuous corn plots than in the corn/soybean plots. Sidedress applied N at low rates (40 lb N/A, 80 lb N/A, anhydrous ammonia) increased yields by up to 95% as compared to fall and spring applied N in the continuous corn treatments (Table 4). Differences in yield, in the continuous corn, plots due to N timing were eliminated with 160 lb N/A. Similar results are observed in the corn/soybean rotation data (Table 6). The low efficiency of N use for fall applied N was probably due to increased N losses from high levels of soil moisture in the previous fall and early spring.

Yields generally were greatest at nitrogen rates of 120 lb N/A (Tables 4 and 6). However, yields in the continuous corn plots with anhydrous ammonia were greatest with N rates of 160 lb N/A.

Table 1. Available Soil Moisture

Sample Date	1994 Total Available Soil Moisture	29 Year Average (1966-1994)
	inches	
9/1/94	4.20	3.87
9/15/94	5.43	4.28
10/1/94	5.24	4.24
10/15/94	5.28	4.4

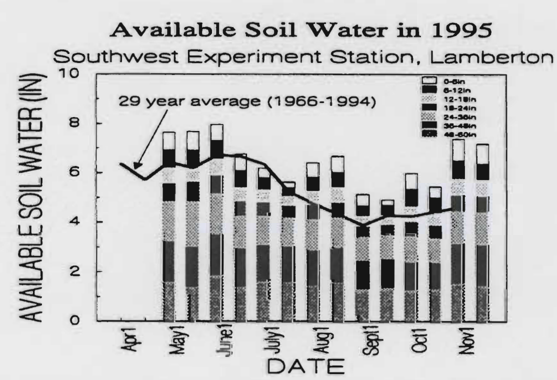

Figure 1. Available Soil Water at Southwest Experiment Station

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Table 2. N-Fertility Plot Management for 1995
Continuous Corn, and Corn/soybean rotations

Item	Type	Rate	Date
Primary Tillage	Moldboard Plow (Corn)	1 pass	Fall 94
	Soil Saver (Soybeans)	1 pass	Fall 94
Secondary Tillage	Field Cultivator	1 pass	5/2/95
		1pass	5/4/95
	Row Cultivation	1 pass	6/9/95
Seed	Pioneer 3531	30,000/A	5/5/95
Fertilizer	Starter	0-30-30 lb/A ($N-P_2O_5-K_2O$)	5/5/95
N Treatment	Fall	40, 80, 120, 160 lb/A	Fall 94*
	Spring	40, 80, 120, 160 lb/A	5/4/95
	Sidedress	40, 80, 120, 160 lb/A	6/8/95
Herbicides	Harness	2.25 pts/A (ai)	5/4/95
	Bladex	2 lb/A (ai)	5/4/95
Insecticides	Force	1.5 lb/A	5/5/95

* Fall fertilizer treatments applied prior to fall tillage

Table 3. Analysis of Variance - Continuous Corn

Source	DF	SS	MS	F	P
Rep	3	1445.19	481.73	3.45	0.0180
N	3	96302.27	32100.76	229.96	0.0001
Time	2	10989.99	5494.99	39.37	0.0001
Form	1	582.96	582.96	4.18	0.0426
N*Time	6	3541.07	590.18	4.23	0.0005
N*Form	3	569.09	189.70	1.36	0.2572
Time*Form	2	2080.30	1040.15	7.45	0.0008
N*Time*Form	6	1957.07	326.18	2.34	0.0342

Table 4. Corn Yields in 1995- Continuous Corn

	Anhydrous Ammonia				Urea			
N-Rate (lb/A)	Fall	Spring	Sidedress	$LSD_{0.05}$	Fall	Spring	Sidedress	$LSD_{0.05}$
	bu/A							
40	42.8	47.6	82.4	7.1*	47.6	59.6	63.3	11.1*
80	77.8	82.7	101.7	13.0*	64.1	92.4	87.7	13.5*
120	100.4	110.4	110.5	11.0	93.6	116.9	112.6	8.9*
160	112.2	122.0	120.9	11.3	106.6	115.2	110.2	13.9
$LSD_{0.05}$	10.6*	9.3*	10.8*		15.9*	15.2*	8.8*	
Check	26.1							

* Significant treatment differences

Table 5. Analysis of Variance - Corn/Soybean

Source	DF	SS	MS	F	P
Rep	3	328.11	109.37	0.59	0.6245
N	3	51198.11	17066.04	91.55	0.0001
Time	2	2756.07	1378.03	7.39	0.0008
Form	1	581.91	581.91	3.12	0.0791
N*Time	6	817.37	136.23	0.73	0.6255
N*Form	3	715.55	238.52	1.28	0.2832
Time*Form	2	2123.17	1061.58	5.69	0.0041
N*Time*Form	6	1926.04	321.01	1.72	0.1188

Table 6. Corn Yields in 1995 - Corn/Soybean

	Anhydrous Ammonia				Urea			
N-Rate (lb/A)	Fall	Spring	Sidedress	$LSD_{0.05}$	Fall	Spring	Sidedress	$LSD_{0.05}$
	bu/A							
40	80.1	83.7	101.0	14.5*	78.1	99.7	80.4	11.3*
80	108.8	111.9	118.9	18.2	95.0	114.3	100.7	15.3*
120	126.9	127.3	123.4	11.6	119.6	132.7	126.4	14.3
160	128.3	132.4	124.9	15.8	123.1	132.0	124.2	16.0
$LSD_{0.05}$	12.4*	18.4*	12.8*		16.7*	14.6*	9.8*	
Check	39.8							

* Significant treatment differences

TILLAGE MANAGEMENT IN CORN-SOYBEAN ROTATIONS AT THE SOUTHWEST EXPERIMENT STATION

L.D. Klossner, and D.R. Huggins[1]

ABSTRACT

Tillage practices that improve environmental quality while remaining economically beneficial is a major objective of agricultural research. Five tillage system: paraplow, ridge tillage, conventional tillage, reduced tillage, and spring tillage were established in corn and soybean crop rotations in 1986. In 1989, the paraplow treatment was converted to no-tillage and in 1994, the tillage systems were further divided into five separate row management systems. Overall corn yields were greater for conventional till than any other tillage treatment. Row management significantly improved yields in ridge-till, reduced till and conventional till treatments. The performance of row cleaners was variable with some effects on yield that were positive and in other cases negative. The effects of starter fertilizer on corn yield were also varied. Overall, tillage treatment had less impact on soybean yields than on corn yields. Soybean yields were greatest in 30" rows for the conventional till plots, and in 7.5" rows for no-till plots. Long-term (1986-1995) corn and soybean yields were greatest in the conventional tillage systems.

INTRODUCTION

This study was initiated in 1986, on a Normania clay loam, to evaluate and monitor five different tillage systems in a corn-soybean rotation for their effects on crop growth, development, yield, soil hydraulic and structural properties, and other soil quality properties.

EXPERIMENTAL DESIGN AND TREATMENTS

Experimental Design: Randomized, complete-block, split plot experiment with four replications. Main plots (50'x155') were tillage treatments of no-tillage, ridge tillage, conventional tillage, reduced tillage, and spring tillage (See Table 1 and 2).

Five subplots (10'x155') consisted of various row management (RM) treatments and differ for corn and soybean crops.

<u>Subplots within corn</u> - detailed corn plot management data is shown in Table 1.

1. Row cleaners (Yetter rolling fingers mounted on J.D. 7200 Conservation Planter)
2. Without row cleaners
3. Row cleaners and starter fertilizer (11-33-11)
4. Without row cleaners and with starter fertilizer (11-33-11)
5. Anhydrous pre-plant indexed on the row (120 lb N/A), with row cleaners and starter fertilizer (11-33-11)

<u>Subplots within soybeans</u> - detailed soil plot management data is shown in Table 2.

1. Row cleaners, 30" rows
2. Without row cleaners, 30" rows
3. With N fertilizer (60 lb N/A) no row cleaner, 30" rows
4. With N fertilizer(60 lb N/A), 7.5" rows
5. Without N fertilizer, 7.5" rows

RESULTS AND DISCUSSION

Corn yields were significantly effected by tillage and RM (Table 3). Row management effected yields in ridge-till, conventional till, and reduced till plots but was not significant for no-till or spring till plots (Table 4). In the ridge tillage, RM5 (A.A. ppi, with row cleaners, and starter fertilizer) was significantly greater than both RM1 (with row cleaners) and RM3 (with row cleaners and starter fertilizer). In the reduced tillage system RM4 (without row cleaners, and starter fertilizer) was significantly greater than every other RM system, except RM5 (A.A. ppi, with row cleaners, and starter fertilizer). When RM systems are compared with tillage, conventional tillage yields were significantly greater in every RM system.

Soybean yields were significantly effected by tillage and RM (Table 5). Row management effected yields in no-till, ridge-till, conventional till and reduced till treatments but was not significant for reduced-till plots (Table 6). In the no-tillage, and reduced tillage systems RM5 (7.5" rows, with no N) showed the greatest yields. In the ridge tillage system RM1 (30" rows, with row cleaners), soybean yields were significantly less than RM3 (reforming ridges prevented the establishment of RM4 and RM5 treatments). Conventional tillage soybeans planted in 30" rows (RM 1, 3) showed greater yields than those planted in 7.5" rows. In contrast, greater yields in no-till and spring till were achieved with drilled soybeans (7.5 in rows) than row soybeans. When soybean RM treatments are compared with each tillage system, no-till yields are greatest with RM5, ridge-till: RM3, conventional till: RM1, reduced till: RM1-5, and spring till: RM2.

Long-term corn yield data (1986-1995) has shown that conventional tillage has been the greatest yielding tillage system in 7 out of 10 years, and has averaged 6 bu/A or more than any other tillage system. Long-term soybean yield data (1986-1995) has also shown that conventional tillage has been the greatest overall yielding tillage system.

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Table 1. 1995 Corn Plot Management

Tillage System	Sub Trt*	Planter	Row Cult	Fertilizer	Seed and Starter Fert.	Spring Tillage	Weed Control
		Corn Sub-Treatments Within Tillage Systems					
No-Tillage	1	JD 4-row	None	Trts 1 and 2	All subtreatments	None	Bladex 2 lb/A (ai)
no fall tillage	2	JD 4-row	None	135 lb N/A 5/26/95	Pioneer 3531 30,000/A		Lasso 3 lb/A (ai) 5/6/95
	3	JD 4-row	None	Trts 3 and 4	Trts 1 and 2 none		
	4	JD 4-row	None	120 lb N/A	Trts 3, 4 and 5		Clarity 1 pt/A (ai)
	5	JD 4-row	None	5/25/95 Trt 5 120 lb N/A A.A. ppi 5/5/95	11-33-11 lb/A ($N-P_2O_5-K_2O$) 5/6/95		5/12/95
Ridge-Tillage	1	JD 4-row	6/27/95	Trts 1 and 2	All subtreatments	None	Lasso 3 lb/A (ai)
no fall tillage	2	JD 4-row	6/27/95	135 lb N/A 5/26/95	Pioneer 3531 30,000/A		5/6/95 Roundup 0/75 lb/A
	3	JD 4-row	6/27/95	Trts 3 and 4	Trts 1 and 2 none		(ai) 5/12/95, 5/25/95
	4	JD 4-row	6/27/95	120 lb N/A	Trts 3, 4 and 5		
	5	JD 4-row	6/27/95	5/25/95 Trt 5 120 lb N/A A.A. ppi 5/5/95	11-33-11 lb/A ($N-P_2O_5-K_2O$) 5/6/95		Clarity 1 pt/A (ai) 5/12/95
Conventional	1	JD 4-row	6/22/95	Trts 1 and 2	All subtreatments	Disc	Doubleplay 6 pts/A
chisel plow	2	JD 4-row	6/22/95	135 lb N/A 5/26/95	Pioneer 3531 30,000/A	5/4/95	(ai) Bladex 2 lb/A (ai)
Fall 1994	3	JD 4-row	6/22/95	Trts 3 and 4	Trts 1 and 2 none		5/4/95
	4	JD 4-row	6/22/95	120 lb N/A	Trts 3, 4 and 5		
	5	JD 4-row	6/22/95	5/25/95 Trt 5 120 lb N/A A.A. ppi 5/5/95	11-33-11 lb/A ($N-P_2O_5-K_2O$) 5/6/95		
Reduced	1	JD 4-row	6/22/95	Trts 1 and 2	All subtreatments	Disc	Doubleplay 6 pts/A
no fall tillage	2	JD 4-row	6/22/95	135 lb N/A 5/26/95	Pioneer 3531 30,000/A	5/4/95	(ai) Bladex 2 lb/A (ai)
	3	JD 4-row	6/22/95	Trts 3 and 4	Trts 1 and 2 none		5/4/95
	4	JD 4-row	6/22/95	120 lb N/A	Trts 3, 4 and 5		
	5	JD 4-row	6/22/95	5/25/95 Trt 5 120 lb N/A A.A. ppi 5/5/95	11-33-11 lb/A ($N-P_2O_5-K_2O$) 5/6/95		
Spring Tillage (95)	1	JD 4-row	6/22/95	Trts 1 and 2	All subtreatments	Disc	Doubleplay 6 pts/A
Flex Tillage (96)	2	JD 4-row	6/22/95	135 lb N/A 5/26/95	Pioneer 3531 30,000/A	5/4/95	(ai) Bladex 2 lb/A (ai)
no fall tillage	3	JD 4-row	6/22/95	Trts 3 and 4	Trts 1 and 2 none		5/4/95
	4	JD 4-row	6/22/95	120 lb N/A	Trts 3, 4 and 5		
	5	JD 4-row	6/22/95	5/25/95 Trt 5 120 lb N/A A.A. ppi 5/5/95	11-33-11 lb/A ($N-P_2O_5-K_2O$) 5/6/95		

Corn Subtreatments Within Tillage Systems
1=with row cleaners
2=without row cleaners
3=with row cleaners + starter
4=without row cleaners + starter fertilizer
5=Anhydrous pre-plant indexed on the row, w/row cleaners + starter fertilizer

Table 2. 1995 Soybean Plot Management

Soybean Sub-Treatments Within Tillage Systems

Tillage System	Sub Trt*	Planter	Row Cult	Fertilizer	Seed	Spring Tillage	Weed Control (ai)
No-Tillage	1	JD 4-row	None		Trt 1, 2, and 3	None	Sencor 0.31 lb/A
no fall tillage	2	JD 4-row	None		Parker 150,000/A		Lasso 3 lb/A Roundup 1 lb/A
	3	JD 4-row	None	Trts 3 and 4	Trt 4 and 5		5/24/95
	4	JD 752	None	60 lb N/A	Parker 200,000/A		Select 8 oz/A
	5	JD 752	None	(NH_4NO_3) broadcast 5/20/95	planted 5/20/95		7/1/95
Ridge-Tillage	1	JD 4-row	7/10/95		Parker 150,000/A	None	Sencor 0.31 lb/A
no fall tillage	2	JD 4-row	7/10/95		planted 5/20/95		Lasso 3 lb/A 5/24/95
	3	JD 4-row	7/10/95	Trts 3 and 4			Select 8 oz/A
	4	JD 4-row	7/10/95	60 lb N/A			7/1/95
	5	JD 4-row	7/10/95	(NH_4NO_3) broadcast 5/20/95			
Conventional	1	JD 4-row	6/16/95		Trt 1, 2, and 3	Disc	Sencor 0.31 lb/A
Primary Tillage	2	JD 4-row	6/16/95		Parker 150,000/A	5/20/95	Lasso 3 lb/A 5/24/95
Moldboard plow	3	JD 4-row	6/16/95	Trts 3 and 4	Trt 4 and 5		Select 8 oz/A
Fall 94	4	JD 752	None	60 lb N/A	Parker 200,000/A		7/1/95
	5	JD 752	None	(NH_4NO_3) broadcast 5/20/95	planted 5/20/95		
Reduced	1	JD 4-row	6/16/95		Trt 1, 2, and 3	Disc	Sencor 0.31 lb/A
Primary Tillage	2	JD 4-row	6/16/95		Parker 150,000/A	5/20/95	Lasso 3 lb/A 5/24/95
Chisel plow	3	JD 4-row	6/16/95	Trts 3 and 4	Trt 4 and 5		Select 8 oz/A
Fall 94	4	JD 752	None	60 lb N/A	Parker 200,000/A		7/1/95
	5	JD 752	None	(NH_4NO_3) broadcast 5/20/95	planted 5/20/95		
Spring Tillage (95)	1	JD 4-row	6/16/95		Trt 1, 2, and 3	Disc	Sencor 0.31 lb/A
Flex Tillage (96)	2	JD 4-row	6/16/95		Parker 150,000/A	5/20/95	Lasso 3 lb/A 5/24/95
no fall tillage	3	JD 4-row	6/16/95	Trts 3 and 4	Trt 4 and 5		Select 8 oz/A
	4	JD 752	None	60 lb N/A	Parker 200,000/A		7/1/95
	5	JD 752	None	(NH_4NO_3) broadcast 5/20/95	planted 5/20/95		

*Soybean Subtreatments Within Tillage Systems
1=with row cleaners, 30" rows
2=without row cleaners, 30" rows
3=with N fert (no row cleaner), 30" rows
4=with N fert, 7.5" rows
5=with no N fert, 7.5" rows

Table 3. Analysis of Variance

Corn - 1995	Source	DF	SS	MS	F	P
	Rep	3	184.10	61.37	1.45	0.2297
	Till	4	6900.57	1725.14	40.82	0.0001
	Rep*Till	12	3822.77	318.56	7.54	0.0001
	RowMgt	4	719.90	179.98	4.26	0.0027
	Till*RowMgt	16	836.48	52.28	1.24	0.2454
	Tests of Hypothesis Using Type III MS for Rep*Till as error term					
	Till	4	6900.57	1725.14	5.42	0.0100

Table 4. Corn Yields in 1995

Tillage System	Row Management 1	2	3	4	5	$LSD_{0.05}$
	(bu/A)					
No-Tillage	115.1	115.4	118.6	121.9	116.1	8.5
Ridge-Tillage	117.8	121.8	118.0	121.3	123.3	5.1*
Conventional	130.8	136.6	138.5	134.4	131.8	5.9*
Reduced	121.2	123.9	125.4	132.2	128.1	6.1*
Spring	125.9	127.9	124.1	131.0	126.3	7.0
$LSD_{0.05}$	8.5	16.1	11.5	9.6	9.8	

*Significant treatment differences

Table 5. Analysis of Variance

Soybeans - 1995	Source	DF	SS	MS	F	P
	Rep	3	93.92	31.31	2.82	0.0409
	Till	4	356.38	89.10	8.03	0.0001
	Rep*Till	12	287.29	23.94	2.16	0.0166
	RowMgt	4	85.01	21.25	1.92	0.1108
	Till*RowMgt	14	570.08	40.72	3.67	0.0001
	Tests of Hypothesis Using Type III MS for Rep*Till as error term					
	Till	4	356.38	89.10	3.72	0.0342

Table 6. Soybean Yields in 1995

Tillage System	Row Management 1	2	3	4	5	$LSD_{0.05}$
	(bu/A)					
No-Tillage	38.9	36.5	40.0	42.7	44.2	3.9*
Ridge-Tillage	36.4	39.6	40.7	nd	nd	3.7*
Conventional	44.5	42.1	44.0	40.7	40.6	3.2*
Reduced	39.5	40.1	40.0	40.3	41.7	2.9
Spring	42.0	45.8	40.5	43.1	45.1	3.3*
$LSD_{0.05}$	5.1*	5.2*	5.2	4.8	3.6*	

*Significant treatment differences

Table 7. 1986-1995 Corn Yields

Tillage	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	Avg
						bu/A					
Notill	142.0	132.4	73.7	122.2	114.5	133.4	134.2	71.9	146.7	117.4	118.8
Ridge	145.4	125.4	82.2	132.6	118.4	128.9	145.3	72.0	162.2	120.4	123.3
Conv.	141.5	136.4	76.7	139.0	137.2	132.2	153.6	76.6	166.3	134.4	129.4
Reduced	139.8	124.8	70.1	128.1	120.5	133.6	130.7	75.1	162.7	126.2	121.2
Spr. till	132.4	119.8	65.4	131.8	122.8	132.6	136.6	73.4	164.5	127.0	120.6
$LSD_{0.05}$	11.7	6.7	6.7	6.9	6.0	6.2	10.2	4.3	6.9	5.8	3.6

Table 8. 1986-1995 Soybean Yields

Tillage	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	Avg
						bu/A					
Notill	47.4	39.3	26.9	40.9	44.7	40.3	35.9	19.8	41.7	40.5	37.7
Ridge	47.2	38.7	26.7	49.2	48.7	41.3	35.3	31.5	42.6	38.9	40.0
Conv.	47.9	38.8	32.7	48.8	51.8	48.0	37.3	38.9	47.1	42.4	43.4
Reduced	46.7	39.5	26.3	45.8	51.6	46.2	37.7	34.5	43.1	40.3	41.2
Spr. till	48.9	37.0	26.2	47.1	45.4	44.4	36.5	33.1	41.6	43.3	40.4
$LSD_{0.05}$	1.5	1.4	1.5	2.6	2.6	3.5	2.0	2.9	1.9	1.5	1.8

VARIABLE INPUT CROP MANAGEMENT SYSTEMS AT THE SOUTHWEST EXPERIMENT STATION: 7-YEAR MANAGEMENT HISTORY AND 1995 YIELDS

C.A. Perillo, P. M. Porter, D.R. Huggins, L.D. Klossner[1]

ABSTRACT

The development of methods to replace or supplement off-farm inputs and energy with on-farm resources is an important goal for agricultural sustainability. Cropping systems with minimum input, lower purchased input, higher purchased input, and organic input were established with two crop rotations and two prior levels of external inputs in 1989. In addition to results for 1995, this article outlines the actual management practices used in each of the seven years of the study.

INTRODUCTION

In 1988 the University of Minnesota gained access to a research site called the 'Koch Farm'. The Koch farm was a minimum input farm for at least 35 years prior to 1988. The overall objective of the Variable Input Crop Management Study (VICM) is to determine how to replace off-farm inputs and energy with on-farm resources, and includes the evaluation of cropping systems with variable off-farm inputs. 1995 was the seventh year of crop production in the study.

METHODS AND MATERIALS

The study began in 1989 with treatments including two prior levels of external (off-farm) input: 1) VICM I located on the Koch Farm with 30 years of minimal inputs; and 2)VICM II located on the Southwest Experiment Station with 30 years of high external inputs. Each study evaluates four different management systems: 1) Minimum Input (MIN), 2) Lower Purchased Inputs (LPI), 3) High Purchased Inputs (HPI), and 4) Organic Inputs (ORG). Each study has two different crop rotations: 1) a four-year rotation of corn/soybeans/oat/alfalfa (CSOA) and 2) and a two-year corn/soybean (CS) rotation. Every crop is grown each year for every rotation.

Each of the four management systems is managed independently of the other three systems, and has the objective of maintaining good yields that are consistent with the philosophy of that system. The philosophies used for the four management systems are as follows:

MIN management systems receive no fertilizer or pesticides. Weed control is only through mechanical means (rotary hoe and row cultivation), and corn and soybeans are planted 1 to 2 weeks later than normal.

LPI management systems are planted as soon as possible to maximize yield potential. Phosphorus & K fertilizers are applied in a 2x2 band for corn and soybeans, N is applied in a 2x2 band in corn, and N, P and/or K fertilizer is broadcast on the oats and alfalfa. Fertilizer rates are based on soil tests, previous crop and realistic yield goals. Weed control includes rotary hoe and row cultivation, as well as moderate herbicide application - banded for corn and soybean, broadcast in oat and alfalfa. Generally this treatment has less intensive fall tillage than the other management strategies.

HPI management systems are planted as soon as possible to maximize yield potential. N, P and K are broadcast on all crops. Fertilizer rates are based on soil tests, previous crop and an optimistic yield goal (10% greater than realistic yield goal). Weed control is through row cultivation and herbicides.

ORG management systems are planted with untreated seed 1 to 2 weeks later than normal (corn and soybeans) to allow additional pre-planting tillage for weed control. The CSOA corn and oat crops rotation receive solid beef manure in the prior fall. Corn in the CS corn rotation receives liquid hog manure prior to planting in the spring. The rates are based on soil tests and previous manure application rates. Weed control is mechanical only, and includes rotary hoe and row cultivation.

Tables 1 and 2 show the details of plot management for 1995 for VICM I and VICM II respectively. Details of plot management for each year from 1989-1995 are given in Tables 5 and 6 for VICM I and VICM II respectively.

RESULTS

VICMS I crop yields for 1995 are summarized in Table 3. In VICM I, there was no difference in yield between the LPI and HPI management systems regardless of rotation (CSOA or CS). MIN had the lowest yield for all crops except oats and the SC-rotation soybean, in which case there were no significant differences between any of the management systems. ORG was never statistically different than LPI, though it was significantly less than HPI for CS corn and CSOA soybean.

VICM II crop yields for 1995 are summarized in Table 4. Patterns in yield with respect to management system are more complicated than for VICM I. Highest yields generally occurred in the HPI system, except for CSOA corn where the LPI system yielded significantly higher than HPI, and for oats where ORG and MIN yields were both significantly higher than HPI. Generally the MIN system had the lowest yields, however the lowest yields for soybean in both rotations was the ORG system, and for oats was the HPI system.

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Table 1. 1995 Plot management - Variable Input Crop Management System I (VICM I).

Mgt Level	Fall Tillage	Spring Tillage	Seed (rate:plants/ac)	Fertilizer	Herbicide	Rotary Hoe	Row Cult.
CS-Rotation: CORN							
MIN	Chisel Fall 94	Field Cult. 5/17, 5/19	P3769 (30,000) 5/19	None	None	5/31, 6/5	6/12,6/19. 6/29
LPI	none	Field Cult. 5/6, 5/17	P3769 (30,000) 5/18	0-65-0 Band 5/18	Buctril/Atrazine 6/12, Stinger 6/12, Accent 6/20 All POST,10" band	6/5	6/15, 6/19. 6/29
HPI	Chisel Fall 94	Field Cult. 5/6, 5/17	P3769 (30,000) 5/18	120-70-25 broadcast 5/17	Doubleplay, Bladex PPI 5/17 Stinger spotspray 6/9	none	6/12
ORG	Chisel Fall 1994	Field Cult. 5/17, 5/19	P3769 (30,000) 5/19	229-269-80 manure 5/19	none	5/31, 6/5	6/12,6/19, 6/29
CS-Rotation: SOYBEAN							
MIN	Moldboard Fall 94	Field Cult. 5/18, 5/22	Parker (158,000) 5/23	none	none	5/31, 6/5	6/15, 6/27, 7/12
LPI	SoilSaver Fall 1994	Field Cult. 5/18, 5/18	Parker (158,000) 5/19	0-0-0	Basagran, Pinnacle 6/19 Select 6/24 POST 10" band	6/5	6/16, 6/29, 7/13
HPI	Moldboard Fall 1994	Field Cult. 5/18, 5/18	Parker (158,000) 5/19	0-0-0	Treflan 5/18 PPI	none	6/15, 7/13
ORG	Moldboard Fall 94	Field Cult. 5/18, 5/22	Parker (158,000) 5/23	none	none	5/31, 6/5	6/15, 6/27, 7/12
CSOA-Rotation: CORN							
MIN	Chisel Fall 94	Field Cult. 5/17, 5/19	P3769 (30,000) 5/19	None	None	5/31,6/2, 6/5	6/12
LPI	none	Field Cult. 5/6, 5/17	P3769 (30,000) 5/18	0-98-0 Band 5/18	Buctril/Atrazine 6/12, Stinger 6/12 All POST,10" band	6/5	6/15
HPI	Chisel Fall 94	Field Cult. 5/6, 5/17	P3769 (30,000) 5/18	15-105-0 broadcast 5/12	Doubleplay, Bladex PPI 5/17 Stinger spotspray 6/9	none	6/12
ORG	Chisel Fall 1994	Field Cult. 5/17, 5/19	P3769 (30,000) 5/19	390-81-not an. manure Fall 94	none	5/31, 6/2, 6/5	6/12
CSOA-Rotation: SOYBEAN							
MIN	Moldboard Fall 94	Field Cult. 5/18, 5/22	Parker (158,000) 5/23	none	none	5/31, 6/5	6/15, 6/27, 7/12
LPI	SoilSaver Fall 1994	Field Cult. 5/18, 5/18	Parker (158,000) 5/19	0-0-0	Basagran, Pinnacle 6/19 Select 6/24 POST 10" band	6/5	6/16, 6/29, 7/13
HPI	Moldboard Fall 1994	Field Cult. 5/18, 5/18	Parker (158,000) 5/19	0-0-0	Sonolan 5/18 PPI	none	6/15, 7/13
ORG	Moldboard Fall 94	Field Cult. 5/18, 5/22	Parker (158,000) 5/23	none	none	5/31, 6/5	6/15, 6/27, 7/12
CSOA-Rotation: OAT							
MIN	Chisel Fall 94	Field Cult. 5/1 Drag&Pack 5/2	Dane (85lb/ac) 5/2	none	none	none	none
LPI	none	Field Cult. 5/1 Drag&Pack 5/2	Dane (85lb/ac) 5/2	50-50-0 5/1	Buctril 6/1 POST	none	none
HPI	Chisel Fall 1994	Field Cult. 5/1 Drag&Pack 5/2	Dane (85lb/ac) 5/2	50-50-50 5/1	Buctril 6/1 POST	none	none
ORG	Chisel Fall 94	Field Cult. 5/1 Drag&Pack 5/2	Dane (85lb/ac) 5/2	130-27-not an.	none	none	none
CSOA-Rotation: ALFALFA							
MIN	none	none	P5265(12 lb/ac) w/ prev year oats	none	none	none	none
LPI	none	none	P5265(12 lb/ac) w/ prev year oats	0-65-15 7/24	Buctril 6/1 POST	none	none
HPI	none	none	P5265(12 lb/ac) w/ prev year oats	0-65-15 7/24	Buctril 6/1 POST	none	none
ORG	none	none	P5265(12 lb/ac) w/ prev year oats	none	none	none	none

Table 2. 1995 Plot Management - Variable Input Crop Management System II (VICM II).

Mgt Level	Fall Tillage	Spring Tillage	Seed (rate:plants/ac)	Fertilizer	Herbicide	Rotary Hoe	Row Cult.
CS-Rotation: CORN							
MIN	Chisel Fall 1994	Field Cult. 5/17, 5/19	P3769 (30,000) 5/19	None	None	5/31, 6/5	6/12,6/19. 6/29
LPI	none	Field Cult. 5/6, 5/17	P3769 (30,000) 5/18	197-0-0 band 5/18	Buctril/Atrazine 6/12, Stinger 6/12, Accent 6/20 All POST,10" band	6/5	6/19,6/29
HPI	Chisel Fall 1994	Field Cult. 5/6, 5/17	P3769 (30,000) 5/18	125-0-0 broadcast 5/17	Doubleplay, Bladex PPI 5/17 Stinger spotspray 6/9	none	6/12
ORG	Chisel Fall 1994	Field Cult. 5/17, 5/19	P3769 (30,000) 5/19	229-269-80 manure 5/19	none	5/31, 6/5	6/12,6/19, 6/29
CS-Rotation: SOYBEAN							
MIN	Moldboard Fall 1994	Field Cult. 5/18, 5/22	Parker (158,000) 5/23	none	none	5/31, 6/5	6/15, 6/27, 7/12
LPI	SoilSaver Fall 1994	Field Cult. 5/18, 5/18	Parker (158,000) 5/19	none	Basagran, 6/19, Select 6/24 POST 10" band	6/5	6/29,7/13
HPI	Moldboard Fall 1994	Field Cult. 5/18, 5/18	Parker (158,000) 5/19	none	Treflan 5/18 PPI Basagran 6/24 POST	none	6/15, 7/13
ORG	Moldboard Fall 1994	Field Cult. 5/18, 5/22	Parker (158,000) 5/23	none	none	5/31, 6/5	6/15, 6/27, 7/12
CSOA-Rotation: CORN							
MIN	Moldboard Fall 1994	Field Cult. 5/17, 5/19	P3769 (30,000) 5/19	None	None	5/31, 6/5	6/12
LPI	Moldboard Fall 1994	Field Cult. 5/6, 5/17	P3769 (30,000) 5/18	*0-98-0* Band 5/18	Buctril/Atrazine,Stinger 6/12 Accent 6/20 All POST,10" band	6/5	6/12
HPI	Moldboard Fall 94	Field Cult. 5/6, 5/17	P3769 (30,000) 5/18	20-15-25 broadcast 5/17	Doubleplay, Bladex PPI 5/17 Stinger spotspray 6/9	none	6/12
ORG	Moldboard Fall 1994	Field Cult. 5/17, 5/19	P3769 (30,000) 5/19	130-27-not an. manure Fall 94	none	5/31, 6/5	6/12
CSOA-Rotation: SOYBEAN							
MIN	Moldboard Fall 94	Field Cult. 5/18, 5/22	Parker (158,000) 5/23	none	none	5/31, 6/5	6/15, 6/29, 7/12
LPI	SoilSaver Fall 1994	Field Cult. 5/18, 5/18	Parker (158,000) 5/19	0-0-0	Basagran 6/19, Select 6/24 POST 10" band	6/5	6/29, 7/13
HPI	Moldboard Fall 1994	Field Cult. 5/18, 5/18	Parker (158,000) 5/19	0-0-0	Sonolan 5/18 PPI	none	6/15, 7/13
ORG	Moldboard Fall 94	Field Cult. 5/18, 5/22	Parker (158,000) 5/23	none	none	5/31, 6/5	6/15, 6/29, 7/12
CSOA-Rotation: OAT							
MIN	Chisel Fall 94	Field Cult. 5/2 Drag&Pack 5/3	Dane (85lb/ac) 5/3	none	none	none	none
LPI	none	Field Cult. 5/2 Drag&Pack 5/3	Dane (85lb/ac) 5/3	30-10-0 5/1	Buctril 6/1 POST	none	none
HPI	Chisel Fall 1994	Field Cult. 5/2 Drag&Pack 5/3	Dane (85lb/ac) 5/3	50-20-0 5/1	Buctril 6/1 POST	none	none
ORG	Chisel Fall 94	Field Cult. 5/2 Drag&Pack 5/3	Dane (85lb/ac) 5/3	130-27-not an.	none	none	none
CSOA-Rotation: ALFALFA							
MIN	none	none	P5265(12 lb/ac) w/ prev year oats	none	none	none	none
LPI	none	none	P5265(12 lb/ac) w/ prev year oats	0-65-15 7/24	none	none	none
HPI	none	none	P5265(12 lb/ac) w/ prev year oats	0-65-15 7/24	none	none	none
ORG	none	none	P5265(12 lb/ac) w/ prev year oats	none	none	none	none

Table 3. 1995 Yields - Variable Input Crop Management Systems (VICM I).

		Management Level				
Rotation	Crop	MIN	LPI	HPI	ORG	$LSD_{0.05}$
		bu/A				
CSOA	Corn	59.0	109	112	102	15.41
CS	Corn	37.6	95.3	103	88.2	13.49
SOAC	Soybeans	32.7	42.6	41.1	41.8	5.39
SC	Soybeans	36.7	41.0	38.8	36.7	7.83
ACSO	Alfalfa*	3.20	5.12	5.56	4.47	0.96
OACS	Oats	34.5	33.6	33.9	32.5	7.30

*Alfalfa yields are (T/A)

Table 4. 1995 Yields - Variable Input Crop Management Systems II (VICM II).

		Management Level				
Rotation	Crop	MIN	LPI	HPI	ORG	$LSD_{0.05}$
		bu/A				
CSOA	Corn	94.4	112	105	111	6.23
CS	Corn	54.0	70.2	104	89.6	12.05
SOAC	Soybeans	34.5	33.8	36.6	33.3	5.17
SC	Soybeans	34.4	25.5	38.4	24.4	5.63
ACSO	Alfalfa*	7.66	7.94	8.38	7.91	0.68
OACS	Oats	28.8	22.8	17.8	30.4	3.48

*Alfalfa yields are (T/A)

Table 5. Tillage and planting information for VICM I 1989-1995.

Rot. - Crop	Prod. Year	Prev.Fall Tillage†	Spring Tillage‡	Rotary Hoe	Seed	Seed Rate	Seed Date	Row Cultiv	Fertilizer ($N-P_2O_5-K_2O$)	Herbicide§ type1(rate1), type2(rate2)
				# passes		plants/ac		# passes	lb/ac	lb ai/ac
CS - Corn										
Min	1989	Ch	FC 2x	1x	P3585	26000	5/15	3x	0-0-0	none
	1990	Ch	FC 1x	3x	P3585	27700	5/8	3x	0-0-0	none
	1991	none	FC 2x	4x	P3585	27700	5/13	2x	0-0-0	none
	1992	none	FC 1x	1x	P3585	29000	5/12	3x	0-0-0	none
	1993	none	FC 1x	3x	P3585	29000	5/14	4x	0-0-0	none
	1994	Ch	FC 2x	3x	P3769	29000	5/13	2x	0-0-0	none
	1995	Ch	FC 2x	2x	P3769	30000	5/19	3x	0-0-0	none
LPI	1989	Ch	FC 1x	1x	P3585	26000	5/3	3x	75-50-50	Alac (3.0), 2,4-D (0.5)
	1990	none	FC 2x	5x	P3585	27700	4/23	3x	60-20-10	Alac (3.0), 2,4-D (0.5)
	1991	none	FC 1x	3x	P3585	27700	4/26	1x	60-30-15	Alac (3.0), 2,4-D (0.5)
	1992	none	FC 1x	1x	P3585	29000	5/1	2x	157-35-35	Alac (3.0), Nico (0.031)
	1993	none	FC 1x	1x	P3585	29000	5/14	2x	122-42-0	Alac (3.0)
	1994	none	FC 1x	1x	P3769	29000	5/9	1x	115-45-25	Nico (0.031), Clpy (0.25)
	1995	none	FC 2x	1x	P3769	30000	5/18	3x	0-65-0	[Brox&Atra](0.19&0.28),Clpy (0.09),Nico(.031)
HPI	1989	Ch	FC 2x	1x	P3585	26000	5/3	2x	150-100-100	[EPTC&R29148](4.0),Cyan(2.0),2,4-D(0.5)
	1990	Ch	FC 2x	none	P3585	27700	4/23	3x	120-40-20	[EPTC&R29148](2.5),Cyan(1.5),2,4-D(0.5)
	1991	Ch	FC 2x	none	P3585	27700	4/26	1x	120-60-30	[EPTC&R29148](2.5),Cyan(1.5),2,4-D(0.5)
	1992	Ch	FC 2x	none	P3585	29000	5/1	3x	197-50-50	[EPTC&R29148](2.5),Cyan(1.5)
	1993	SS	FC 2x	none	P3585	29000	5/14	2x	142-74-25	[EPTC&R29148](2.5),Cyan(1.5), Nico (0.031)
	1994	Ch	FC 3x	none	P3769	29000	5/9	1x	130-90-50	[EPTC&R29148](2.5),Cyan(1.5),Clpy (0.25)
	1995	Ch	FC 2x	none	P3769	30000	5/18	1x	120-70-25	[EPTC&R29148&Acet](4.2&1.2),Cyan(2),Clpy(0.25)
Org	1989	Ch	FC 2x	1x	P3585	26000	5/15	3x	352-3-158	none
	1990	Ch	FC 3x	3x	P3585	27700	5/8	3x	126-155-71	none
	1991	none	FC 2x	4x	P3585	27700	5/13	2x	263-244-76	none
	1992	none	FC 2x	1x	P3585	29000	5/12	4x	156-81-63	none
	1993	none	FC 2x	3x	P3585	29000	5/14	2x	228-137-87	none
	1994	Ch	FC 3x	3x	P3769	29000	5/13	2x	283-104-87	none
	1995	Ch	FC 2x	2x	P3769	30000	5/19	3x	229-269-80	none
CS - Soybean										
Min	1989	Ch	disk 1x	1x	Hardin	150,000	5/25	3x	0-0-0	none
	1990	MB	disk/FC	2x	Hardin	150,000	5/18	3x	0-0-0	none
	1991	MB	FC 2x	1x	Hardin	150,000	5/23	2x	0-0-0	none
	1992	MB	disk 2x	2x	Hardin	150,000	5/6	3x	0-0-0	none
	1993	MB	disk/FC	1x	Hardin	150,000	5/26	2x	0-0-0	none
	1994	MB	FC 3x	1x	Parker	158.000	5/27	3x	0-0-0	none
	1995	MB	FC 2x	2x	Parker	158.000	5/23	3x	0-0-0	none
LPI	1989	Ch	disk 2x	1x	Hardin	150,000	5/11	3x	0-50-50	Alac (3.0), Bent (0.75)
	1990	SS	disk 2x	3x	Hardin	150,000	5/10	3x	0-31-16	Alac (3.0), Seth+COC (0.2)
	1991	SS	FC 1x	3x	Hardin	150,000	5/14	2x	0-25-25	Alac (3.0), Seth+COC (0.2)
	1992	SS	disk 2x	2x	Hardin	150,000	5/6	2x	5-25-25	Alac (3.0)
	1993	SS	disk/FC	1x	Hardin	150,000	5/26	2x	0-0-0	Alac (3.0)
	1994	SS	FC 1x	1x	Parker	158,000	5/12	2x	0-35-0	Clet (0.125), Imep (0.047)
	1995	SS	FC 2x	1x	Parker	158.000	5/19	3x	*0-0-0*	Bent (0.75), Thif (0.002), Clet (0.125)
HPI	1989	Ch	FC 2x	none	Hardin	150,000	5/11	2x	0-100-100	Bent (0.75), Seth+COC (0.2)
	1990	MB	disk2x/ FC	none	Hardin	150,000	5/10	2x	0-40-20	Trif (0.75)
	1991	MB	FC 2x	none	Hardin	150,000	5/14	2x	0-40-40	Trif (0.75)
	1992	MB	disk 2x	none	Hardin	150,000	5/8	2x	11-50-50	Trif (0.75)
	1993	MB	disk/FC2x	none	Hardin	150,000	5/26	2x	0-50-0	Trif (0.75)
	1994	MB	FC 2x	none	Parker	158,000	5/12	1x	0-50-0	Trif (0.75), Metr(0.25)
	1995	MB	FC 2x	none	Parker	158,000	5/19	3x	0-0-0	Trif (0.75)
Org	1989	Ch	disk 1x	1x	Hardin	150,000	5/25	3x	127-1-57	none
	1990	MB	disk/FC	1x	Hardin	150,000	5/18	3x	0-0-0	none
	1991	MB	FC 2x	1x	Hardin	150,000	5/23	2x	0-0-0	none
	1992	MB	disk 2x	1x	Hardin	150,000	5/18	4x	0-0-0	none
	1993	MB	disk/FC	1x	Hardin	150,000	5/26	2x	0-0-0	none
	1994	MB	FC 3x	1x	Parker	158,000	5/27	3x	0-0-0	none
	1995	MB	FC 2x	2x	Parker	158,000	5/23	3x	0-0-0	none

† Primary tillage previous fall: MB=moldboard plow, Ch=chisel, SS=Soil Saver.
‡ Spring tillage: FC=field cultivator, #x = # of passes. Designation of disk/FC indicates 1 pass with disk, and a later pass with FC.

§Alac=alachlor(Lasso II) preemergent (PRE); Bent= bentazon (Basagran) post-emergent (POST); Bnfn=benefin (Balan) preplant incorporated (PPI); Brox=bromoxynil (Buctril) POST; [Brox&Atra] = broxynil & atrazine POST; Clet=clethodim (Select) POST; Clpy=clopyralid (Stinger) POST spot-spray; Cyan=cyanazine (Bladex) PPI; [EPTC&R29148] = EPTC plus safener (Eradicane), PPI; [EPTC&R29148&Acet]= EPTC+safener+acetochlor (Doubleplay), PPI; Etha=ethalfluralin (Sonalan) PPI; Imep=imazethapyr (Pursuit) POST; Metr=metribuzin (Sencor) PPI; Nico=nicosulfuron (Accent) +surfactant+28% N fertilizer, POST; Seth+COC = sethoxydim (Poast+COC), POST; Thif= thifensulfuron (Pinnacle), POST; Trif=trifluralin (Treflan) PPI.

Table 5 (con't). Tillage and planting information for VICM I 1989-1995.

Rot. - Crop	Prod. Year	Prev.Fall Tillage†	Spring Tillage‡	Rotary Hoe	Seed	Seed Rate	Seed Date	Row Cultiv	Fertilizer (N-P_2O_5-K_2O)	Herbicide§ type1(rate1), type2(rate2)
				#passes		plants/ac			# passes	lb/ac (lb ai/ac)
CSOA - Corn										
Min	1989	Ch	FC 2x	1x	P3585	26000	5/15	3x	0-0-0	none
	1990	MB	FC 2x	3x	P3585	27700	5/8	3x	0-0-0	none
	1991	MB	FC 2x	4x	P3585	27700	5/13	2x	0-0-0	none
	1992	MB	FC 1x	1x	P3585	29000	5/12	3x	0-0-0	none
	1993	MB	FC 1x	3x	P3585	29000	5/14	2x	0-0-0	none
	1994	Ch	FC 2x	3x	P3769	29000	5/13	2x	0-0-0	none
	1995	Ch	FC 2x	3x	P3769	30000	5/19	1x	0-0-0	none
LPI	1989	Ch	FC 1x	1x	P3585	26000	5/3	3x	75-50-50	Alac (3.0), 2,4-D (0.5)
	1990	none	FC 2x	5x	P3585	27700	4/23	3x	60-20-10	Alac (3.0), 2,4-D (0.5)
	1991	none	FC 2x	3x	P3585	27700	4/26	1x	40-20-20	Alac (3.0), 2,4-D (0.5)
	1992	none	FC 1x	1x	P3585	29000	5/1	2x	80-20-20	Alac (3.0), Nico (0.031)
	1993	none	FC 1x	1x	P3585	29000	5/14	3x	19-40-0	Alac (3.0)
	1994	none	FC 1x	2x	P3769	29000	5/9	1x	20-45-25	Nico (0.031), Clpy (0.25)
	1995	none	FC 2x	1x	P3769	30000	5/18	1x	0-98-0	[Brox&Atra](0.19&0.28),Clpy(0.09),Nico (.031)
HPI	1989	Ch	FC 2x	none	P3585	26000	5/3	1x	150-100-100	[EPTC&R29148](4.0), Cyan(2.0), 2,4-D(0.5)
	1990	Ch	FC 2x	none	P3585	27700	4/23	3x	120-40-20	[EPTC&R29148](2.5), Cyan(1.5), 2,4-D(0.5)
	1991	Ch	FC 2x	none	P3585	27700	4/26	1x	80-40-40	[EPTC&R29148](2.5), Cyan(1.5), 2,4-D(0.5)
	1992	SS	FC 2x	none	P3585	29000	5/1	3x	117-50-50	[EPTC&R29148](2.5), Cyan(1.5), 2,4-D(0.25)
	1993	Ch	FC 2x	none	P3585	29000	5/14	2x	37z-88-25	[EPTC&R29148](2.5), Cyan(1.5), Nico (0.031)
	1994	Ch	FC 3x	none	P3769	29000	5/9	1x	40-90-50	[EPTC&R29148](2.5), Cyan(1.5), Clpy (0.25)
	1995	Ch	FC 2x	none	P3769	30000	5/18	1x	15-105-0	[EPTC&R29148&Acet](4.2&1.2),Cyan (2),Clpy(0.25)
Org	1989	Ch	FC 2x	1x	P3585	26000	5/15	3x	162-10-185	none
	1990	Ch	FC 2x	3x	P3585	27700	5/8	3x	141-77-110	none
	1991	none	FC 2x	4x	P3585	27700	5/13	2x	275-88-132	none
	1992	Ch	FC 2x	1x	P3585	29000	5/12	3x	431-178-380	none
	1993	SS	FC 1x	3x	P3585	29000	5/14	2x	317-178-511	none
	1994	Ch	FC 2x	3x	P3769	29000	5/13	2x	177-76-125	none
	1995	Ch	FC 2x	3x	P3769	30000	5/19	1x	390-81-not an.	none
CSOA - Soybean										
Min	1989	Ch	disk 1x	1x	Hardin	150,000	5/25	3x	0-0-0	none
	1990	MB	disk/FC	3x	Hardin	150,000	5/18	3x	0-0-0	none
	1991	MB	FC 2x	1x	Hardin	150,000	5/23	2x	0-0-0	none
	1992	MB	disk 2	2x	Hardin	150,000	5/6	2x	0-0-0	none
	1993	MB	disk/FC	1x	Hardin	150,000	5/26	2x	0-0-0	none
	1994	MB	FC 3x	1x	Parker	158,000	5/27	3x	0-0-0	none
	1995	MB	FC 2x	2x	Parker	158,000	5/23	3x	0-0-0	none
LPI	1989	Ch	FC 2x	1x	Hardin	150,000	5/11	3x	0-50-50	Alac (3.0), Bent (0.75)
	1990	SS	disk 2x	3x	Hardin	150,000	5/10	3x	0-31-16	Alac (3.0), Seth (0.2)
	1991	SS	FC 1x	3x	Hardin	150,000	5/14	2x	0-25-25	Alac (3.0), Seth (0.2)
	1992	SS	disk 2x	2x	Hardin	150,000	5/6	3x	4-20-20	Alac (3.0)
	1993	SS	disk/FC	1x	Hardin	150,000	5/26	2x	0-0-0	Alac (3.0)
	1994	SS	FC 1x	1x	Parker	158,000	5/12	2x	0-35-0	Clet (0.125), Imep (0.047)
	1995	SS	FC 2x	1x	Parker	158,000	5/19	3x	0-0-0	Bent(0.75), Thif (0.002), Clet (0.125)
HPI	1989	Ch	disk 2x	none	Hardin	150,000	5/11	2x	0-100-100	Etha (0.9), Bent (0.75), Seth (0.02)
	1990	MB	disk 2x	none	Hardin	150,000	5/10	2x	0-40-20	Etha (1.0)
	1991	MB	FC 2x	none	Hardin	150,000	5/14	2x	0-40-40	Etha (0.75)
	1992	MB	disk 2x	none	Hardin	150,000	5/6	2x	8-40-40	Etha (0.75)
	1993	MB	disk/FC2x	none	Hardin	150,000	5/26	2x	0-50-0	Etha (0.75)
	1994	MB	FC 2x	none	Parker	158,000	5/12	1x	0-50-0	Etha (1.0), Metr (0.25)
	1995	MB	FC 2x	none	Parker	158,000	5/19	2x	0-0-0	Etha (1.0)
Org	1989	Ch	FC 1x	1x	Hardin	150,000	5/25	3x	68-4-77	none
	1990	MB	disk/FC	3x	Hardin	150,000	5/18	3x	0-0-0	none
	1991	MB	FC 2x	1x	Hardin	150,000	5/23	2x	150-48-72	none
	1992	MB	disk/FC	1x	Hardin	150,000	5/18	2x	0-0-0	none
	1993	MB	disk/FC	1x	Hardin	150,000	5/26	2x	0-0-0	none
	1994	MB	FC 3x	1x	Parker	158,000	5/27	3x	0-0-0	none
	1995	MB	FC 2x	2x	Parker	158,000	5/23	3x	0-0-0	none

† Primary tillage previous fall: MB=moldboard plow, Ch=chisel, SS=Soil Saver.
‡ Spring tillage: FC=field cultivator, #x = # of passes. Designation of disk/FC indicates 1 pass with disk, and a later pass with FC.

§Alac=alachlor(Lasso II) preemergent (PRE); Bent= bentazon (Basagran) post-emergent (POST); Bnfn=benefin (Balan) preplant incorporated (PPI); Brox=bromoxynil (Buctril) POST; [Brox&Atra] = broxynil & atrazine POST; Clet=clethodim (Select) POST; Clpy=clopyralid (Stinger) POST spot-spray; Cyan=cyanazine (Bladex) PPI; [EPTC&R29148] = EPTC plus safener (Eradicane), PPI; [EPTC&R29148&Acet]= EPTC+safener+acetochlor (Doubleplay), PPI; Etha=ethalfluralin (Sonalan) PPI; Imep=imazethapyr (Pursuit) POST; Metr=metribuzin (Sencor) PPI; Nico=nicosulfuron (Accent) +surfactant+28% N fertilizer, POST; Seth+COC = sethoxydim (Poast+COC), POST; Thif= thifensulfuron (Pinnacle), POST; Trif=trifluralin (Treflan) PPI.

Table 5 (con't). Tillage and planting information for VICM I, 1989-1995.

Rot. - Crop	Prod. Year	Prev.Fall Tillage†	Spring Tillage‡	Rotary Hoe	Seed	Seed Rate	Planting Date	Row Cultiv	Fertilizer ($N-P_2O_5-K_2O$)	Herbicide§ type1(rate1), type2(rate2)
				# passes		lb/ac		# passes	lb/ac	(lb ai/ac)
CSOA - Oat										
Min	1989	Ch	FC 2x	none	Don	64	4/18	none	0-0-0	none
	1990	Ch	FC 1x	none	Don	72	4/17	none	0-0-0	none
	1991	none	FC 1x	none	Don	72	4/24	none	0-0-0	none
	1992	none	FC 1x	none	Don	*80*	4/28	none	0-0-0	none
	1993	none	FC 1x	none	Don	*80*	4/24	none	0-0-0	none
	1994	Ch	FC 1x	none	Dane	70	4/21	none	0-0-0	none
	1995	Ch	FC 1x	none	Dane	85	5/2	none	0-0-0	none
LPI	1989	Ch	FC 2x	none	Don	64	4/18	none	40-40-40	*Seth (0.2)*
	1990	none	FC 1x	none	Don	72	4/17	none	40-40-80	none
	1991	none	FC 1x	none	Don	72	4/24	none	30-20-20	none
	1992	none	FC 1x	none	Don	*80*	4/28	none	30-75-150	none
	1993	none	FC 1x	none	Don	*80*	4/24	none	40-60-0	none
	1994	none	FC 1x	none	Dane	70	4/21	none	50-50-50	Brox (0.25)
	1995	none	FC 1x	none	Dane	85	5/2	none	50-50-0	Brox (0.25)
HPI	1989	Ch	FC 2x	none	Don	64	4/18	none	80-80-80	*Seth (0.2)*
	1990	Ch	FC 1x	none	Don	72	4/17	none	40-80-160	none
	1991	Ch	FC 1x	none	Don	72	4/24	none	30-40-20	none
	1992	Ch	FC 1x	none	Don	*80*	4/28	none	30-100-200	none
	1993	SS	FC 1x	none	Don	*80*	5/4	none	40-40-0	none
	1994	Ch	FC 1x	none	Dane	70	4/21	none	50-50-50	Brox (0.25)
	1995	Ch	FC 1x	none	Dane	85	5/2	none	50-50-0	Brox (0.25)
Org	1989	Ch	FC 1x	none	Don	64	4/18	none	68-4-77	none
	1990	Ch	FC 1x	none	Don	72	4/17	none	0-0-0	none
	1991	none	FC 1x	none	Don	72	4/24	none	150-48-72	none
	1992	Ch	FC 1x	none	Don	80	4/28	none	299-124-264	none
	1993	SS	FC 1x	none	Don	80	4/44	none	317-178-511	none
	1994	Ch	FC 1x	none	Dane	70	4/21	none	172-75-126	none
	1995	Ch	FC 1x	none	Dane	85	5/2	none	130-27-not an.	none
CSOA - Alfalfa										
Min	1989	Ch	FC 2x	none	P5262	12	5/9/89	none	0-0-0	none
	1990	none	none	none	P5262	12	pr.yr.oats¶	none	0-0-0	none
	1991	none	none	none	P5262	11	pr.yr.oats	none	0-0-0	none
	1992	none	none	none	P5262	11	pr.yr.oats	none	0-0-0	none
	1993	none	none	none	P5262	11	pr.yr.oats	none	0-0-0	none
	1994	none	none	none	P5262	12	pr.yr.oats	none	0-0-0	none
	1995	none	none	none	P5262	12	pr.yr.oats	none	0-0-0	none
LPI	1989	Ch	FC 2x	none	P5262	12	5/9/89	none	0-50-50	Bnfn (1.25)
	1990	none	none	none	P5262	12	pr.yr.oats	none	0-40-80	Bnfn (1.25)
	1991	none	none	none	P5262	11	pr.yr.oats	none	0-50-100	none
	1992	none	none	none	P5262	11	pr.yr.oats	none	0-75-150	none
	1993	none	none	none	P5262	11	pr.yr.oats	none	*0-95-0*	none
	1994	none	none	none	P5262	12	pr.yr.oats	none	0-100-0	none
	1995	none	none	none	P5262	12	pr.yr.oats	none	0-65-15	none
HPI	1989	Ch	FC 2x	none	P5262	12	5/9/89	none	0-100-100	Bnfn (1.25)
	1990	none	none	none	P5262	12	pr.yr.oats	none	0-80-160	Bnfn (1.25)
	1991	none	none	none	P5262	11	pr.yr.oats	none	0-50-100	none
	1992	none	none	none	P5262	11	pr.yr.oats	none	0-100-200	none
	1993	none	none	none	P5262	11	pr.yr.oats	none	*0-95-0*	none
	1994	none	none	none	P5262	12	pr.yr.oats	none	0-100-0	none
	1995	none	none	none	P5262	12	pr.yr.oats	none	0-65-15	none
Org	1989	Ch	none	none	P5262	12	5/9/89	none	68-4-77	none
	1990	none	none	none	P5262	12	pr.yr.oats	none	0-0-0	none
	1991	none	none	none	P5262	11	pr.yr.oats	none	0-0-0	none
	1992	none	none	none	P5262	11	pr.yr.oats	none	0-0-0	none
	1993	none	none	none	P5262	11	pr.yr.oats	none	0-0-0	none
	1994	none	none	none	P5262	12	pr.yr.oats	none	0-0-0	none
	1995	none	none	none	P5262	12	pr.yr.oats	none	0-0-0	none

† Primary tillage previous fall: MB=moldboard plow, Ch=chisel, SS=Soil Saver.
‡ Spring tillage: FC=field cultivator, #x = # of passes. Designation of disk/FC indicates 1 pass with disk, and a later pass with FC.
§Alac=alachlor(Lasso II) preemergent (PRE); Bent= bentazon (Basagran) post-emergent (POST); Bnfn=benefin (Balan) preplant incorporated (PPI); Brox=bromoxynil (Buctril) POST; [Brox&Atra] = broxynil & atrazine POST; Clet=clethodim (Select) POST; Clpy=clopyralid (Stinger) POST spot-spray; Cyan=cyanazine (Bladex) PPI; [EPTC&R29148] = EPTC plus safener (Eradicane), PPI; [EPTC&R29148&Acet]= EPTC+safener+acetochlor (Doubleplay), PPI; Etha=ethalfluralin (Sonalan) PPI; Imep=imazethapyr (Pursuit) POST; Metr=metribuzin (Sencor) PPI; Nico=nicosulfuron (Accent) +surfactant+28% N fertilizer, POST; Seth+COC = sethoxydim (Poast+COC), POST; Thif= thifensulfuron (Pinnacle), POST; Trif=trifluralin (Treflan) PPI.
¶ Alfalfa planted previous year along with the oats.

Table 6. Tillage and planting information for VICM II, 1989-1995.

Rot. - Crop	Prod. Year	Prev.Fall Tillage†	Spring Tillage‡	Rotary Hoe	Seed	Seed Rate	Seed Date	Row Cultiv	Fertilizer ($N-P_2O_5-K_2O$)	Herbicide§ type1(rate1), type2(rate2)
				# passes		plants/ac		# passes	lb/ac	(lb ai/ac)
CS - Corn										
Min	1989	Ch	FC 2x	1x	P3585	26000	5/15	2x	0-0-0	none
	1990	Ch	FC/disk	3x	P3585	27700	5/7	2x	0-0-0	none
	1991	Ch	FC 2x	4x	P3585	27700	5/13	2x	0-0-0	none
	1992	none	FC 1x	1x	P3585	29000	5/12	3x	0-0-0	none
	1993	none	FC 2x	3x	P3585	29000	5/14	3x	0-0-0	none
	1994	Ch	FC 2x	3x	P3769	29000	5/13	3x	0-0-0	none
	1995	Ch	FC 2x	2x	P3769	30000	5/19	3x	0-0-0	none
LPI	1989	Ch	FC 1x	1x	P3585	26000	5/3	2x	75-50-50	Alac (3.0)
	1990	none	FC 2x	5x	P3585	27700	4/23	2x	60-0-0	Alac (*3.0*)
	1991	none	FC 1x	3x	P3585	27700	4/26	1x	60-0-0	Alac (3.0), 2,4-D (0.5)
	1992	none	FC 1x	1x	P3585	29000	5/1	3x	169-10-10	Alac (3.0)
	1993	none	FC 2x	1x	P3585	29000	5/14	2x	120-0-0	Alac (3.0),Nico (0.031)
	1994	none	FC 1x	3x	P3769	29000	5/9	2x	125-0-0	Brox (0.25)
	1995	none	FC 2x	1x	P3769	30000	5/18	2x	197-0-0	[Brox&Atr](0.19&0.28),Clpy(0.09),Nico(0.031)
HPI	1989	Ch	FC 2x	1x	P3585	26000	5/3	2x	150-100-100	[EPTC&R29148] (4.0), Cyan (2.0)
	1990	Ch	FC 2x	none	P3585	27700	4/23	2x	120-0-0	[EPTC&R29148] (2.5), Cyan (1.5)
	1991	Ch	FC 2x	none	P3585	27700	4/26	1x	120-0-0	[EPTC&R29148] (2.5), Cyan (1.5),2,4-D(0.5)
	1992	Ch	FC 2x	none	P3585	29000	5/1	4x	183-0-0	[EPTC&R29148] (2.5), Cyan (1.5),2,4-D(0.25)
	1993	SS	FC 2x	none	P3585	29000	5/14	2x	132-0-0	[EPTC&R29148](2.5),Cyan (1.5),Nico(.031),Brox(.25)
	1994	Ch	FC 3x	none	P3769	29000	5/9	2x	145-35-0	[EPTC&R29148] (2.5), Cyan (1.5)
	1995	Ch	FC 2x	none	P3769	30000	5/18	1x	125-0-0	[EPTC&R29148&Acet](4.2&1.2),Cyan(2.0),Clpy(0.25)
Org	1989	Ch	FC 2x	1x	P3585	26000	5/15	2x	352-3-158	none
	1990	Ch	FC/disk	3x	P3585	27700	5/8	2x	126-155-71	none
	1991	Ch	FC 2x	4x	P3585	27700	5/13	2x	263-244-76	none
	1992	none	FC 2x	1x	P3585	29000	5/12	3x	156-80-63	none
	1993	none	FC 2x	3x	P3585	29000	5/14	2x	312-186-119	none
	1994	Ch	FC 3x	2x	P3769	29000	5/13	3x	339-125-104	none
	1995	Ch	FC 2x	2x	P3769	30000	5/19	3x	229-269-80	none
CS - Soybean										
Min	1989	Ch	FC 1x	1x	Hardin	150,000	5/25	2x	0-0-0	none
	1990	MB	disk 2x	3x	Hardin	150,000	5/18	1x	0-0-0	none
	1991	MB	disk/FC2x	1x	Hardin	150,000	5/23	2x	0-0-0	none
	1992	MB	disk 2x	2x	Hardin	150,000	5/6	3x	0-0-0	none
	1993	MB	disk/FC	1x	Hardin	150,000	5/26	2x	0-0-0	none
	1994	MB	FC 3x	1x	Parker	158,000	5/27	3x	0-0-0	none
	1995	MB	FC 2x	2x	Parker	158,000	5/23	3x	0-0-0	none
LPI	1989	Ch	disk 2x	1x	Hardin	150,000	5/11	2x	0-50-50	Alac (3.0)
	1990	SS	disk 2x	3x	Hardin	150,000	5/10	2x	0-0-0	Alac (*3.0*)
	1991	SS	disk/FC	3x	Hardin	150,000	5/14	2x	0-0-0	Alac (*3.0*), Seth (0.2)
	1992	SS	disk 2x	2x	Hardin	150,000	5/6	3x	0-0-0	Alac (3.0)
	1993	SS	disk/FC	1x	Hardin	150,000	5/26	2x	0-0-0	*Alac (3.0)*
	1994	SS	FC 1x	1x	Parker	158,000	5/12	3x	*0-0-0*	Clet (0.125), Imep (0.047)
	1995	SS	FC 2x	1x	Parker	158,000	5/19	2x	0-0-0	Bent (0.75), Clet (0.125)
HPI	1989	Ch	FC 2x	none	Hardin	150,000	5/11	2x	0-100-100	Trif (0.75)
	1990	MB	disk 2x	none	Hardin	150,000	5/10	1x	0-0-0	Trif (0.75)
	1991	MB	FC/disk	none	Hardin	150,000	5/14	2x	0-0-0	Trif (0.75)
	1992	MB	disk 2x	none	Hardin	150,000	5/6	1x	*0-0-0*	Trif (0.75)
	1993	MB	disk/FC 2x	none	Hardin	150,000	5/26	2x	0-0-20	Trif (0.75)
	1994	MB	FC 2x	none	Parker	158,000	5/12		*0-0-0*	Trif (0.75), Metr (0.25)
	1995	MB	FC 2x	none	Parker	158,000	5/19	2x	0-0-0	Trif (0.75), Bent (0.75)
Org	1989	Ch	FC 1x	1x	Hardin	150,000	5/25	2x	127-1-57	none
	1990	MB	disk 2x	3x	Hardin	150,000	5/18	1x	0-0-0	none
	1991	MB	disk/FC2x	1x	Hardin	150,000	5/23	2x	0-0-0	none
	1992	MB	disk/FC	none	Hardin	150,000	5/18	3x	0-0-0	none
	1993	MB	disk/FC	1x	Hardin	150,000	5/26	2x	0-0-0	none
	1994	MB	FC 3x	1x	Parker	158,000	5/27	3x	0-0-0	none
	1995	MB	FC 2x	2x	Parker	158,000	5/23	3x	0-0-0	none

† Primary tillage previous fall: MB=moldboard plow, Ch=chisel, SS=Soil Saver.
‡ Spring tillage: FC=field cultivator, #x = # of passes. Designation of disk/FC indicates 1 pass with disk, and a later pass with FC.

§Alac=alachlor(Lasso II) preemergent (PRE); Bent= bentazon (Basagran) post-emergent (POST); Bnfn=benefin (Balan) preplant incorporated (PPI); Brox=bromoxynil (Buctril) POST; [Brox&Atra] = broxynil & atrazine POST; Clet=clethodim (Select) POST; Clpy=clopyralid (Stinger) POST spot-spray; Cyan=cyanazine (Bladex) PPI; [EPTC&R29148] = EPTC plus safener (Eradicane), PPI; [EPTC&R29148&Acet]= EPTC+safener+acetochlor (Doubleplay), PPI; Etha=ethalfluralin (Sonalan) PPI; Imep=imazethapyr (Pursuit) POST; Metr=metribuzin (Sencor) PPI; Nico=nicosulfuron (Accent) +surfactant+28% N fertilizer, POST; Seth+COC = sethoxydim (Poast+COC), POST; Thif= thifensulfuron (Pinnacle), POST; Trif=trifluralin (Treflan) PPI.

Table 6 (con't). Tillage and planting information for VICM II, 1989-1995.

Rot. - Crop	Prod. Year	Prev.Fall Tillage†	Spring Tillage‡	Rotary Hoe	Seed	Seed Rate	Planting Date	Row Cultiv	Fertilizer (N-P_2O_5-K_2O)	Herbicide§ type1(rate1), type2(rate2),...
				# passes		plants/ac		# passes	lb/ac	(lb ai/ac)
CSOA - Corn										
Min	1989	-	-	-	-	-	-	-	-	-
	1990	MB	disk 2x	2x	P3585	27700	5/8	2x	0-0-0	none
	1991	MB	FC 2x	4x	P3585	27700	5/13	2x	0-0-0	none
	1992	MB	FC 1x	1x	P3585	29000	5/12	2x	0-0-0	none
	1993	MB	FC 2x	3x	P3585	29000	5/14	3x	0-0-0	none
	1994	MB	FC 2x	4x	P3769	29000	5/13	2x	0-0-0	none
	1995	MB	FC 2x	2x	P3769	30000	5/19	1x	0-0-0	none
LPI	1989	-	-	-	-	-	-	-	-	-
	1990	MB	disk/FC 2x	3x	P3585	27700	4/23	2x	60-20-10	Alac (*3.0*)
	1991	MB	FC 2x	3x	P3585	27700	4/26	1x	40-0-0	Alac (*3.0*), 2,4-D (0.5)
	1992	MB	FC 1x	1x	P3585	29000	5/1	2x	89-10-10	Alac (3.0), Nico (0.031), 2,4-D (0.375)
	1993	MB	FC 2x	1x	P3585	29000	5/14	2x	58-0-0	Alac (3.0)
	1994	MB	FC 1x	3x	P3769	29000	5/9	2x	*25-0-0*	Brox (0.25)
	1995	MB	2x	1x	P3769	30000	5/18	1x	0-98-0	[Brox&Atra] (0.19&0.28),Clpy(0.09),Nico(0.031)
HPI	1989	-	-	-	-	-	-	-	-	-
	1990	MB	disk/FC2x	none	P3585	27700	4/23	2x	120-0-0	[EPTC&R29148] (2.5), Cyan (1.5)
	1991	MB	FC 2x	none	P3585	27700	4/26	1x	80-0-0	[EPTC&R29148] (2.5), Cyan (1.5), 2,4-D (0.5)
	1992	MB	FC 2x	none	P3585	29000	5/1	3x	130-0-0	[EPTC&R29148] (2.5), Cyan (1.5),2,4-D(0.25)
	1993	MB	FC 2x	none	P3585	29000	5/14	2x	43-41-0	[EPTC&R29148] (2.5), Cyan (1.5)
	1994	MB	FC 3x	none	P3769	29000	5/9	2x	*40-50-0*	[EPTC&R29148] (2.5), Cyan (1.5)
	1995	MB	FC 2x	none	P3769	30000	5/18	1x	20-15-25	[EPTC&R29148&Acet](4.2&1.2),Cyan(2.0),Clpy(0.25)
Org	1989	-	-	-	-	-	-	-	-	-
	1990	MB	disk 2x	2x	P3585	27700	5/8	2x	141-77-110	none
	1991	MB	FC 2x	4x	P3585	27700	5/13	2x	150-48-72	none
	1992	MB	FC 2x	1x	P3585	29000	5/12	2x	431-178-380	none
	1993	MB	FC 2x	3x	P3585	29000	5/14	3x	*0-0-0*	none
	1994	MB	FC 2x	4x	P3769	29000	5/13	2x	59-25-42	none
	1995	MB	FC 2x	2x	P3769	30000	5/19	1x	130-27-not an.	none
CSOA - Soybean										
Min	1989	-	-	-	-	-	-	-	-	-
	1990	MB	disk/FC	2x	Hardin	150,000	5/18	1x	0-0-0	none
	1991	MB	disk/FC2x	1x	Hardin	150,000	5/23	2x	0-0-0	none
	1992	MB	disk 2x	2x	Hardin	150,000	5/6	3x	0-0-0	none
	1993	MB	disk/FC	1x	Hardin	150,000	5/26	2x	0-0-0	none
	1994	MB	FC 3x	1x	Parker	158,000	5/27	3x	0-0-0	none
	1995	MB	FC 2x	2x	Parker	158,000	5/23	3x	0-0-0	none
LPI	1989	-	-	-	-	-	-	-	-	-
	1990	MB	disk 2x	2x	Hardin	150,000	5/10	1x	0-0-0	Alac (*3.0*)
	1991	SS	disk/FC	3x	Hardin	150,000	5/14	2x	0-0-0	Alac (*3.0*), Seth (0.2)
	1992	SS	disk 2x	2x	Hardin	150,000	5/6	3x	0-0-0	Alac (3.0)
	1993	SS	disk/FC	1x	Hardin	150,000	5/26	2x	0-20-10	Alac (3.0)
	1994	SS	FC 1x	1x	Parker	158,000	5/12	2x	*0-0-0*	Clet (0.125), Imep (0.047)
	1995	SS	FC 2x	1x	Parker	158,000	5/19	2x	0-0-0	Bent (0.75), Clet (0.125)
HPI	1989	-	-	-	-	-	-	-	-	-
	1990	MB	disk 2x	none	Hardin	150,000	5/10	1x	0-0-0	Etha (1.0)
	1991	MB	FC/disk/FC	none	Hardin	150,000	5/14	2x	0-0-0	Etha (0.75)
	1992	MB	disk 2x	none	Hardin	150,000	5/6	2x	0-0-0	Etha (0.75)
	1993	MB	disk/FC 2x	none	Hardin	150,000	5/26	2x	0-30-20	Etha (0.75)
	1994	MB	FC 2x	none	Parker	158,000	5/12	none	*0-0-0*	Etha (1.0), Metr (0.25)
	1995	MB	FC 2x	none	Parker	158,000	5/19	2x	0-0-0	Etha (1.0)
Org	1989	-	-	-	-	-	-	-	-	-
	1990	MB	disk/FC	2x	Hardin	150,000	5/18	1x	0-0-0	none
	1991	MB	disk/FC2x	1x	Hardin	150,000	5/23	2x	0-0-0	none
	1992	MB	disk/FC	1x	Hardin	150,000	5/18	3x	0-0-0	none
	1993	MB	disk/FC	1x	Hardin	150,000	5/26	2x	0-0-0	none
	1994	MB	FC 3x	1x	Parker	158,000	5/27	3x	0-0-0	none
	1995	MB	FC 2x	2x	Parker	158,000	5/23	3x	0-0-0	none

† Primary tillage previous fall: MB=moldboard plow, Ch=chisel, SS=Soil Saver.
‡ Spring tillage: FC=field cultivator, #x = # of passes. Designation of disk/FC indicates 1 pass with disk, and a later pass with FC.

§Alac=alachlor(Lasso II) preemergent (PRE); Bent= bentazon (Basagran) post-emergent (POST); Bnfn=benefin (Balan) preplant incorporated (PPI); Brox=bromoxynil (Buctril) POST; [Brox&Atra] = broxynil & atrazine POST; Clet=clethodim (Select) POST; Clpy=clopyralid (Stinger) POST spot-spray; Cyan=cyanazine (Bladex) PPI; [EPTC&R29148] = EPTC plus safener (Eradicane), PPI; [EPTC&R29148&Acet]= EPTC+safener+acetochlor (Doubleplay), PPI; Etha=ethalfluralin (Sonalan) PPI; Imep=imazethapyr (Pursuit) POST; Metr=metribuzin (Sencor) PPI; Nico=nicosulfuron (Accent) +surfactant+28% N fertilizer, POST; Seth+COC = sethoxydim (Poast+COC), POST; Thif= thifensulfuron (Pinnacle), POST; Trif=trifluralin (Treflan) PPI.

Table 6 (con't). Tillage and planting information for VICM II, 1989-1995.

Rot. - Crop	Prod. Year	Prev.Fall Tillage†	Spring Tillage‡	Rotary Hoe	Seed	Seed Rate	Planting Date	Row Cultiv	Fertilizer ($N-P_2O_5-K_2O$)	Herbicide§ type1(rate1), type2(rate2)
				# passes		lb/ac		# passes	lb/ac	(lb ai/ac)
CSOA - Oat										
Min	1989	-	-	-	-	-	-		-	-
	1990	MB	disk 2x	none	Don	72	4/17	none	0-0-0	none
	1991	Ch	FC 1x	none	Don	72	4/24	none	0-0-0	none
	1992	none	FC 1x	none	Don	*80*	4/28	none	0-0-0	none
	1993	none	FC 1x	none	Don	*80*	4/24	none	0-0-0	none
	1994	Ch	FC 1x	none	Dane	70	4/21	none	0-0-0	none
	1995	Ch	FC 1x	none	Dane	85	5/3	none	0-0-0	none
LPI	1989	-	-	-	-	-	-	-	-	
	1990	MB	disk 2x	none	Don	72	4/17	none	40-0-80	none
	1991	none	FC 1x	none	Don	72	4/24	none	30-0-0	none
	1992	none	FC 1x	none	Don	*80*	4/28	none	30-0-100	Brox (0.25)
	1993	none	FC 1x	none	Don	*80*	4/24	none	19-0-38	*Brox (0.25)*
	1994	none	FC 1x	none	Dane	70	4/21	none	*50-50-50*	Brox (0.25)
	1995	none	FC 1x	none	Dane	85	5/3	none	30-10-0	Brox (0.25)
HPI	1989	-	-	-	-	-	-	-	-	-
	1990	MB	disk 2x	none	Don	72	4/17	none	40-0-160	none
	1991	Ch	FC 1x	none	Don	72	4/24	none	30-0-0	none
	1992	Ch	FC 1x	none	Don	*80*	4/28	none	30-0-150	Brox (0.25)
	1993	SS	FC 1x	none	Don	*80*	4/24	none	19-0-38	*Brox (0.25)*
	1994	Ch	FC 1x	none	Dane	70	4/21	none	50-50-50	Brox (0.25)
	1995	Ch	FC 1x	none	Dane	85	5/3	none	50-20-0	Brox (0.25)
Org	1989	-	-	-	-	-	-	-	-	
	1990	MB	disk 2x	none	Don	72	4/17	none	0-0-0	none
	1991	Ch	FC 1x	none	Don	72	4/24	none	0-0-0	none
	1992	Ch	FC 1x	none	Don	*80*	4/28	none	299-124-64	none
	1993	none	FC 1x	none	Don	*80*	4/24	none	*0-0-0*	none
	1994	Ch	FC 1x	none	Dane	70	4/21	none	59-25-42	none
	1995	Ch	FC 1x	none	Dane	85	5/3	none	130-27-not an.	none
CSOA - Alfalfa										
Min	1989	-	-	-	-	-	-	-	-	-
	1990	none	disk 2x	none	P5262	11	4/17/90	none	0-0-0	none
	1991	none	none	none	P5262	11	pr.yr. oats¶	none	0-0-0	none
	1992	none	none	none	P5262	11	pr.yr. oats	none	0-0-0	none
	1993	none	none	none	P5262	11	pr.yr. oats	none	0-0-0	none
	1994	none	none	none	P5262	12	pr.yr. oats	none	0-0-0	none
	1995	none	none	none	P5262	12	pr.yr. oats	none	0-0-0	none
LPI	1989	-	-	-	-	-	-	-	-	-
	1990	none	FC/disk	none	P5262	11	4/17/90	none	0-0-80	Bnfn (*1.25*)
	1991	none	none	none	P5262	11	pr.yr. oats	none	0-0-100	none
	1992	none	none	none	P5262	11	pr.yr. oats	none	0-0-100	none
	1993	none	none	none	P5262	11	pr.yr. oats	none	*0-20-0*	none
	1994	none	none	none	P5262	12	pr.yr. oats	none	*0-40-0*	none
	1995	none	none	none	P5262	12	pr.yr. oats	none	0-65-15	none
HPI	1989	-	-	-	-	-	-	-	-	-
	1990	none	FC/disk	none	P5262	11	4/17/90	none	0-0-160	Bnfn (*1.25*)
	1991	none	none	none	P5262	11	pr.yr. oats	none	0-0-100	none
	1992	none	none	none	P5262	11	pr.yr. oats	none	0-0-150	none
	1993	none	none	none	P5262	11	pr.yr. oats	none	*0-20-0*	none
	1994	none	none	none	P5262	12	pr.yr. oats	none	*0-40-0*	none
	1995	none	none	none	P5262	12	pr.yr. oats	none	0-65-15	none
Org	1989	-	-	-	-	-	-	-	-	-
	1990	none	disk 2x	none	P5262	11	4/17/90	none	0-0-0	none
	1991	none	none	none	P5262	11	pr.yr. oats	none	0-0-0	none
	1992	none	none	none	P5262	11	pr.yr. oats	none	0-0-0	none
	1993	none	none	none	P5262	11	pr.yr. oats	none	0-0-0	none
	1994	none	none	none	P5262	12	pr.yr. oats	none	0-0-0	none
	1995	none	none	none	P5262	12	pr.yr. oats	none	0-0-0	none

† Primary tillage previous fall: MB=moldboard plow, Ch=chisel, SS=Soil Saver.
‡ Spring tillage: FC=field cultivator, #x = # of passes. Designation of disk/FC indicates 1 pass with disk, and a later pass with FC.

§Alac=alachlor(Lasso II) preemergent (PRE); Bent= bentazon (Basagran) post-emergent (POST); Bnfn=benefin (Balan) preplant incorporated (PPI); Brox=bromoxynil (Buctril) POST; [Brox&Atra] = broxynil & atrazine POST; Clet=clethodim (Select) POST; Clpy=clopyralid (Stinger) POST spot-spray; Cyan=cyanazine (Bladex) PPI; [EPTC&R29148] = EPTC plus safener (Eradicane), PPI; [EPTC&R29148&Acet]= EPTC+safener+acetochlor (Doubleplay), PPI; Etha=ethalfluralin (Sonalan) PPI; Imep=imazethapyr (Pursuit) POST; Metr=metribuzin (Sencor) PPI; Nico=nicosulfuron (Accent) +surfactant+28% N fertilizer, POST; Seth+COC = sethoxydim (Poast+COC), POST; Thif= thifensulfuron (Pinnacle), POST; Trif=trifluralin (Treflan) PPI.
¶ Alfalfa planted previous year along with the oats.

IMPACT OF RELATIVE MATURITY AND DATE OF PLANTING ON CORN YIELD AT LAMBERTON -- 1993-1995[1]

P.M. Porter, C.A. Perillo, D.R. Hicks, W.E. Lueschen, and J.H. Ford[2]

Abstract

Eight corn hybrids differing in relative maturity were planted on 5 dates from mid-April through early-June in 1993, 1994, and 1995 at Lamberton, Waseca and Morris. This article discusses only the yields obtained at Lamberton. The hybrids ranged in relative maturities from 115 to 80. The highest yielding hybrid was the 105 relative maturity DeKalb DK 512. The lowest yields were from the short-season 85 and 80 relative maturity hybrids. The data suggest there is no yield benefit to planting a short-season hybrid, even when planting is delayed to as late as early-June. Yields of the full-season 115 and 110 relative maturity hybrids were more adversely impacted by delayed planting (late-May or early-June) than the shorter-season hybrids.

Introduction

There is a need to better understand how corn hybrid relative maturity and planting date affect corn growth and development, date of physiological maturity, grain yield, and kernel moisture content at various times during the harvest period. A better understanding of the relationship between corn hybrid relative maturity and planting date will enable producers to make more informed decisions about what maturity hybrid to plant if conditions allow early planting or mandate a late planting to occur. Likewise, the effect of planting date and hybrid maturity on the dry-down rate of corn will influence when producers will want to harvest their crop.

This study was conducted at three branch station locations during the years 1993 through 1995. The data in this report are from the Southwest Experiment Station at Lamberton, and only involve selected yield and harvest moisture content.

Experimental Procedure

Eight corn hybrids ranging in relative maturity from 115 to 80 days were selected for this study (Ciba G4490, Northrup King N5220, DeKalb DK512, ICI 8777, Pioneer 3861, DeKalb DK401, Top Farm SX1184, and Pioneer 3963). Each corn hybrid was planted on five dates (late-April, early-May, mid-May, and late-May, and early June) in 1993, 1994 and 1995. The trial had a split-plot arrangement of a randomized complete block design with 4 replicates. Planting date was the main-plot variable and corn hybrid was the sub-plot variable. Sub-plot size was 10-ft wide (4 rows) by 28-ft long. Harvest area consisted of two rows, 25-ft long. Row width was 30 inches. The crop was managed for optimum production, and fertility was not limiting. Phosphorus and K were applied according to soil test such that high levels of each existed. Nitrogen rates were approximately 140 lb acre^{-1}. Seeding rates were 30,000 plants acre^{-1}. Weeds were controlled with herbicides and hand-weeding.

Tasseling, silking, and black layer dates were recorded for all treatments. After physiological maturity, 10 ears were hand harvested at regular intervals and kernel moisture contents were determined. Grain yields are reported at 15.5% moisture.

Results and Discussion

Averaged across all 8 hybrids, the 3-year average yields for corn planted in late-April and early-May were higher than for corn planted later in May or in early June (Table 1). Corn planted on the two earliest planting dates yielded 124 bushels acre^{-1}, and decreased 6, 19 and 35% as planting was delayed. Averaged over all hybrids, yields were highest in 1994 and lowest in 1993. The lower yields for the early-May planting compared to the late-April and mid-May planting in 1995 may have been due to unusually high temperatures near anthesis for the early-May planting or the impact of corn borer.

Averaged across all 5 planting dates, the 3-year average yields were highest for the 105 relative maturity corn hybrid DK 512 (Table 2). The hybrids with the next highest yields included those of 115, 100, 95 and 90 relative maturity (G4490, ICI 8777, and P 3861 and DK 401). The harvest moisture content declined as the relative maturity of the hybrids decreased (Table 2). Harvest moisture contents were quite high in 1993, which had below normal cumulative growing degree units during the growing season.

The impact of planting date on grain yield of each corn hybrid for the 3-years combined and each individual year is graphed in Figures 1 and 2, respectively. For the 3-year combined data the 105 relative maturity hybrid DK 512 yielded very well (compared to the other hybrids) regardless of planting date, while the 85 and 90 relative maturity hybrids (SX1184 and P3963) yielded relatively poorly regardless of planting date. Yields of specific hybrids did not respond in the same fashion as planting was delayed, especially when one compares numbers from one year to another. For example, NK N5220 yielded relatively poorly in 1993 for all but the first planting date, but yielded comparatively well the other two years. The hybrid DK 512 yielded extremely well in 1994, the highest yielding year, and tended to not drop off as fast in yield as the other hybrids as planting date was delayed. The yields of the 110 and 115 relative maturity hybrids (G 4490 and NK N5220) were most adversely impacted by delayed planting.

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Conclusions

In choosing a corn hybrid to plant, most producers will consider not only yield potential but also relative maturity, since relative maturity impacts when the hybrid reaches physiological maturity and to some extent when the corn will be at a desired moisture content for harvest. This study found that yields of full-season hybrids (with 115 and 110 relative maturities) were most adversely impacted as planting date was delayed. Yields of short-season hybrids (with 85 and 80 relative maturities) yielded the least, regardless of planting date. Not surprisingly, when harvested on the same date the full-season hybrids had higher moisture contents at harvest then the short-season hybrids. These data suggest there is no yield benefit to planting a short-season hybrid in southwest Minnesota, even when planting is delayed to as late as early-June.

Table 1. Corn yield for 5 planting dates, averaged across 8 hybrids ranging in relative maturity from 115 to 80 days, at Lamberton.

------Planting date ---------		---- Actual planting date ----			-----------Yield (bushel acre^{-1}) ----------			
		1993	1994	1995	1993	1994	1995	Avg.
Date 1	late-April	April 24	April 21	April 28	106	162	104	124
Date 2	early-May	May 5	May 4	May 5	108	168	97	124
Date 3	mid-May	May 15	May 16	May 12	85	158	108	117
Date 4	late-May	May 28	May 31	May 26	87	128	89	101
Date 5	early-June	June 10	June 10	June 9	72	106	66	81
$LSD_{(0.10)}$					12	5	10	5

Table 2. Yield and harvest kernel moisture content for 8 corn hybrids, averaged across 5 planting dates, at Lamberton.

------ Corn hybrid ------	RM	-----------Yield (bushel acre^{-1}) ----------				---- Harvest moisture content (%) ----			
		1993	1994	1995	Avg.	1993	1994	1995	Avg.
Ciba G4490	115	91	159	94	115	36	30	24	30
Northrup King N5220	110	71	150	92	104	30	25	21	25
DeKalb DK512	105	101	166	102	123	26	23	20	23
ICI 8777	100	103	151	92	115	24	20	18	21
Pioneer 3861	95	96	149	95	113	20	20	20	20
DeKalb DK401	90	100	142	99	114	22	19	19	20
Top Farm SX1184	85	90	120	87	99	19	19	18	19
Pioneer 3963	80	81	119	82	94	20	17	17	18
$LSD_{(0.10)}$		6	5	6	3	1	1	1	1

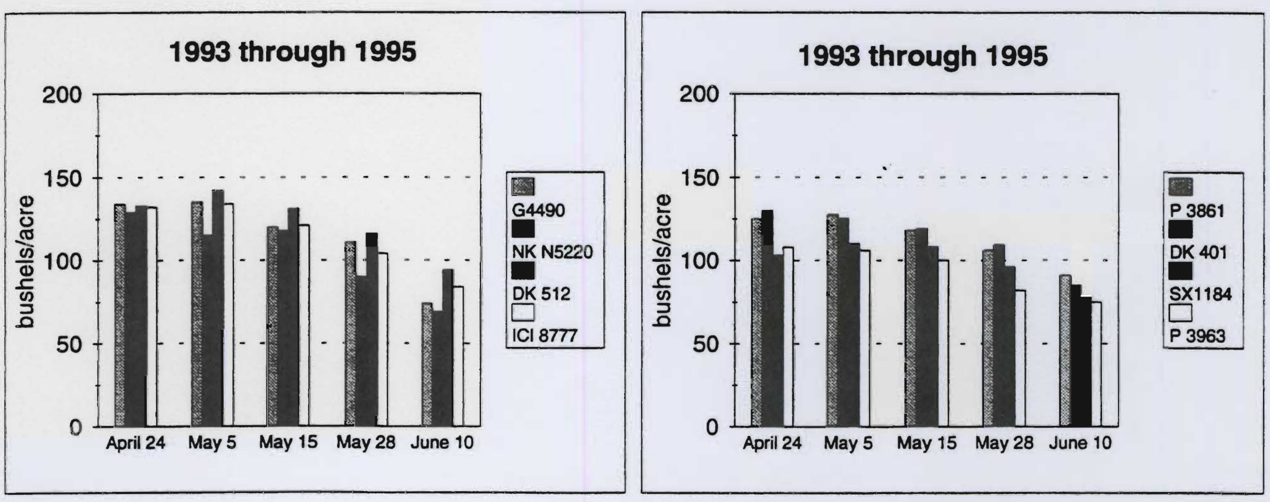

Figure 1. Three-year combined yield data for 8 corn hybrids planted on 5 dates at Lamberton.

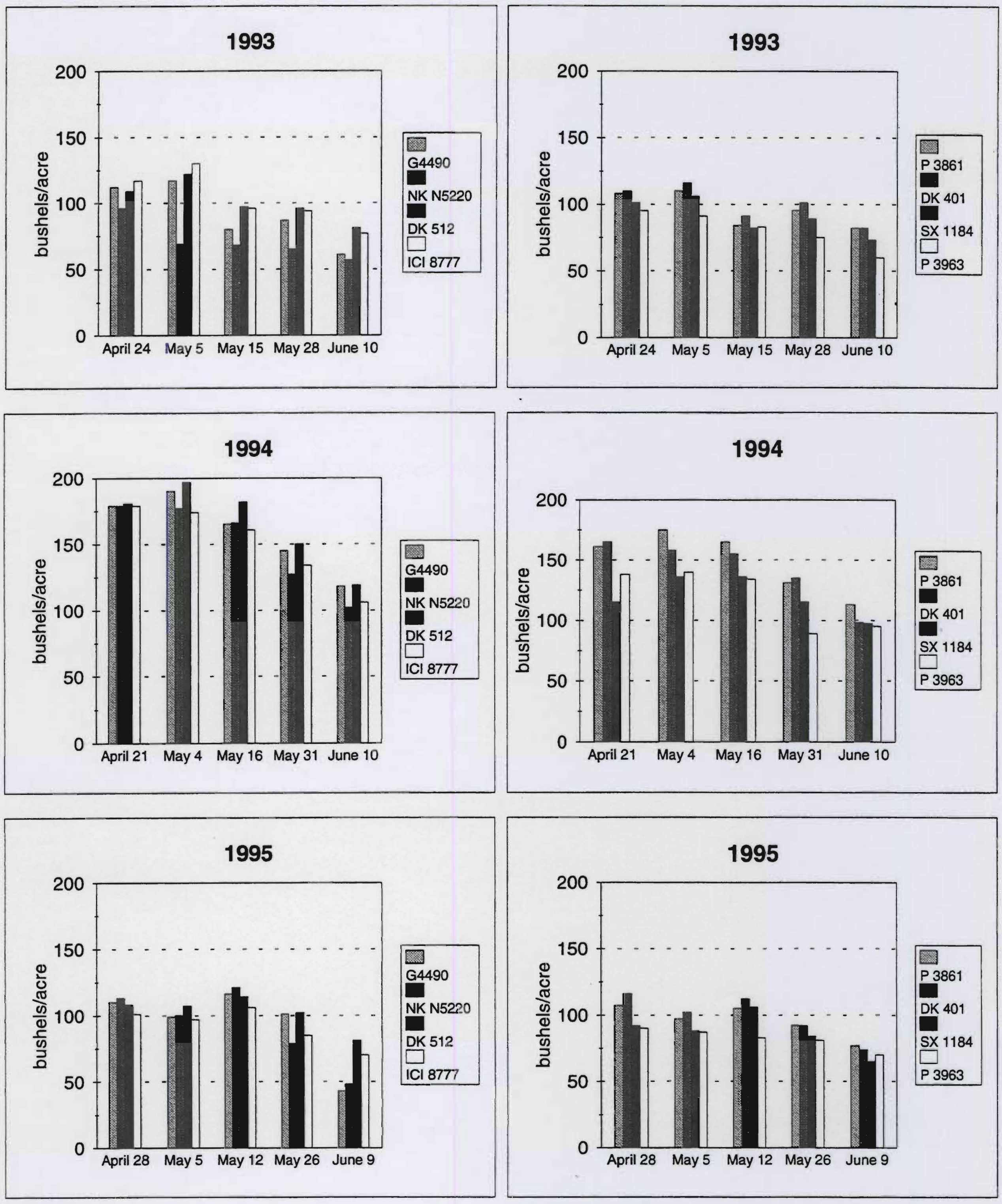

Figure 2. Effect of planting date on 8 corn hybrids in 1993, 1994 and 1995 at Lamberton.

EFFECT OF *RHIZOBIUM* INOCULANT ON SOYBEAN YIELD AT LAMBERTON -- 1995[1]

P.M. Porter and C.A. Perillo[2]

Abstract

Rhizobium cause soybeans to form nodules on their roots where the bacteria fix large amounts of free nitrogen. This trial evaluated yield and other agronomic traits of soybeans that were treated with no inoculant, treated with a regular inoculant (532C), and treated with a USDA-patented inoculant. The presence or absence of an inoculant did not affect grain yield, moisture content at harvest, plant height or final plant stand. Results from several other states suggest there may be a slight yield increase when using the USDA-patented inoculant.

Introduction

Plants in the legume family such as soybeans have the potential to utilize atmospheric nitrogen indirectly through a symbiotic relationship with certain soil bacteria known as *Rhizobium.* If the proper strain of *Rhizobium* is present and nodules form, the soybean plants require little soil nitrogen. To encourage the formation of nodules, some producers add pure cultures of *Rhizobium* to soybean seed before planting . This process is known as inoculation. Effective strains of *Rhizobium* cause soybeans to produce large, pinkish nodules on their roots where the bacteria fix large amounts of free nitrogen.

Rhizobium are present in most Midwestern soils that have produced soybeans in the recent past, and on these soils inoculation is not commonly practiced. A company in the inoculation industry has developed a new strain of *Rhizobium* that they wanted to test across the upper Midwest. This study evaluated two strains of *Rhizobium* treated soybean seed and untreated soybean seed at the Southwest Experiment Station in 1995.

Experimental Procedure

The trial was conducted on a Ves loam soil (fine-loamy, mixed, mesic Udic Haplustolls) having high levels of P and K. The 3 treatments included soybean cultivar "Parker" treated with no inoculant, treated with a regular inoculant (532C), and treated with a USDA-patented *Bradyrhizobium japonicum* inoculant. The treatments were compared in a randomized complete block design with 12 replicates. Six of the replicates were planted no-till into corn residue, and 6 replicates were planted in an adjoining area where a Soil Saver was used to till the soil and corn residue the previous fall. The soybeans were planted on May 26, 1995 with a JD750 no-till drill. Plot size was 10 rows spaced 7.5 inches apart by 30 ft in length. The seeding rate was 680 seeds/plot or 158,000 seeds acre^{-1}. Weeds were controlled with Dual/Broadstrike on June 1.Plants were combined on September 28 with an Almaco plot combine. Harvest area was 5.0ft by 9.0ft. Plant height, plant stand, yield and % seed moisture were determined at harvest. Treatment mean comparisons were made using Fisher's protected least significant difference (LSD) test at $P \leq 0.05$.

Results and Discussion

The presence or absence of an inoculant did not affect grain yield, moisture content at harvest, plant height or final plant stand at the 5% (or 10%) level of significance (Table 1). This was true for both no-till soybeans as well as soybeans planted into corn that had been previously worked with a Soil Saver. Although not significant, the yield of the non-inoculated soybean was numerically lower than the yield of the two treatments where inoculant was used (3.1% in the case of the USDA-patented inoculant and 6.4% in the case of the 532C inoculant).

Our results were in agreement with other research conducted across the upper Midwest. According to the company that funded this research, the same trial was conducted at a total of 28 sites in 9 states. A positive response (but not necessarily a significant response) was observed at 20 of the 28 sites when comparing yields of the soybeans treated with the USDA-patented inoculant to the non-treated soybeans. Averaged over all 28 sites, the yield of the soybeans grown with the USDA-patented inoculant was 3.4% higher than the yield of the non-treated soybeans.

It is anticipated this trial will be repeated in 1996.

Conclusions

In this highly replicated field trial we could not detect a significant yield increase due to treating soybean seed with either of two types of inoculant compared to non-treated seed. Moisture content at harvest, plant height and final plant stand were also not significantly affected. Based on experimental results from other states the magnitude of the yield response, if actually present, would probably be less than 4%.

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[1] This project was funded in part by Urbana Laboratories and the MN Ag. Expt. Stn.

[2] P.M. Porter (assistant professor) and C.A. Perillo (assistant scientist) are at the Southwest Experiment Station, Lamberton, MN 56152.

Table 1. Soybean yield, plant height, plant stand and moisture content at harvest for two seed inoculant treatments and a non-inoculated control treatment conducted at Lamberton in 1995.

Treatment	Grain yield	Plant height	Plant stand	Harvest moisture
	bu/ac	in.	plants/ac	%
From all 12 replicates:				
No inoculant control	45.1	50.1	100,000	9.33
USDA patented inoculant	46.5	51.3	112,000	9.28
532C inoculant	48.0	50.7	107,000	9.23
Statistics				
C.V. (%)	9.0	7.8	20.0	1.3
Pr>F	0.24	0.74	0.38	0.15
LSD[1] $_{(0.05)}$	3.5	3.3	18,000	0.11
From 6 replicates planted into no-till corn :				
No inoculant control	44.3	47.3	90,000	9.32
USDA patented inoculant	46.3	48.2	99,000	9.28
532C inoculant	47.0	48.0	92,000	9.27
Statistics				
C.V. (%)	10.0	2.4	17.2	0.9
Pr>F	0.58	0.44	0.63	0.60
LSD[1] $_{(0.05)}$	5.9	2.4	21,000	0.11
From 6 replicates planted into corn tilled with a Soil Saver:				
No inoculant control	45.9	52.8	109,000	9.35
USDA patented inoculant	46.6	54.5	125,000	9.27
532C inoculant	49.1	53.3	121,000	9.20
Statistics				
C.V. (%)	8.6	5.9	15.4	1.2
Pr>F	0.39	0.66	0.34	0.13
LSD[1] $_{(0.05)}$	5.2	4.1	23,000	0.15

[1] Note that in no instance was the $P \leq 0.05$, thus none of the LSD values presented are significant using Fisher's protected least significant difference.

SOYBEAN NO-TILL VARIETY PERFORMANCE TRIALS AT LAMBERTON – 1994 & 1995[1]

P.M. Porter, J.H. Orf, and C.A. Perillo[2]

Abstract

There is some question whether soybean varieties grown in southwest Minnesota will yield as well under no-till conditions as under conventional production practices. Likewise, it is not known whether all varieties will respond similarly when grown under no-till and conventional systems. This study evaluated soybean varieties grown in side-by-side variety performance trials where the soybeans were planted either no-till into corn residue or on land worked by more conventional production practices. In 1995, the mean yield of 32 soybean varieties grown either no-till or conventionally was 46.0 and 48.2 bushels acre^{-1}, respectively. In 1994, the mean yield of 32 soybean varieties grown either no-till or conventionally was 48.3 and 54.8 bushels acre^{-1}, respectively. Two varieties that yielded very well in both tillage trials both years were Pioneer 9171 and Sturdy.

Introduction

Environmental concern with wind, water and soil erosion has led to increased pressure to re-evaluate traditional production practices that include primary fall tillage of corn residue prior to planting soybeans the following spring. Planting soybean no-till into corn residue is increasing in popularity, but questions concerning variety selection for no-till soybean production remain. This study was part of a 3-year multi-state program designed in part to evaluate the impact variety selection had on no-till soybean production. It involved side-by-side variety performance trials where soybean cultivars were planted either no-till into corn residue or on land worked by more conventional production practices. Results from 1994 and 1995 at Lamberton are reported here. The study will be repeated a third year in 1996.

Experimental Procedure

In 1995, 32 soybean varieties were grown on 2 adjacent sites where corn was planted in 1994. One site was tilled conventionally with a JD Soil Saver in the fall whereas the other was left un-tilled. On each site there were 3 replicates of each variety arranged in a randomized complete block design. The trial was conducted on a Ves loam soil (fine-loamy, mixed, mesic Udic Haplustolls).

The soybeans were planted on May 26, 1995 with a JD750 no-till drill. Plot size was 10 ft wide by 15 ft in length. Row width was 7.5 inches. The seeding rate was approximately 150,000 seeds acre^{-1}. Directly after planting it was estimated there was 85% residue cover following no-till and 30% following the Soil Saver. Weeds were controlled with Dual/Broadstrike on June 1. Plants were harvested on September 28 with an Almaco plot combine. Harvest area varied but averaged about 5.0ft by 9.0ft. Plant height, plant stand, and seed moisture at harvest were determined. Fisher's protected least significant difference (LSD) test at $P \leq 0.10$ was reported for these variables within for each of tillage regimes. It was not possible to calculate statistical comparisons between the tillage regimes since they were side-by-side trials. Seed oil and protein will be determined in Dr. Jim Orf's laboratory, and are not reported here.

A similar study was conducted in 1994, and those results are included. The trials were planted on May 16, 1994.

Results and Discussion

In 1995, the mean soybean yield for all 32 varieties when grown no-till and conventionally was 46.0 and 48.2 bushels acre^{-1}, respectively (Table 1 and 2). IA 2008 provided the highest yield (53.0 bu/A) in the no-till trial but Sturdy, Pioneer 9171, Archer, Bert, Parker, Hardin, Kasota, Dawson, Hendricks, Kenwood, Asgrow A1929, Asgrow A2234 and Corsoy 79 yields were not statistically different from IA 2008. Hardin provided the highest yield (55.8 bu/A) in the corresponding conventional tillage trial but Marcus BC, Northrup King S19-90, Glenwood, Pioneer 9171, Hardin 91, Asgrow A1929, and Kenwood yields were not statistically different from Hardin. Hardin, Pioneer 9171, Sturdy, and Bert produced superior yields in both tillage trials in 1995. No variety yielded 10 bushels acre^{-1} less under no-till conditions than with conventional tillage.

In 1994, the mean soybean yield for all 32 varieties when grown no-till and conventionally was 48.3 and 54.8 bushels acre^{-1}, respectively (Table 3). IA2014 provided the highest yield (58.8 bu/A) in the no-till trial but Asgrow A2234, DeKalb CX264, Hardin 91 IA 2008 Marcus, Marcus BC, Northrup King S19-90, Pioneer 9171, and Sturdy yields were not statistically different from IA 2014. IA 2008 provided the highest yield (64.0 bu/A) in the corresponding conventional tillage trial but DeKalb CX264, Kenwood, Parker, Pioneer 9171 and Sturdy yields were not statistically different from IA 2008. DeKalb CX264, IA2008, Pioneer 9171 and Sturdy produced superior yields in both tillage trials in 1994. Several varieties (Bert, Dawson, Faribault, Hodgson 78, Parker, IA2008 Kenwood, and DeKalb CX264) yielded at least 10 bushels acre^{-1} less under no-till conditions than with conventional tillage.

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[1] This project was funded in part by the North Central Soybean Research Program and the MN Ag. Expt. Stn.

[2] P.M. Porter (assistant professor) and C.A. Perillo (assistant scientist) are at the Southwest Experiment Station, Lamberton, MN 56152. J.H. Orf is Professor in the Department of Agronomy and Plant Genetics.

Conclusions

Although a direct statistical comparison was not possible, in both 1994 and 1995 the mean soybean yield for all 32 varieties when grown no-till was less than the mean soybean yield for all 32 varieties when grown conventionally. In 1994 the difference was 12% and in 1995 the difference was 5%. In 1994 several varieties yielded substantially less when grown no-till as compared to when grown conventionally, however this trend was not noted in 1995. Two varieties that yielded very well in both tillage trials both years were Pioneer 9171 and Sturdy.

Table 1. Soybean yields, yield ranking, plant stand and harvest moisture content for varieties in the no-till trial at Lamberton in 1995. Ranking for the conventional tillage variety performance trial are listed in parentheses.

Variety	Maturity group	No-till Yield	No-till Rank	Conv. rank	No-till Stand	No-till Rank	Conv. rank	No-till Moisture	No-till Rank	Conv. rank
		bu/ac			plants/ac			%		
Public varieties										
Glenwood	0.4	43.6	23	(4)	112000	17	(10)	8.9	27	(16)
Evans	0.6	42.8	25	(26)	127000	8	(15)	8.7	32	(13)
Dawson	0.7	48.3	9	(32)	124000	11	(18)	8.7	31	(32)
Hendricks	0.9	48.2	10	(23)	125000	9	(5)	8.9	29	(30)
Lambert	0.9	45.2	20	(16)	128000	7	(7)	8.9	28	(29)
Dassel	1.1	38.4	32	(30)	93000	27	(17)	9.1	22	(17)
Kasota	1.3	48.3	8	(12)	101000	21	(24)	9.0	24	(28)
Alpha	1.4	40.0	31	(31)	148000	2	(1)	9.1	21	(26)
Faribault	1.4	45.8	18	(27)	93000	28	(20)	9.5	11	(6)
Hodgson 78	1.4	42.9	24	(17)	128000	6	(8)	8.8	30	(25)
Kato	1.4	42.0	28	(19)	103000	20	(30)	9.1	20	(14)
Parker	1.4	49.5	6	(13)	113000	16	(26)	9.2	19	(9)
Bell	1.6	41.2	30	(22)	63000	32	(29)	9.9	7	(2)
Leslie	1.8	42.7	26	(20)	93000	29	(23)	9.5	13	(20)
Bert	1.9	50.1	5	(11)	115000	15	(12)	8.9	26	(31)
Hardin	1.9	49.3	7	(1)	142000	4	(11)	9.1	23	(23)
Hardin 91	1.9	46.7	15	(6)	116000	14	(9)	9.3	16	(27)
BSR 101	1.9	42.2	27	(15)	97000	23	(16)	9.4	14	(10)
Archer	1.9	50.9	4	(21)	98000	22	(13)	9.5	12	(19)
Sturdy	2.0	51.3	2	(9)	94400	26	(27)	9.7	8	(12)
IA 2008	2.1	53.0	1	(24)	139000	5	(4)	9.5	10	(18)
Corsoy 79	2.1	47.1	14	(18)	124000	10	(21)	10.1	6	(5)
Kenwood	2.1	47.9	11	(8)	82000	30	(31)	11.3	1	(3)
IA 2014	2.1	44.6	21	(28)	152000	1	(3)	10.3	5	(4)
Private varieties										
Asgrow A1929	1.9	47.7	12	(7)	107000	19	(25)	9.2	18	(21)
Asgrow A2234	2.2	47.2	13	(25)	94000	25	(19)	10.6	2	(1)
DeKalb CX 264	2.6	46.5	17	(29)	119000	13	(22)	10.4	4	(8)
Marcus	2.2	41.4	29	(14)	147000	3	(14)	9.4	15	(24)
Marcus BC	2.2	46.6	16	(2)	96000	24	(2)	10.6	3	(11)
Nor. King S1990	1.9	45.6	19	(3)	123000	12	(28)	9.6	9	(15)
Pioneer 9091	0.9	44.6	22	(10)	78000	31	(32)	9.0	25	(7)
Pioneer 9171	1.7	51.2	3	(5)	111000	18	(6)	9.3	17	(22)
Mean		46.0			112000			9.5		
CV (%)		9.7			16.5			3.4		
Probability		<0.05			<0.001			<0.001		
$LSD_{(0.10)}$		6.07			25300			0.4		

Table 2. Soybean yields, yield ranking, plant stand and harvest moisture content for varieties in the conventionally planted trial at Lamberton in 1995. Ranking for the no-till variety performance trial are listed in parentheses.

Variety	Maturity group	Conventional Yield	Conventional Rank	No-till rank	Conventional Stand	Conventional Rank	No-till rank	Conventional Moisture	Conventional Rank	No-till rank
		bu/ac			plants/ac			%		
Public varieties										
Glenwood	0.4	52.3	4	(23)	130000	10	(17)	9.4	16	(27)
Evans	0.6	46.0	26	(25)	125000	15	(8)	9.6	13	(32)
Dawson	0.7	41.6	32	(9)	121000	18	(11)	8.3	32	(31)
Hendricks	0.9	46.3	23	(10)	139000	5	(9)	9.0	30	(29)
Lambert	0.9	48.6	16	(20)	136000	7	(7)	9.1	29	(28)
Dassel	1.1	43.8	30	(32)	121000	17	(27)	9.4	17	(22)
Kasota	1.3	49.3	12	(8)	107000	24	(21)	9.1	28	(24)
Alpha	1.4	42.9	31	(31)	166000	1	(2)	9.1	26	(21)
Faribault	1.4	45.7	27	(18)	117000	20	(28)	10.4	6	(11)
Hodgson 78	1.4	48.4	17	(24)	135000	8	(6)	9.1	25	(30)
Kato	1.4	48.0	19	(28)	88000	30	(20)	9.5	14	(20)
Parker	1.4	49.2	13	(6)	104000	26	(16)	10.1	9	(19)
Bell	1.6	46.4	22	(30)	94000	29	(32)	10.5	2	(7)
Leslie	1.8	47.6	20	(26)	109000	23	(29)	9.3	20	(13)
Bert	1.9	49.4	11	(5)	130000	12	(15)	8.8	31	(26)
Hardin	1.9	55.8	1	(7)	130000	11	(4)	9.2	23	(23)
Hardin 91	1.9	50.7	6	(15)	131000	9	(14)	9.1	27	(16)
BSR 101	1.9	48.7	15	(27)	124000	16	(23)	10.0	10	(14)
Archer	1.9	46.7	21	(4)	127000	13	(22)	9.3	19	(12)
Sturdy	2.0	49.5	9	(2)	101000	27	(26)	9.7	12	(8)
IA 2008	2.1	46.3	24	(1)	142000	4	(5)	9.4	18	(10)
Kenwood	2.1	50.1	8	(11)	76000	31	(30)	10.5	3	(1)
Corsoy 79	2.1	48.3	18	(14)	117000	21	(10)	10.4	5	(6)
IA 2014	2.1	45.6	28	(21)	142000	3	(1)	10.5	4	(5)
Private varieties										
Asgrow A1929	1.9	50.6	7	(12)	104000	25	(19)	9.2	21	(18)
Asgrow A2234	2.2	46.1	25	(13)	120000	19	(25)	10.9	1	(2)
DeKalb CX 264	2.6	45.0	29	(17)	113000	22	(13)	10.2	8	(4)
Marcus	2.2	49.0	14	(29)	127000	14	(3)	9.1	24	(15)
Marcus BC	2.2	52.5	2	(16)	147000	2	(24)	9.8	11	(3)
Nor. King S1990	1.9	52.4	3	(19)	101000	28	(12)	9.5	15	(9)
Pioneer 9091	0.9	49.5	10	(22)	71000	32	(31)	10.3	7	(25)
Pioneer 9171	1.7	50.8	5	(3)	139000	6	(18)	9.2	22	(17)
Mean		48.2			119800			9.6		
CV (%)		8.8			17.5			6.5		
Probability		<0.10			<0.001			<0.001		
$LSD_{(0.10)}$		5.77			28600			0.8		

Table 3. Soybean yields, yield ranking and plant heights for varieties in the no-till and conventional trials at Lamberton in 1994.

Variety	Maturity group	No-till Trial Yield	No-till Trial Yield rank	Conventional Trial Yield	Conventional Trial Yield rank	No-till Trial Plant height	Conventional Trial Plant height
		bu/A		bu/A		inches	inches
Public varieties							
Glenwood	0.4	41.0	28	43.0	31	30	33
Evans	0.6	40.4	29	41.2	32	32	32
Dawson	0.7	37.6	32	49.4	26	33	34
Hendricks	0.9	39.9	30	47.8	29	29	31
Lambert	0.9	44.1	25	48.3	27	32	31
Dassel	1.1	41.7	27	46.9	30	31	30
Kasota	1.3	47.4	19	51.1	24	37	36
Alpha	1.4	44.2	23	50.1	25	40	37
Faribault	1.4	44.2	23	56.7	14	39	35
Hodgson 78	1.4	42.9	26	54.0	21	36	39
Kato	1.4	53.8	6	52.0	23	39	39
Parker	1.4	50.4	11	60.6	5	40	39
Bell	1.6	48.5	18	55.3	18	38	35
Leslie	1.8	49.8	14	58.9	8	38	40
Bert	1.9	45.1	22	57.9	11	44	41
Hardin	1.9	48.7	17	53.8	22	41	38
Hardin 91	1.9	55.7	4	54.1	20	40	35
BSR 101	1.9	46.4	21	55.9	16	41	39
Archer	1.9	46.9	20	55.7	17	41	42
Sturdy	2.0	53.6	7	62.2	3	41	40
IA 2008	2.1	53.4	8	64.0	1	45	42
Corsoy 79	2.1	49.3	15	57.6	12	44	39
Kenwood	2.1	49.2	16	63.8	2	38	41
IA 2014	2.1	58.8	1	58.4	9	39	38
Private varieties							
Asgrow A2234	2.2	52.4	9	59.4	7	39	38
Asgrow A1929	1.9	49.9	13	56.7	14	39	37
DeKalb CX 264	2.6	50.7	10	60.8	4	41	39
Marcus	2.2	50.4	11	58.4	9	37	37
Marcus BC	2.2	58.1	2	56.8	13	35	37
Nor. King S1990	1.9	57.1	3	55.3	18	39	36
Pioneer 9091	0.9	39.6	31	48.1	28	30	30
Pioneer 9171	1.7	54.0	5	60.6	5	36	36
Means		48.3		54.8		38	37
$LSD_{(0.10)}$		8.5		4.5		4	3

IMPACT OF ROW SPACING AND PLANT POPULATION ON CORN YIELDS -- 1992 through 1994

P.M. Porter, D.R. Hicks, W.E. Lueschen, D.D. Warnes, T.R. Hoverstad, and C.A. Perillo[2]

Abstract

This study was designed to investigate the relationships between row spacing, plant population, and hybrid at 3 Minnesota locations during the 1992, 1993, and 1994 growing seasons. At Lamberton and Waseca, row spacings were 10, 20 and 30 in.; target plant populations were 25000, 30000, 35000, and 40000 plants acre^{-1}; and hybrids were Ciba 'G4372,' DeKalb 'DK512,' and Pioneer Brand 'P3563.' At Morris, the same row spacings were evaluated but the plant populations were 22000, 27000 and 32000 plants acre^{-1} and the hybrids were Northrup King 'N3624,' DeKalb 'DK421,' and Pioneer Brand 'P3751.' At Lamberton and Waseca, the yield advantage for 10- and 20-in. rows compared with 30-in. rows was 7.2% when averaged over all hybrids and all plant populations, whereas at Morris the yield advantage was 8.5%. Choice of hybrid influenced grain yield, but had no interactive effect with row spacing or plant population at the 3 locations. There was a plant population by year interaction at Lamberton and Waseca: grain yields increased with greater plant populations in 1992 and 1994, but not in 1993 when yields were low due to climatic conditions. Analysis of yield versus harvest plant population showed yields were highest at harvest plant populations of about 35000 plants acre^{-1} in 1992 at Lamberton and 1994 at Waseca and Lamberton, but were unaffected by plant populations in 1992 at Waseca and in 1993 at both locations. At Morris, analysis of yield versus harvest plant population in 1993 and 1994 showed yields were highest at plant populations of 32000 plants acre^{-1}, the highest plant population studied at that location. These data show a yield advantage by narrowing row widths from 30 to 20 or 10 in., and that in some years maximum yields were obtained at plant populations substantially higher than the current average Minnesota harvest plant population of 26400 plants acre^{-1}.

Introduction

In the northern Corn Belt most corn is grown on 30 in. or wider row widths, and recommended plant densities range from 24000 to 28000 plants acre.$^{-1}$ The trend over time has been toward a narrowing of row width and an increase in plant density. There is a desire by some Minnesota producers to match row width of corn and soybean with that of sugarbeet, which is typically grown on less than 30-in. rows. That desire, coupled with the development of stronger-stemmed hybrids that seed companies say maintain high yields at higher plant populations, led to the need to address the question of how row spacing and plant population affect hybrid performance. The objectives of this study were to: (i) determine if popular corn hybrids responded similarly to row spacing of less than 30 in., and (ii) determine if the response differed over a range of plant populations.

Experimental Procedure

A 3-yr field study (1992-1994) was conducted at three Minnesota locations (Morris, Lamberton and Waseca) to examine the relationship between row spacing, plant population, and hybrid. At all three locations 3 row spacings were evaluated: 10, 20 and 30 in. At Lamberton and Waseca the plant populations were 25000, 30000, 35000, and 40000 plants acre^{-1} and hybrids were Ciba 'G4372,' DeKalb 'DK512,' and Pioneer Brand 'P3563' (relative maturities of 105). At Morris the plant populations were 22000, 27000 and 32000 plants acre^{-1}, and hybrids were Northrup King 'N3624,' DeKalb 'DK421,' and Pioneer Brand 'P3751' (relative maturities of 100). Fertilizer rates, weed control practices, previous crop, and planting and harvest dates varied with location, but recommended agronomic practices were followed for optimum production.

Planting dates were timely at all location all years. In 1993, rainfall was much above normal and early season temperatures were below normal. Growing season (April through June) precipitation and early season (May through June) growing degree day departures from average:

	Rainfall (in.)			Growing degree days in May and June		
	Lamberton	Waseca	Morris	Lamberton	Waseca	Morris
Average	19.8	22.7	17.9	890	842	769
1992	0.5	0.8	-1.1	47	46	48
1993	13.9	14.2	8.5	-162	-104	-95
1994	1.7	2.1	1.6	141	156	151

Results and Discussion

Does planting corn in rows narrower than 30 inches increase yield?
Each year of the study and at all locations corn planted on 20- and 10-in. rows yielded more than corn planted on 30-in. rows. At Lamberton and Waseca, the yield advantage for 10- and 20-in. rows compared with 30-in. rows was 7.2% when averaged over all hybrids and all plant populations, whereas at Morris the yield advantage was 8.5% (Table 1). The percentage yield increase (decrease) each year at each location associated with 20-in. rows compared to 30-in. rows are listed in Table 2.

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Should plant population be changed if corn is planted at narrower than 30-inch row spacings?
At Lamberton and Waseca, there was no interaction between row spacing and plant population, meaning that plant population should not be changed when planting in row widths narrower than a 30-in. row width. At Morris, the yields were unaffected by plant population for the narrower rows evaluated, but declined at the intermediate plant population for the 30-in. row width.

There was a plant population by year interaction at Lamberton and Waseca: grain yields increased with greater plant populations in 1992 and 1994, but not in 1993 when yields were low due to climatic conditions. Regression analysis of yield versus harvest plant population showed yields were highest at plant populations at or above 35000 plants/acre in 1992 at Lamberton and 1994 at Waseca and Lamberton, but were unaffected by plant populations in 1992 at Waseca and in 1993 at both locations. At Morris, regression analysis of yield versus harvest plant population in 1993 and 1994 showed yields were highest at plant populations of 32000 plants/acre, the highest plant population studied at that location.

Do hybrids to differ in response to row width and plant population?
Choice of hybrid influenced grain yield, but had no interactive effect with row spacing or plant population at the three locations. It is important to note that the hybrids evaluated were planted in a timely fashion and were considered to be the proper maturity for the locations where they were grown. Choice of hybrid and climatic conditions had a greater effect on grain moisture content at harvest, test weight, and ear length than row spacing or plant population (data not shown).

Conclusions

Thirty-in. rows consistently yielded less that 20- or 10-in. rows. The yield advantage of the narrower rows averaged about 7% across nine site-years. All hybrids evaluated responded similarly, and the yield advantage occurred regardless of plant population. At Lamberton and Waseca grain yields increased with greater plant populations in 1992 and 1994, but not in 1993 when yields were low due to climatic conditions. In some years of the study, especially when growing conditions were good, higher yields were obtained at plant populations higher than currently recommended by the Extension Service. Regardless of growing conditions, yields did not decline at the highest plant populations evaluated. These data show a yield advantage by narrowing row widths from 30 to 20 or 10 in., and that in some years maximum yields were obtained at plant populations substantially higher than the currently recommended harvest plant population of 29000 plants/acre.

Table 1. Corn grain yields for year, row spacing, plant population, hybrid main effects for the 3-year study.

	Lamberton and Waseca†					Morris			
	bushels acre^{-1}					bushels acre^{-1}			
Year:	1992	1993	1994		$LSD_{(0.05)}$	1992	1993	1994	$LSD_{(0.05)}$
	155b	82c	193a		4.6	111b	73c	153a	5.9
Row spacing:	10-in.	20-in.	30-in.			10-in.	20-in.	30-in.	
	146a	146a	136b		3.9	116a	114a	106b	5.9
Hybrid:	DK512	P3563	G4372			DK421	P3751	N3624	
	148a	144b	137c		3.1	106b	122a	109b	5.9
Plant Population:	25000	30000	35000	40000		22000	27000	32000	
(plants acre^{-1})	140	143	144	145	NS	112	112	112	NS

† Since the hybrids and plant populations were similar, data from Lamberton and Waseca were combined.

Table 2. Percentage yield increase (decrease) when planting corn in row widths of 20-in. rows compared to 30-in. rows.

Location	Yield increase with 20" vs. 30" rows				3-yr average
	1992	1993	1994	AVG.	Yield
	%				bushels acre^{-1}
Lamberton	7	15	5	7.1	136 vs. 127
Waseca	10	10	4	7.5	157 vs. 146
Morris	7	(-2)	11	7.5	114 vs. 106

THE CORN AND SOYBEAN ROTATION EFFECT: IMPORTANCE OF CROP ROTATION

P.M. Porter, R.K. Crookston, W.E. Lueschen, D.R. Huggins, J.H. Ford, and T.R. Hoverstad[1]

Abstract

Ongoing research begun in the early 1980s at Lamberton and Waseca clearly demonstrates the importance of crop rotation in a study specifically designed to evaluate the effect of crop rotation. Corn grown in an annual rotation with soybeans out-yielded continuous corn by 12% (138 vs. 122 bu/ac). Soybeans grown in an annual rotation with corn out-yielded continuous soybean by 14% (40.7 vs. 35.9 bu/ac). First-year corn following five consecutive years of soybean yielded 13% more than continuous corn. First-year soybean following five consecutive years of corn yielded 22% more than continuous soybeans. Soybean yields increased when grown on land that was not planted to soybeans in the previous five years as compared to when grown on land planted every other year with corn (43.7 vs. 40.7 bu/ac). This was not observed for corn: corn yields were the same whether corn was planted on land where soybeans were grown the previous five years or on land where soybeans were grown every other year. The relative increase in yields of both corn and soybean in annual rotation compared to continuous monoculture were two-fold greater in low yielding environments than in high yielding environments. In low yielding environments, the yield advantage of an annual rotation of corn and soybean compared to continuous monoculture was frequently greater than 25%

Introduction

Corn and soybean are the backbone of Midwest crop production. Alternating corn and soybeans results in increased yields for both crops as compared to growing either crop continuously. Yield increases associated with crop rotation have been referred to as the "rotation effect." Researchers have tried to pinpoint the cause of the rotation effect, but to date there is not a definitive explanation for the phenomenon. The objective of this study were to determine the impact of various corn and soybean cropping patterns on the yield of both crops, and to evaluate the impact of environment on the rotation effect.

Experimental Procedure

The study was established on the Southwest Experiment Station at Lamberton, MN in 1981 and on the Southern Experiment Station at Waseca, MN in 1982. Details of the soil types, soil fertility, and fertilizers and pesticides used through 1989 are described by Crookston et al. (Agron. J. 83:108-113). Recommended practices for optimum production were followed.

The original study design consisted of 16 treatments arranged in a randomized complete block replicated four times. This paper will discuss 14 of those treatments with the following general cropping sequences: (i) 5 years of consecutive corn alternated with 5 years of consecutive soybean, arranged so that during each year of the study there occurred a first-, second-, third-, fourth-, and fifth-yr of each crop following 5 years of the other crop; (ii) continuous monoculture of each crop; and (iii) an annual rotation of each crop. Data from the initial 4 years, when the rotation sequences were being established, were not included in the analysis. At Lamberton, 11 years of yield data were analyzed. At Waseca, 9 years of corn and 8 years of soybean yield data were analyzed.

Results and Discussion

Averaged over all the years and both the Lamberton and Waseca locations, annually rotated corn yielded 12% better, and first-year corn yielded 13% better than a continuous corn monoculture. Annually rotated soybean yielded 14% better, and first-year soybean yielded 22% better than a continuous soybean monoculture (Table 1).

There were differences in the response of the two crops to increasing years of consecutive planting. Second- to fifth-year corn yields following five consecutive years of soybeans were not different from continuous corn yields. Second-year soybeans yielded 11% better and third- to fifth-year soybeans following five consecutive years of corn yielded 5% better than continuous soybeans. These results suggest that the commonly practiced annual rotation of corn and soybean optimized corn yields, but not soybean yields, relative to the other sequences studied.

The relative increase in yields of both corn and soybean in annual rotation compared to monoculture (continuous corn or continuous soybeans) were twofold greater in low yielding environments than in high yielding environments (Tables 2 and 3). In low yielding environments, the yield advantage of an annual rotation compared to continuous corn or continuous soybeans was frequently greater than 25%. Low-yielding environments included seasons of drought (1988) as well as seasons of too much moisture (1993).

Conclusions

We conclude that the rotation effect observed for both corn and soybean was more pronounced in low-yielding environments than in high-yielding environments. Under our conditions, the commonly practiced annual rotation of corn and soybean optimized corn yields, but not soybean yields, relative to the other sequences studied.

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Table 1. Combined Lamberton and Waseca corn (C) and soybean (SB) yield when grown with seven 6-year cropping sequences. The data were averaged over an 11 year period from 1985 through 1995.

Corn: Cropping sequence last 6 years		Yield	Soybean: Cropping sequence last 6 years		Yield
		(bu/ac)			(bu/ac)
Continuous corn	C-C-C-C-C-**C**[1]	122	Continuous soybean	SB-SB-SB-SB-SB-**SB**	35.9
Alternating C-SB	SB-C-SB-C-SB-**C**	136 (12%)[2]	Alternating C-SB	C-SB-C-SB-C-**SB**	40.7 (14%)[2]
1st-yr corn	SB-SB-SB-SB-SB-**C**	138 (13%)	1st-yr soybean	C-C-C-C-C-**SB**	43.7 (22%)
2nd-yr corn	SB-SB-SB-SB-C-**C**	123 (1%)	2nd-yr soybean	C-C-C-C-SB-**SB**	40.0 (11%)
3rd-yr corn	SB-SB-SB-C-C-**C**	123 (1%)	3rd-yr soybean	C-C-C-SB-SB-**SB**	37.7 (5%)
4th-yr corn	SB-SB-C-C-C-**C**	123 (1%)	4th-yr soybean	C-C-SB-SB-SB-**SB**	37.7 (5%)
5th-yr corn	SB-C-C-C-C-C	122 (0%)	5th-yr soybean	C-SB-SB-SB-SB-**SB**	37.6 (5%)

[1] Yield is listed for the crop on the left of the sequence (in bold). For example, 1st-yr corn refers to the yield of the corn crop following 5 years of soybean, SB-SB-SB-SB-SB-**C**.
[2] Numbers in parentheses indicate the percentage yield increase over the continuous monoculture.

Table 2. Continuous corn yield and the yield advantage (disadvantage) when corn was grown the first-year following 5 years of soybean or in a corn-soybean rotation at Lamberton and Waseca.

Location	Cropping sequence	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	'85-'95
Lamberton	Continuous corn (bu/ac)	121	140	128	84	143	134	111	122	58	111	118	115
		Percent yield advantage (disadvantage) compared to continuous corn											
	First-yr corn	6	23	5	19	12	7	5	21	41	10	12	13
	Corn-soybean rotation	11	21	0	2	15	8	7	15	29	30	11	13
Waseca	Continuous corn (bu/ac)	--	120	174	76	169	145	--	147	65	148	121	129
		Percent yield advantage (disadvantage) compared to continuous corn											
	First-yr corn	--	9	6	30	18	9	--	17	13	15	12	13
	Corn-soybean rotation	--	(-9)	(-3)	34	16	6	--	12	33	12	11	10

[1] See Table 1 for the combined Lamberton and Waseca data.

Table 3. Continuous soybean yield and the yield advantage (disadvantage) when soybean was grown the first-year following 5 years of corn or in a corn-soybean rotation at Lamberton and Waseca.

Location	Cropping sequence	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	'85-'95
Lamberton	Continuous soybean (bu/ac)	38.2	37.3	41.9	27.8	27.8	40.1	44.5	24.4	28.4	37.8	41.0	35.3
		Percent yield advantage (disadvantage) compared to continuous corn											
	First-yr soybean	14	28	13	12	33	25	13	36	43	5	10	20
	Corn-soybean rotation	12	15	12	19	33	21	7	25	43	(-2)	5	16
Waseca	Continuous soybean	--	34.3	42.5	27.7	36.6	42.7	--	27.1	--	41.8	40.7	36.7
		Percent yield advantage (disadvantage) compared to continuous corn											
	First-yr soybean	--	38	13	20	16	28	--	35	--	27	21	24
	Corn-soybean rotation	--	13	5	(-8)	13	17	--	32	--	6	9	11

[1] See Table 1 for the combined Lamberton and Waseca data.

INTERRUPTING THE CONTINUOUS CORN YIELD DEPRESSION: COMPARATIVE EFFECTIVENESS OF SEVERAL CROP ROTATIONS

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Abstract

It has been well documented that monoculture corn yields less than corn grown in certain rotations. This field study investigated several agronomic crops, rotated with corn, for their relative effectiveness at interrupting the yield depression associated with corn monoculture. The study was conducted on a Webster clay loam soil near Lamberton, MN. Corn grain yields were increased ($P \leq 0.05$) by a single-year cropping of either alfalfa or sunflower prior to planting corn for each of 4 years, with the exception of the corn-sunflower rotation in 1992. Averaged across 4 years, corn yields were increased by 19 and 17% when corn followed a single-year of either alfalfa and sunflower, respectively. A single-year of either sorghum, sorghumXsudangrass, or fallow prior to planting corn did not improve corn yields compared to corn monoculture; this was true for each year and when averaged across 4 years, with the exception of the corn-fallow rotation in 1995. Averaged across 4 years, a two-year interruption of sunflower followed by alfalfa increased corn yield by 22% compared to corn monoculture. A 2-year interruption of sorghum followed by sorghumXsudangrass increased the following corn yield by 6% compared to corn monoculture. We conclude that the closely-related grasses were relatively ineffective rotation crops at interrupting the monoculture corn yield depression. Both dicots, however, improved corn yields; leguminous alfalfa being no better than the non-legume sunflower.

Introduction

In the northern U.S. Corn Belt, it has been well documented that corn grain yields are improved when annually rotated with soybean compared to monoculture. Yield decline associated with corn monoculture has been referred to as a "monoculture yield decline" or the rotation effect. While there have been numerous studies involving the monoculture corn yield depression in comparison to a soybean-corn rotation, only a limited number of studies involve other crops rotated annually with corn.

The purpose of this study was to investigate the nature of the corn monoculture yield decline by evaluating several 2- and 3-year rotations. One of our hypotheses was that "corn is bad for corn," and that any other crop (or a fallow), when rotated annually with corn, would benefit corn yields. We hypothesized all alternate crops (and a fallow) would be equally effective in interrupting the corn monoculture yield decline. To test this hypothesis we compared the yield of continuous corn to corn alternated with 1) fallow; 2) two grass species closely related to corn; and 3) two dicot species, one a nitrogen fixing legume and the other not. With the selected dicots we tested the sub-hypothesis that, with adequate nitrogen supplied to the corn, alfalfa (the nitrogen fixer) would provide no more effective yield benefit to corn than sunflower (not a nitrogen fixer). Another hypothesis was that, for either the selected grasses or dicots, a rotation sequence where corn was grown once every third-year would result in greater corn yield than a 2-year rotation sequence where corn was grown every other year. In testing this hypothesis, we compared the corn yield in either a 3-year grass-grass-corn or dicot-dicot-corn rotation to that of either a 2-year grass-corn or dicot-corn rotation.

Experimental Procedure

The study was established on the Southwest Experiment Station at Lamberton, MN in 1990 on a Webster clay loam (fine, loamy, mixed, mesic Typic Haplaquoll). Soil tests made during the study indicated a medium (3.1 to 4.5%) organic matter level, and high P and K levels (17 to 28 and 113 to 159 ppm, respectively). Fertilizer P and K were applied according the University of Minnesota Soil Testing Service recommendations. Over the course of the study, N rates ranged from 80 to 140 lbs acre^{-1} for corn and sorghum. Sunflower and sorghumXsudangrass received lower N rates ranging from 50 to 130 lbs acre $^{-1}$, and no N was applied to alfalfa or the fallow. These N rates were chosen to ensure N was not a limiting factor in this study. Weeds were controlled with herbicides, cultivation, and hand-weeding.

Study design consisted of 18 treatments arranged in a randomized complete block design replicated four times. The treatments consisted of the following sequences: (i) continuous corn; (ii) five 2-yr rotations of corn with fallow, sorghum, sorghumXsudangrass, sunflower, or alfalfa; and (iii) two 3-yr rotations of sorghum-sorghumXsudangrass-corn or sunflower-alfalfa-corn. The experimental design was such that corn was grown each year with each cropping sequence. In order to have an even number of treatments so that the trial would utilize the space available, there were two continuous corn treatments.

During the course of the study, corn hybrids were Pioneer Brands '3615' and '3563'; the sorghum hybrids were Northrup King '1210' and Pioneer Brand '894'; sorghumXsudangrass hybrids were Northrup King 'Sordan 79' and Pioneer Brand '877F'; sunflower hybrid was Pioneer Brand '594'; and alfalfa varieties were Pioneer Brand '5262,' 'Nitro,' and 'Saranac.' Grain was harvested from the corn, sorghum, and sunflower. Alfalfa and sorghumXsudangrass were cut 1 to 3 times annually, and only the alfalfa residue was removed from the plots. Primary tillage consisted of fall moldboard plowing, which was followed in the spring by either disking or field cultivation.

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Planting and harvest dates varied according to seasonal conditions. Planting of all crops took place between 18 April and 30 May. Corn was harvested between 30 September and 27 October. Corn, sorghum, sorghumXsudangrass and sunflower were planted in 30-inch rows, whereas alfalfa was broadcast seeded. Plots were 15ft wide (12 rows) and 35ft long; corn harvest for yield determination was from 30ft of 4 center rows. Plots were harvested with field-plot equipment.

Grain yield data were analyzed using the general linear model (GLM) procedure. Treatment mean comparisons were made using Fisher's protected LSD at $P \leq 0.05$.

Results and Discussion

Growing conditions were near excellent during the 1994 growing season, and corn yields were 19, 132 and 33% higher that year than in 1992, 1993, and 1995 respectively. Cool and wet conditions during the growing season in 1993 resulted in very poor corn yields (Tables 1 and 2). Each of the four years, cropping sequence had an effect on corn yields. For the 4-year combined data there was no cropping sequence by year interaction.

Corn yields averaged across 4 years were increased by 19% for the 2-year alfalfa-corn rotation compared to continuous corn (Table 2). Each year, corn in the alfalfa-corn rotation yielded more than continuous corn: 10, 45, 20, and 13% in 1992 through 1995, respectively. Corn yields averaged across 4 years were 17% greater for the 2-year sunflower-corn rotation than for continuous corn. The sunflower-corn rotation yielded 26, 26, and 15% more corn than continuous corn in 1993 through 1995, respectively. Only in 1993 was the corn yield of the 2-year alfalfa-corn rotation greater than the corn yield of the 2-year sunflower-corn rotation.

For the 4-year combined data there was no difference in corn yield between the two 2-year dicot rotations: annually rotating corn with alfalfa or sunflower resulted in 19 and 17% greater corn yields, respectively, than corn monoculture. It is probably not realistic to expect this level of yield advantage over time. In a corn-soybean rotation study conducted on a site directly adjacent to this study, researchers found annual rotation of soybean with corn resulted in a 20% corn yield advantage averaged over the same 4-year period (corn yielded 15, 29, 30, and 11% more when grown in annual rotation with soybean compared to monoculture in 1992 through 1995, respectively). In that study, however, corn yields were only 12% higher when corn was grown in annual rotation with soybean compared to monoculture when comparing 18 location by yr environments, and in low yielding environments the relative magnitude of the rotation effect increased.

Corn yields from the 2-year sorghum-corn and the 2-year sorghumXsudangrass-corn rotations were not different from yields of continuous corn in any of the 4 years of the study, or for the 4-year combined data (Table 2). Only in 1995 did corn yield from the 2-year fallow-corn rotation yield more than continuous corn. In the other 3 years of the study, and for the 4-year combined data, there was no difference in yield between continuous corn and corn in the fallow-corn rotation.

Corn yield averaged across 4 years for the 3-year sunflower-alfalfa-corn rotation was 22% greater than the continuous corn yield (Table 2). Each year corn in the sunflower-alfalfa-corn rotation yielded more than continuous corn: 15, 41, 24, and 17% in 1992 through 1995, respectively. Averaged across 4 years, the 3-year sorghum-sorghumXsudangrass-corn rotation resulted in a 6% increase in corn yield compared to continuous corn, however, corn yields from the 3-year sorghum-sorghumXsudangrass-corn rotation were not different than continuous corn yields in any of the 4 years of the study. Averaged across 4 years, corn yielded 15% more in the 3-year sunflower-alfalfa-corn rotation than in the 3-year sorghum-sorghumXsudangrass-corn rotation (Table 2). Corn in the sunflower-alfalfa-corn rotation yielded 10, 34, and 12% more than corn in the sorghum-sorghumXsudangrass-corn rotation in 1992, 1993 and 1995, respectively. In 1994, there was no difference in corn yield between the two 3-year rotations.

Averaged across 4 years, there was no significant difference in corn yield between the 3-year rotation involving the monocots and the two 2-year rotations involving monocots (Table 2). Likewise, there was no significant difference in corn yield between the 3-year rotation involving the dicots and the two 2-year rotations involving dicots.

With dicots as the alternate crop, corn yields were not affected whether the interruption of the corn monoculture occurred annually or two of three yr; both rotations improved yields. With grasses as the alternate crop, corn yields were not affected by an annual interruption of the corn monoculture, but increased slightly when grasses other than corn were grown two of three years in a 3-year rotation. However, corn yielded more for the 3-year sunflower-alfalfa-corn rotation compared to the 3-year sorghum-sorghumXsudangrass-corn rotation, again suggesting dicots were more effective at interrupting the corn monoculture yield depression.

These results show sorghum and sorghumXsudangrass, grasses closely related to corn, grown in annual rotation with corn had no effect on yields relative to monoculture. The results also show that the dicots alfalfa and sunflower grown in annual rotation with corn improved corn yields relative to monoculture. Whether it is true that all dicots interrupt the monoculture yield depression is uncertain, and warrants further research.

Since the dicots selected for this study effectively alleviated corn monoculture yield decline while the selected grasses and fallow did not, our hypothesis that all alternate crops (and a fallow) would be equally effective in interrupting the corn monoculture yield decline was incorrect. The concept that "corn is bad for corn" needs to be expanded to include that certain grasses, when alternated with corn, are bad for corn.

Our sub-hypothesis that, under conditions where nitrogen was not limiting, alfalfa alternated with corn would provide no more effective corn yield benefit than sunflower alternated with corn was correct.

With dicots as the rotation crop, we did not detect a corn yield advantage when comparing corn grown every other yr to corn grown every third year. Likewise, with grasses as the rotation crop, we did not detect a corn yield advantage when comparing corn grown every other year to corn grown every third year. These data suggest corn yields would not be increased if corn were grown once every third year as compared to every other year. Thus, the hypothesis that a rotation sequence where corn was grown once every third-year would result in greater corn yield than a 2-year rotation sequence where corn was grown every other year was not true.

Conclusion

These results show sorghum and sorghumXsudangrass, grasses closely related to corn, grown in annual rotation with corn had no effect on corn yields relative to continuously grown corn. The results also show that the dicots alfalfa and sunflower grown in annual rotation with corn improved corn yields relative to continuously grown corn, The yield increase from a 2-year rotation of corn with the leguminous alfalfa was not significantly different than that observed for the non-legume sunflower. Whether it is true that all dicots interrupt the monoculture yield depression is uncertain, and warrants further research.

Table 1. Corn planting and harvest dates, seasonal rainfall, and growing degree days at Lamberton MN during the 1992 through 1995 growing seasons.

	Year								35-year average	
	1992		1993		1994		1995			
Plant date	May 4		May 20		May 10		May 5		early-May	
Harvest date	Oct. 17		Oct. 27		Oct. 21		Oct. 6		mid-Oct.	
Monthly rainfall (inches) and growing degree days (GDD)[†]										
Month	in.	GDD	in.	GDD	in.	GDD	in.	GDD	in.	GDD
May	1.61	450	7.09	281	1.34	430	4.17	270	3.19	342
June	4.09	487	11.14	447	4.45	601	1.69	571	3.86	548
July	4.80	470	5.24	600	2.68	577	6.93	631	3.90	661
August	5.12	480	5.28	594	4.06	520	3.35	659	2.99	588
September	2.09	370	2.36	262	3.74	429	2.20	371	3.19	369
Total	17.72	2257	31.10	2184	16.26	2557	17.56	2502	17.13	2508

[†] Growing degree days were calculated with a base of 50° and 86°F.

Table 2. Grain yield of corn grown from 1992 to 1995 at Lamberton, MN for continuous corn and seven cropping sequences involving five 2-year and two 3-year rotations.

Sequence description	Year 1992	1993	1994	1995	4-year average
	Corn yield bushels/acre				
Continuous corn	145	66	162	124	124
2-yr sorghum-corn rotation	146	73	165	134	130
2-yr sorghumXsudangrass-corn rotation	143	71	170	125	127
2-yr fallow-corn rotation	139	72	170	139*	130
2-yr alfalfa-corn rotation	160*[†]	96*	195*	140*	148*
2-yr sunflower-corn rotation	154	84*	203*	143*	146*
3-yr sorghum-sorghumXsudangrass-corn rotation	152	70	178	129	132*
3-yr sunflower-alfalfa-corn rotation	167*	94*	201*	145*	152*

[†] In each column, a * indicates that cropping sequence was significantly greater in yield than continuous corn.

ORGANIC CROP ROTATION STUDY AT LAMBERTON -- 1995

P.M. Porter, C.A. Perillo, and D.R. Huggins[1]

Abstract

In 1995, manure application in an on-going organically managed study employing no herbicides or synthetic fertilizer increased corn yields, but not soybean yields, regardless of rotation length. Corn yields in the manured and non-manured treatments averaged 112 and 51 bushels acre^{-1},respectively. Soybean yields in the manured and non-manured treatments averaged 24.6 and 30.4 bushels acre^{-1},respectively. Length of rotation had no effect on corn yields in the manured treatments, but impacted yields in the non-manured treatments with continuous corn yielding less than corn in 2- and 4-year rotations. For soybeans, highest yields were obtained with the 4-year rotation compared to the 2- and 3-year rotations, with the increase especially pronounced in the manured treatments. Oat yields were unaffected by rotation length or manure application. The high coefficients of variations, particularly in the non-manured treatments, were probably due in part to high and variable weed pressure.

Introduction

This on-going study evaluates various crop rotations managed organically under both high and low fertility levels. The crop rotations include 1) continuous corn, 2) a 2-year corn-soybean rotation, 3) a 3-year corn-soybean-oat rotation, and 4) a 4-year corn-soybean-oat-alfalfa rotation. The site of the study (Koch Farm adjacent to the Southwest Experiment Station) had a 30+ year history of no synthetic fertilizer use and minimal pesticide use. The study began in 1990, and at that time the Bray 1 phosphorus level was 10 ppm and the potassium level was 171 ppm. All the crop rotations have been grown both with and without poultry manure applications. There were no chemical weed control practices used, only mechanical weed control methods. The 1995 yield results are reported here. Previous results were presented in last year's edition of this publication.

Experimental Procedure

The study involved a randomized complete block design with a split-plot arrangement and 4 replicates. Rotation length was the main plot variable, and fertility management was the sub-plot variable. Main plot size was 60 ft by 155 ft, and sub-plot size was 30 ft by 155 ft. The composted poultry manure rate was based on the soil test results from the previous fall sampling and University of Minnesota Extension recommendations. The rate used was expected to meet the crop requirement of the most limiting nutrient (P or N). The manure was broadcast and incorporated prior to secondary tillage in the spring (Table 1). Soil samples for phosphorus and potassium were taken on Nov. 21 to a depth of 1 ft with 8 composite cores per sub-plot. Soil nitrate samples were taken on Nov. 16 in 1 ft increments to a depth of 5 ft with 2 composite cores per sub-plot.

After oat and oat/alfalfa treatments were planted, the plots were harrowed and packed in an effort to increase weed control and improve soil to seed contact. Corn and soybean plots were rotary-hoed and cultivated in an effort to better control weeds. Tillage and rotary hoeing in like crops in all rotations were treated the same, but row-cultivation in corn varied depending on fertility level. As in the past, all plots except those with oats under-seeded with alfalfa were moldboard plowed in the fall.

Total weed counts were taken in all plots. All weed species were identified and counted in each sample. In corn and soybean three samples 4-ft long and 2.5-ft wide were collected for grassy weeds, and three samples 150 ft by 2.5 ft were collected for broadleaf weeds. In oats and alfalfa five 1-ft squares per plot were collected for both grassy and broadleaf weeds.

Results and Discussion

In 1995, corn yields were increased with the addition of manure regardless of rotation length: manured and non-manured treatments averaged 112 and 51 bushels acre^{-1},respectively (Table 2). Length of rotation had no effect on corn yields in the manured treatments, but impacted yields in the non-manured treatments. Without manure the continuous corn yield substantially less than corn in the 2- and 4-year rotations. Weed pressure in the 3-year rotation may have contributed to the corn yield of that rotation being no different than the continuous corn yield. In the 3-year rotation the crop preceding corn was oats, and weeds were more difficult to manage in oats than in either the soybeans or the alfalfa - crops which preceded corn in the 2- and 4-year rotations.

In 1995, as in 1994, soybean yields were higher when grown without manure as compared to with manure (24.6 and 30.4 bushels acre^{-1},respectively), as weeds were more of a problem in the manured treatments (Table 2). Soybean yields responded favorably to increasing rotation length in treatments receiving manure. Oat yields were unaffected by rotation length or manure application, but in general were low. There was no difference between the manured and non-manured alfalfa treatments. The high coefficients of variations, particularly in the non-manured treatments, were probably due in part to high and variable weed pressure.

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[1] P.M. Porter (assistant professor - Department of Agronomy and Plant Genetics), C.A. Perillo (assistant scientist), and D.R. Huggins (assistant professor- Department of Soil, Water, and Climate) are at the Southwest Experiment Station, Lamberton, MN 56152.

Table 1. 1995 management information for the organic crop rotation study at Lamberton.

Rotation	Spring tillage and dates	Seed, rate, and planting date †	Rotary hoeing dates	Cultivation dates	Fertilizer rates and dates
Continuous corn	Field cultivator 5/18 (N) 5/18, 5/19 (Y)	Pioneer P3769 30000 seeds acre^{-1} 5/20	5-31 6/02 6/05	6/13, 6/22, 7/7 (N)‡ 6/13, 6/22 (Y)	289-361-289 on 5/19
Corn-soybean	Field cultivator 5/18 (N) 5/18, 5/19 (Y)	Pioneer P3769 30000 seeds acre^{-1} 5/20	5-31 6/02 6/05	6/13, 6/22, 7/7 (N) 6/13, 6/22 (Y)	249-315-252 on 5/19
Corn-soybean-oats	Field cultivator 5/18 (N) 5/18, 5/19 (Y)	Pioneer P3769 30000 seeds acre^{-1} 5/20	5-31 6/02 6/05	6/13, 6/22, 7/7 (N) 6/13, 6/22 (Y)	252-315-252 on 5/19
Corn-soybean-oats-alfalfa	Field cultivator 5/18 (N) 5/18, 5/19 (Y)	Pioneer P3769 30000 seeds acre^{-1} 5/20	5-31 6/02 6/05	6/13, 6/22, 7/7 (N) 6/13, 6/22 (Y)	40-50-40 on 5/19
Corn-**soybean**	Field cultivator 5/18, 5/22 (N) 5/18, 5/20, 5/22 (Y)	Parker 158,000 seeds acre^{-1} 5/22	5/31 6/05	6/13, 6/22, 7/10 (N) 6/13, 6/22, 7/10 (Y)	24-30-24 on 5/20
Corn-**soybean**-oats	Field cultivator 5/18, 5/22 (N) 5/18, 5/20, 5/22 (Y)	Parker 158,000 seeds acre^{-1} 5/22	5/31 6/05	6/13, 6/22, 7/10 (N) 6/13, 6/22, 7/10 (Y)	24-30-24 on 5/20
Corn-**soybean**-oats-alfalfa	Field cultivator 5/18, 5/22 (N) 5/18, 5/20, 5/22 (Y)	Parker 158,000 seeds acre^{-1} 5/22	5/31 6/05	6/13, 6/22, 7/10 (N) 6/13, 6/22, 7/10 (Y)	24-30-24 on 5/20
Corn-soybean-**oats**	Field cultivator and harrow / packer 5/02 (N and Y)	Dane 85 lbs acre^{-1} 5/02	none	none	40-50-40 on 5/20
Corn-soybean-**oats**-**alfalfa**	Field cultivator and harrow / packer 5/02 (N and Y)	Dane and Pioneer P5262 85 and 15 lbs acre^{-1} 5/02 and 5/02	none	none	40-50-40 on 5/20
Corn-soybean-oats-**alfalfa**	none	Planted previous year	none	none	52-65-52 on 5/20

† Hybrid or variety is listed, followed by seeding rate in seeds acre^{-1} and planting date.
‡ N refers to non-fertilized treatments, Y refers to fertilized treatments. Analysis of the composted manure was 4-5-4% N-P_2O_5-K_2O.

Table 2. Rotation length and fertility effects on corn, soybean, oats and alfalfa yields in an organically-managed study at Lamberton, 1995.

Rotation	With manure	Without manure
Corn yield	---- bushels acre^{-1} -----	
Continuous corn	112.8	34.1 c
Corn-soybean	119.7	56.9 ab
Corn-soybean-oats	110.5	44.8 bc
Corn-soybean-oats-alfalfa	106.6	66.2 a
Mean	112.4	50.5
CV (%)	5.0	21.5
Pr> F	0.051	0.011
$LSD_{(0.05)}$	9.0	17.3
Soybean yield	---- bushels acre^{-1} -----	
Soybean-corn	17.0 b	29.5
Soybean-oats-corn	20.7 b	29.5
Soybean-oats-alfalfa-corn	36.0 a	32.3
Mean	24.6	30.4
CV (%)	27.0	26.0
Pr> F	0.015	0.85
$LSD_{(0.05)}$	11.4	13.7

Rotation	With manure	Without manure
Oat yield	--- bushels acre^{-1} ---	
Oats-corn-soybean	34.6	34.0
Oats-alfalfa-corn-soybean	36.4	32.7
Mean	35.5	33.4
CV (%)	4.2	18.7
Pr> F	0.18	0.80
$LSD_{(0.05)}$	3.35	14.0
Alfalfa yield	---- ton acre^{-1} ----	
Alfalfa-corn-soybean-oats	5.90	4.23
With vs. without manure		
CV (%)	20.3	
Pr>F	0.11	
$LSD_{(0.05)}$	2.31	

WEST CENTRAL EXPERIMENT STATION
WEATHER SUMMARY - 1995

Month/ Period	Dates/ Period	Precipitation 1995	Precipitation 100-yr. average	Precipitation Dev. from av.	Air Temperature 1995	Air Temperature 100-yr. average	Air Temperature Dev. from av.	Soil Temperature (10 cm depth) 1995	Soil Temperature (10 cm depth) 10-yr. average
January	1-31	0.91	0.68	+0.23	12.1	8.0	+4.1	25.6	20.7
February	1-28	0.55	0.67	-0.12	14.4	12.8	+1.6	25.4	23.9
March	1-31	3.77	1.13	+2.64	28.7	26.7	+2.0	32.1	29.2
April	1-10	0.16	0.57	-0.41	32.7	38.0	-5.3	36.0	
	11-20	1.98	0.64	+1.34	38.0	44.4	-6.4	35.8	
	21-30	0.36	1.05	-0.69	43.9	48.3	-4.4	43.6	
Total/av.		2.50	2.26	+0.24	38.2	43.6	-5.4	38.4	41.4
May	1-10	0.75	0.77	-0.02	52.0	52.0	–	50.2	
	11-20	1.25	0.95	+0.30	55.4	55.8	-0.4	54.0	
	21-31	1.10	1.25	-0.15	56.9	60.0	-3.1	57.2	
Total/av.		3.10	2.97	+0.13	54.8	56.1	-1.3	53.9	57.1
June	1-10	1.21	1.29	-0.08	66.3	63.0	+3.3	67.5	
	11-20	0.41	1.30	-0.89	73.5	66.3	+7.2	73.0	
	21-31	0.48	1.37	-0.89	71.8	68.1	+3.7	74.3	
Total/av.		2.10	3.96	-1.86	70.5	65.8	+4.7	71.6	69.3
July	1-10	5.06	1.44	+3.62	66.5	70.1	-3.6	69.0	
	11-20	0.56	1.06	-0.50	73.2	71.4	+1.8	77.7	
	21-31	1.12	1.01	+0.11	69.7	71.4	-1.7	75.5	
Total/av.		6.74	3.51	+3.23	69.8	70.9	-1.1	74.0	76.7
August	1-10	0.71	1.04	-0.33	70.2	70.4	-0.2	76.3	
	11-20	2.97	0.93	+2.04	72.0	69.0	+3.0	76.5	
	21-31	2.58	1.04	+1.54	71.8	66.9	+4.9	76.2	
Total/av.		6.26	3.01	+3.25	71.4	68.7	+2.7	76.3	73.9
September	1-30	2.68	2.20	+0.48	58.6	59.0	-0.4	64.7	61.5
October	1-31	3.35	1.74	+1.61	44.7	47.2	-2.5	48.5	47.8
November	1-30	0.44	0.97	-0.53	23.2	29.7	-6.5	30.1	33.6
December	1-31	1.04	0.68	+0.36	15.4	15.2	+0.2	22.4	23.4
Growing Season	4/1-8/31	20.70	15.71	+4.99	60.9	61.0	-0.1	63.9	63.8
Annual	1/1-12/31	33.44	23.78	+9.66	41.8	42.0	-0.2	46.9	46.7

ANHYDROUS AMMONIA - KNIFE SPACING STUDY[1]

S.D. Evans and G.A. Nelson[2]

Abstract

A field study was initiated in Morris, MN in 1994 and repeated in 1995 to study the effects of 2 anhydrous ammonia applicator knife spacings at sidedress on corn grain yield. Nitrogen was sidedressed at 0, 36, 72, 108, and 144 lb/A using 30- and 60-inch applicator knife spacings. In 1994 and 1995 there was an increase in grain yield up to 72 lb N/A but no difference in yield due to knife spacing.

Objectives

Anhydrous ammonia is the dominant source of inorganic nitrogen used in corn production. Normally anhydrous ammonia is injected into the soil through knives that run 6 to 10 inches deep. Horse-power requirements and fuel consumption are high during this process. It would be advantageous to space anhydrous ammonia knives 60 inches apart, rather than the conventional 30-inch spacing, to reduce horse-power and fuel requirements during the anhydrous ammonia application process. At the 60-inch spacing no ammonia is applied in the tractor wheel tracks. This study was designed to evaluate corn grain yield response due to spacing of anhydrous ammonia applicator knives at 30-inch intervals versus 60-inch intervals. The anhydrous ammonia was applied sidedress at the V5 stage of corn with a conventional ammonia applicator.

Experimental Procedures

The 1995 experiment was established on a Nutley clay soil. For 1994 experimental procedures see 'Blue Book' Miscellaneous Publication 88-1995, page 55. The experimental design was a randomized complete block with 4 replications. The experimental site was in Oats in 1994 and fall chisel plowed. Initial soil tests are shown in Table 1. The 1995 individual plots were 6 rows (15ft) wide and 45 feet long. The experimental site was field cultivated and seeded to Ciba Geigy 4172 corn at 30,000 seeds per acre on May 1, 1995. Force 1.5G was band applied at 10 lb/A at seeding. A 6-row J.D. Maxemerge planter was used for seeding. Lasso @ 3.0 lb/A a.i. + Bladex @ 2.2 lb/A a.i. was applied pre-emergence broadcast on May 2. Basagran @ 0.75 lb/A a.i. + 1 qt/A COC was applied on June 12 for Canada thistle control. Anhydrous ammonia was sidedress applied on June 21. Nitrogen was applied at rates of 36, 72, 108, and 144 lb/A at 30- and 60-inch knife spacings. A check treatment was also included by running knives at 30- and 60-inch spacings through the check plots without applying any nitrogen. Corn was in the V5 stage, 4-5 collars visible at the time of nitrogen application. The study was row cultivated prior to nitrogen application on June 21. Corn tasseling and silking dates were recorded and occurred between July 24-29. The study was harvested with a plot combine on October 12. Grain yield and grain moisture were recorded.

Results

There were significant differences in grain yield due to nitrogen rate (Table 2) in 1994 and 1995. Grain yield was maximized at about 72 lb/N in both years. Grain moisture at harvest was highest and tasseling and silking were latest for the 0 lb/N treatment in both years (data not shown). There were no significant effects on grain yield due to knife spacing in 1994 or 1995. The knife spacing x treatment interaction was not significant in 1994, but was significant in 1995. Examination of data for the 1995 interaction indicated that most of the effects were attributed to nitrogen rate. Two years of results show no differences in grain yield due to 30- and 60-inch anhydrous ammonia knife applicator spacings at sidedress.

Table 1. Analysis of site soil samples taken in the fall of 1994.

Organic Matter	pH	Olsen P	K	0-2 ft NO_3-N	2-5 ft NO_3-N
%	--	ppm	ppm	lb/A	lb/A
5.2	7.3	22	246	22	16

[1] Funding provided by the West Cent. Expt. Sta., Univ. of Minnesota.

[2] Professor and Assistant Scientist, West Cent. Expt. Sta., Univ. of Minnesota

Table 2. Effect of applicator knife spacing on corn grain yield, Morris 1994 and 1995.

Nitrogen Rate	Knife Spacing	1994 Grain Yield	1995 Grain Yield
lb/A	inches	bu/A	bu/A
0	30	80.5	103.6
36	30	106.9	115.7
72	30	150.3	162.6
108	30	142.7	162.8
144	30	159.3	163.2
0	60	80.5	89.5
36	60	113.5	139.0
72	60	148.9	155.7
108	60	153.3	158.7
144	60	159.8	162.4
Nitrogen Rate			
Sig. Level (%)		99	99
BLSD (.05)		20.5 bu	7.6 bu
Knife Spacing			
Sig. Level (%)		34	12
N Rate x Knife Spacing			
Sig. Level (%)		2	99
C.V. (%)		16.7	5.8

Continuous Corn Silage, 1965-1995[1]

S.D. Evans[2]

Abstract

In 1965 an experiment was initiated on a McIntosh silt loam soil to determine the effects of removal of continuous corn silage or continuous corn grain on corn silage yields and soil fertility levels under low- and high-fertility regimes. 1995 was the last year of the study. A 30-year analysis shows no silage yield differences due to the removal of continuous corn silage versus continuous corn grain. A significant difference in yield exists between the low- and high-fertility regime. Significant soil test P and K differences exist due to fertility regime but the K soil test and not the P soil test was affected by above ground silage removal compared to removing only the grain.

Objective

This the 30th and final year of a corn silage study initiated in 1965 on a McIntosh silt loam soil. The study was initiated to determine the effects of removal of continuous corn silage and continuous corn grain on corn silage yields and soil fertility level. Yields were assessed under low (74+48+48, $N+P_2O_5+K_2O$ in lbs/a) and high (148+96+96, $N+P_2O_5+K_2O$ in lbs/a) fertilizer regimes.

Experimental Procedures

The experiment was designed as a latin square with 4 treatments: (1) silage-low fertility, SLF (2) silage-high fertility, SHF (3) grain-low fertility, GLF and (4) grain-high fertility, GHF. Silage yields were recorded from 1966 to 1995 except in 1993 when the corn failed to reach maturity and was chopped down and incorporated back into the soil. From 1965 to 1994 the plots were fertilized each fall with specific plots receiving a 74+48+48 or a 148+96+96 fertilizer blend. Each fall after fertilization the plots were moldboard plowed. The study was seeded at optimum rates to established corn hybrids usually in early to mid May as soil temperature and moisture conditions allowed. A rootworm insecticide was applied at planting. Weed control was normally achieved through pre-emergence or post-emergence applications of grass and broadleaf herbicides and through row cultivation once or twice a year depending on soil conditions and weed pressure. Designated plots were either harvested as corn silage or had only the grain harvested. Silage yields were obtained by hand chopping and weighing 3 10-foot rows from each plot. Ears and stover were separated and weighed separately. Ear moisture was obtained by removing the center 3/4 inch section of 10 ears and forage moisture was obtained by running 5 stalks through a forage chopper. Ear and forage samples were weighed wet, dried for 48 hours at 150°F, and weighed dry for moisture determination. On "silage" plots the remaining bulk of the corn was harvested with a conventional forage harvester as corn silage. On the "grain" plots corn grain was harvested with a combine. Silage yields were also taken on an adjacent unfertilized (check) area. This check was not a part of the experimental design.

Results

Silage Yields

There were significant differences in silage yields after 30 years of continuous corn in low- versus high-fertility regimes, (Table 1). The difference in silage yields between the low- and high-fertility regime was 0.63 tons/A for the continuous silage plots and 0.48 tons/A for the continuous grain plots. The 30-year average silage yield for the check treatment adjacent to the study was 3.39 tons/A compared to 5.57 tons/A for the low- and 6.13 tons/A for the high-fertility regime. There was no significant difference in corn silage yield when silage was removed versus when only the grain was removed at the low- or high-fertility regime. This would indicate that continuous corn silage removal had no effect on silage yield if an adequate fertility regime is maintained. In Fig.1 silage yields are presented in 5 year intervals. The high fertility treatments and low fertility treatments performed similarly throughout the life of the study.

Soil Fertility

The results of soil analysis for the initial year of the study in 1965, and for 1985 and 1991, as well as results for the final year of the study in 1995 are given in Table 2. The P soil test differs significantly in 1985 between low- and high-fertility regimes 20 years after initiation of the study. P soil test levels continued to increase from 1985 to 1995. It appears that initial low P soil test levels were increased to high and very high P soil test levels and maintained at low 48-lb P and high 96-lb P fertility regimes respectively. Corn silage removal had no appreciable effect on P soil test levels, but K soil test levels were substantially affected. K soil test levels were unchanged from 1965 to 1995 on the SLF treatment, but raised by 24, 51, and 107 ppm on the SHF, GLF, and GHF treatments respectively. Corn silage removed more K than grain only but soil test levels were still maintained by the SLF treatment.

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[1] Funding provided by the West Cent. Expt, Sta., Univ. of Minnesota.

[2] Professor, West Cent. Expt. Sta., Univ. of Minnesota.

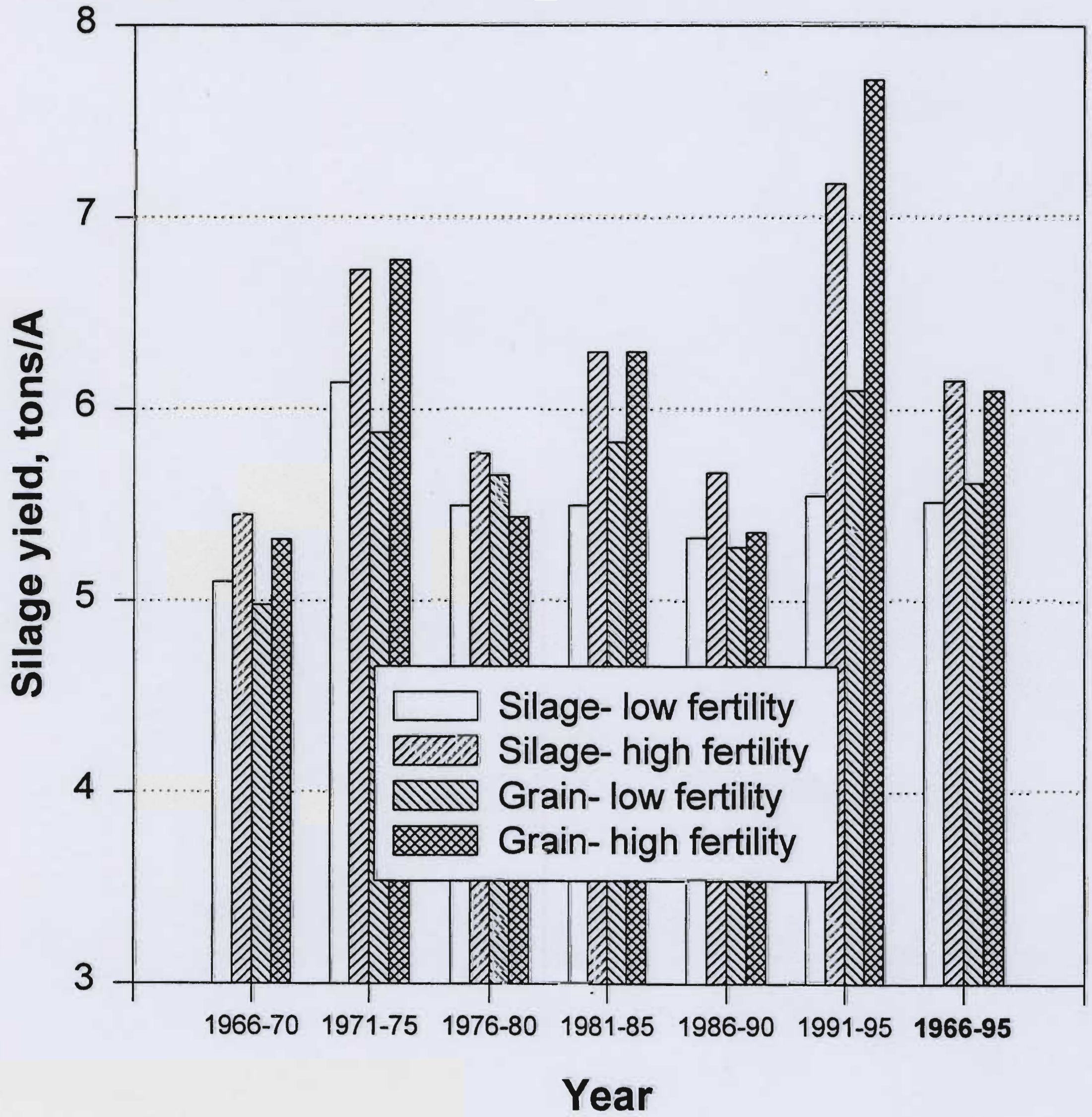
Table 1. Effect of removal of continuous silage or grain only on silage yields.

Treatment	1966-1995 Silage Yield
	dry matter, tons/A
Silage, low fertility	5.52
Silage, high fertility	6.15
Grain, low fertility	5.62
Grain, high fertility	6.10
Signif. Levels (%)	
Treatment	>99
Year	>99
Treatment x Year	>99
BLSD, Treatment (.05)	0.16
C.V. (%)	11.8

Table 2. Effect of removal of continuous silage or grain at 2 fertility regimes on P and K soil tests at four intervals over a 30 year period.

Treatment	1965	1985	1991	1995
Silage-low fertility				
pH	7.8	8.1	8.2	8.2
O.M. %	4.5	–	–	4.0
P Soil test-ppm	6	13	14	16
K Soil test-ppm	129	131	119	120
Silage-high fertility				
pH	7.9	8.1	8.2	8.2
O.M. %	4.3	–	–	4.1
P Soil test -ppm	6	21	33	31
K Soil test -ppm	127	146	139	151
Grain-low fertility				
pH	7.9	8.1	8.1	8.2
O.M. %	4.4	–	–	3.9
P Soil test -ppm	5	9	17	15
K Soil test -ppm	123	166	158	174
Grain-high fertility				
pH	7.9	8.1	8.1	8.2
O.M. %	4.2	–	–	4.0
P Soil test -ppm	6	24	37	38
K Soil test -ppm	119	199	199	236
P Signif. Level (%)	NS	99	>99	>99
P BLSD (.05)	–	8	9	5
K Signif. Level (%)	NS	>99	>99	>99
K BLSD (.05)	–	17	15	16

Fig.1. Effect of removal of continuous corn silage or grain only on silage yields with low and high fertility treatments in 5 year increments, 1966 - 1995.



SOUTHERN EXPERIMENT STATION
35838 120th STREET
WASECA, MINNESOTA 56093-4521

WEATHER DATA - 1995

Month	Period	Precipitation		Avg. Air Temp.		Growing Degree Units	
		1994	Normal[1/]	1994	Normal[1/]	1994	Normal[1/]
		---- inches ----		----- °F -----			
January	1 - 31	0.40	0.98	16.1	10.2		
February	1 - 28	0.21	0.97	19.0	16.1		
March	1 - 31	3.28	2.28	33.2	29.1		
April	1 - 30	3.73	2.97	40.7	43.1		
May	1 - 10	0.47		52.5		61.0	
	11 - 20	1.40		57.2		99.0	
	21 - 31	1.52		58.2		105.0	
	Total	3.39	3.65	56.0	57.7	265.0	327
June	1 - 10	0.88		65.8		166.5	
	11 - 20	0.03		71.2		211.0	
	21 - 30	2.28		74.6		229.0	
	Total	3.19	4.11	70.8	67.1	606.5	515
July	1 - 10	0.27		66.1		164.5	
	11 - 20	2.65		76.4		241.5	
	21 - 31	2.34		72.3		242.5	
	Total	5.26	4.21	71.6	71.3	648.5	646
August	1 - 10	3.56		71.7		217.0	
	11 - 20	0.65		74.4		234.5	
	21 - 31	0.35		74.6		263.5	
	Total	4.56	4.20	73.6	68.4	715.0	567
September	1 - 30	4.08	3.56	59.2	59.9	277.5	316
October	1 - 31	4.98	2.45	47.1	47.9	-	31
November	1 - 30	1.17	1.72	25.9	32.3		
December	1 - 31	1.28	1.35	18.6	16.2		
Year	Jan-Dec	35.53	32.45	44.3	43.4	2512.5[2/]	2402
Growing Season	May-Sep	20.48	19.73	66.3	64.9	2512.5	2371

[1/] 30-year normal from 1961 - 1990.
[2/] 50 to 86° F base, May 1 until first fall frost.

Notes:
1) Highest 24-hour precipitation on August 5 --- 1.92"
2) Growing degree units 5% above normal for season.
3) Highest temperature on July 14 --- 101°F.
4) Last spring frost --- April 28.
5) First fall frost --- September 22.

1995 Soil Moisture

0-5' Profile, Webster Clay Loam

Continuous Corn

Southern Experiment Station, Waseca, MN 56093

Depth	4/14	5/1	5/15	6/1	6/16	6/30	7/17	7/31	8/17	8/31	9/15	10/4	10/16	11/2
inches	inches available water in zone													
0 - 6[1/]	1.03	1.21	1.17	1.14	1.12	0.93	0.40	0.90	1.11	0.66	0.75	1.21	1.14	1.23
6 - 12	1.02	1.05	0.95	0.88	0.84	0.68	0.11	0.64	0.61	0.42	0.56	0.81	0.80	0.98
12 - 18	1.00	1.09	0.79	0.96	0.83	0.72	0.29	0.70	0.66	0.42	0.67	0.95	0.95	1.05
18 - 24	0.69	0.82	0.74	0.78	0.63	0.58	0.33	0.53	0.57	0.37	0.39	0.74	0.72	0.75
24 - 36	1.79	1.69	1.88	2.12	1.57	1.85	1.28	1.44	1.54	1.15	1.21	1.46	1.66	1.83
36 - 48	2.49	2.52	2.51	2.71	2.42	2.58	2.05	2.36	2.34	2.13	2.15	2.00	2.29	2.54
48 - 60	1.92	2.12	2.18	2.23	2.01	2.08	1.90	1.98	2.00	1.88	1.88	1.64	2.03	2.07
Total available water in 0-5' profile (inches)	9.93	10.50	10.22	10.82	9.42	9.43	6.38	8.55	8.84	7.03	7.61	8.81	9.60	10.45
% of Capacity[2/]	90	95	92	98	85	85	58	77	80	64	69	80	87	95

[1/] All values obtained by gravimetric sampling using Waseca D_b and WP constants.

[2/] Assuming 11.05" field moist capacity.

Above average rainfall resulted in plentiful soil moisture in the five-foot profile throughout the 1995 growing season. Lowest soil moisture levels occurred in mid-July and again in late August following two-week dry periods with very hot conditions when peak ET occurred. Soil moisture in early November was at 95% of field capacity and reflects the abnormally wet October. With any snow melt or early spring rainfall, soil moisture will likely be at field capacity in April and could delay field operations.

NITROGEN AND MANURE MANAGEMENT FOR CORN AFTER ALFALFA IN WINONA COUNTY

G. W. Randall and J. A. Vetsch

1995

ABSTRACT: Semi-solid dairy manure was applied at rates of 10, 20, and 30 T/A (wet basis) to a 3-yr old stand of alfalfa in October, 1993 and chisel plowed in immediately. After growing corn in 1994 and removing it for silage, liquid dairy manure was applied and immediately incorporated at rates of 7500, 10000, and 13800 gal/A to plots which both received and did not receive manure for first-year corn. The manure treatments were compared to urea applied at rates from 0 to 160 lb N/A. Grain yields were improved above the control by all of the manure and most of the fertilizer N treatments. Responses were greater for manure, especially when applied for two consecutive years, compared to fertilizer N. Yields were not improved by applying more than 7500 gal/A. Nitrate-N concentrations in the soil water at a 5-ft depth were consistently higher throughout the season when manure or fertilizer N had been applied for first-year corn after alfalfa. Due to dry conditions in 1995, manure applied in October 1994 did not affect the NO_3-N concentration at this depth. Although these data show a slight yield advantage for applying manure to both first and second-year corn after alfalfa, the environmental consequence is substantial - - greatly elevated concentrations of residual soil NO_3 at the end of the season and NO_3 concentrations in the soil water leaching out of the soil profile.

Surveys of land owners in Winona County indicate a substantial acreage of corn is planted following alfalfa. Previous studies have shown little or no corn yield response to fertilizer N for first-year corn after alfalfa. Yet many farmers often add some fertilizer N and dairy farmers without an adequate land base for manure often apply manure following alfalfa for corn. The result of these fertilizer and manure additions is an abundant supply of N, which is in excess of plant use and which can contribute significantly to nitrates in the ground water. Nitrogen management for second year corn after alfalfa can be impacted by the N inputs to the previous corn crop. The purposes of this study were to determine: (1) the effect of dairy manure and fertilizer N applied to first and second-year corn following alfalfa on corn production, nitrate-N in the soil profile, and nitrate-N in the soil water at the 5' and 7.5' depths and (2) the "available" N to corn in an animal-based cropping system by evaluating various soil N tests from samples taken periodically during the season.

MATERIALS AND METHODS

The site is located on a Seaton silt loam at the Robert and Eugene Kalmes farm in Winona County. Alfalfa was companion seeded with oats in May 1991 following five years of continuous corn. After removing three cuttings of alfalfa in 1993, semi-solid dairy manure was applied on Oct. 27 at rates of 10, 20, and 30 T/A (wet) to plots that were replicated four times. Three manure samples were taken and analyzed. Average values were: 18.7% dry matter, 10.8 lb total N/ton, 4.0 lb NH_4-N/ton, 10.9 lb P_2O_5/ton, and 14.4 lb K_2O/ton. All plots were chisel plowed to an 8 - 9" depth within 6 hours. Corn was then grown in 1994. After grain and silage yields were measured, all of the corn was removed from the plots as silage.

Liquid dairy manure was applied to selected treatments on October 25, 1994. The manure was broadcast applied on the surface and incorporated with a chisel plow within 3 hours. Two manure samples were analyzed. Average values were 8.1% dry matter, 27.6 lb total N/1000 gal, 14.1 lb NH_3-N/1000 gal, 18.5 lb P_2O_5/1000 gal, and 30.0 lb K_2O/1000 gal.

Corn (Pioneer 3861) was planted on May 5 after field cultivation. Weeds were controlled well with herbicides. No mechanical cultivation was practiced. Urea was broadcast applied and incorporated on May 5. Soil water samples were taken periodically during the season from porous cup samplers installed at a depth of 5'. Grain and silage yields were taken by hand-harvesting 60' of row from each plot on Oct. 3.

Soil samples consisting of six random cores/plot were taken at the V-5 stage (June 23) when corn was about 12" tall. After harvest (October 13) three random cores/plot were taken in 1-foot increments to a depth of 5 feet. Cores from each plot were composited by depth, placed in paper bags, forced-air dried at 125 degrees F., ground, and analyzed for NO_3-N.

RESULTS AND DISCUSSION

Grain yields obtained in this study were much poorer than expected due primarily to the hybrid used, dry weather, severe root lodging caused by strong winds on Aug. 13, and very high levels of European corn borer. Yields were improved by the fertilizer N treatments but especially by the manure treatments (Table 1). The highest second-year corn yields were obtained where some manure had been applied for both first and second-year corn. Yields were slightly lower (6 bu/A) when manure was applied only for second-year corn. When no manure was applied and only fertilizer N was used, yields were about another 6 bu/A lower. The response to manure was easily visibly seen in June as the manure plots produced taller and darker green corn. Rate of manure application had no effect on grain yield; yields with 7500 gal/A were as good as with 13800 gal/A.

Table 1. Grain, stover, and silage yields, grain and stover N content, and total N removal in the grain, stover, and silage as affected by manure and fertilizer applied to second-year corn following alfalfa.

'93-94 Treatments		'94-95 Treatments		Yield			N Concentration		N Removal		
Manure[1/]	Nitrogen	Manure[1/]	Nitrogen	Grain	Stover	Silage	Grain	Stover	Grain	Stover	Silage
T/A(wet)	lb/A	gal/A	lb/A	bu/A	T DM/A	T DM/A	--- % ---		----- lb N/A -----		
0	0	0	0	97	1.91	4.21	1.21	0.62	55	24	79
10	0	7500	0	124	2.44	5.37	1.32	0.72	77	35	112
20	0	10000	0	126	2.54	5.51	1.42	0.68	84	35	119
30	0	13800	0	124	2.30	5.23	1.40	0.70	82	32	114
0	75	0	160	113	2.25	4.92	1.45	0.66	78	31	109
0	0	7500	0	118	2.69	5.49	1.34	0.70	75	38	112
0	0	10000	0	118	2.64	5.42	1.31	0.67	73	35	108
0	0	13800	0	124	2.68	5.60	1.43	0.68	84	36	120
0	0	0	40	112	2.16	4.81	1.35	0.71	72	30	102
0	0	0	80	114	1.98	4.67	1.35	0.71	72	28	101
0	0	0	120	112	2.24	4.90	1.40	0.75	78	34	111
0	0	0	160	102	2.10	4.53	1.43	0.80	69	33	102
Statistical Analysis of Treatments											
P > F:				<0.01	<0.01	<0.01	0.02	0.23	<0.01	0.03	<0.01
LSD (0.05):				11	0.36	0.55	0.12		10	7	12
C.V. (%):				7	11	8	6	11	9	15	8
Contrast Statistics											
P > F: 'Manure vs Fertilizer N'				<0.01	<0.01	<0.01	0.27	0.17	0.01	0.01	<0.01
P > F: '2-yr Manure vs 1-yr Manure'				0.20	0.03	0.39	0.59	0.51	0.18	0.26	0.70

[1/] Manure rates applied 10/27/93 as semi-solid dairy manure and 10/25/94 as liquid dairy manure.

Nitrate-N concentrations in the soil water at a 5' depth also were affected significantly by the manure and N treatments (Table 2). Treatments 2 - 5, which received either manure or urea for first-year corn, gave consistently higher NO_3-N concentrations throughout the season than did those manure and urea treatments that were applied only for second-year corn. Due to the dry weather, which severely limited leaching, no impact of the manure applied in the fall of 1994 or urea applied in the spring of 1995 was observed at this depth in 1995.

Table 2. Nitrate-N concentrations in the soil water at 5' in July, August, and September, 1995 as affected by manure and fertilizer N applied for second-year corn after alfalfa.

'93-94 Treatments		'94-95 Treatments		Nitrate-N Concentration in Soil Water at 5'		
Manure	Nitrogen	Manure	Nitrogen	June	August	September
T/A(wet)	lb/A	gal/A	lb/A	---------- mg/l ----------		
0	0	0	0	12	10	10
10	0	7500	0	17	18	--
20	0	10000	0	40	35	34
30	0	13800	0	33	--	30
0	75	0	160	32	31	26
0	0	7500	0	12	12	11
0	0	10000	0	12	13	12
0	0	13800	0	24	--	16
0	0	0	40	19	20	19
0	0	0	80	16	16	16
0	0	0	160	15	16	16

Soil NO_3-N at the V-5 stage was surprisingly high at this site for all treatments, and it was increased further above the control by the high rate of manure and by fertilizer N rates ≥ 80 lb/A (Table 3). The 19 ppm concentration found in the control plots was very close to the critical level of 21 ppm which has been established in several research studies as the value above which a yield response to N will not occur. This may partially explain the small yield response (< 30 bu/A) to N in this study.

Residual soil NO_3-N (RSN) in the 0-5' profile was increased significantly over the control by the treatments where manure and fertilizer N were applied to both first and second year corn after alfalfa (Table 3). Manure applications caused increased soil NO_3-N primarily in the top 3 to 4' while the 75-lb fertilizer N rate applied in 1994 followed by 160 lb N/A in 1995 showed elevated RSN levels throughout the profile. Application of either manure or fertilizer only for second year corn resulted in somewhat higher RSN levels compared to the control, primarily in the top 2 feet. This accumulation near the surface was likely due to the dry weather in 1995. Contrast statistics showed higher RSN levels in the top 3 feet for the fertilizer N treatments compared to the manure treatments and for the second year manure applications compared to the single year applications.

Table 3. Nitrate-N concentrations in the 0-1' layer at the V-5 stage (June 23) and in the 0-5' soil profile after harvest (Oct. 13) as influenced by manure and fertilizer N rates.

'93-94 Treatments		'94-95 Treatments		Nitrate-N Concentration						
				June 23	October 13					
Manure	Nitrogen	Manure	Nitrogen	0-1'	0-1'	1-2'	2-3'	3-4'	4-5'	0-5'
T/A(wet)	lb/A	gal/A	lb/A	ppm						lb/A
0	0	0	0	19	4.6	1.9	1.6	2.2	2.6	52
10	0	7500	0	26	7.6	6.6	3.9	4.2	3.3	102
20	0	10000	0	25	8.1	7.6	5.9	4.1	3.9	118
30	0	13800	0	31	8.1	8.4	6.2	4.4	3.7	123
0	75	0	160	36	15.4	19.0	9.5	6.4	4.4	219
0	0	7500	0	21	5.5	3.7	2.7	2.9	2.9	70
0	0	10000	0	25	6.6	5.4	3.2	3.1	2.7	84
0	0	13800	0	30	5.0	3.5	3.7	5.5	4.5	89
0	0	0	40	20	6.1	4.8	3.1	3.1	2.4	78
0	0	0	80	30	6.2	5.2	4.1	3.4	4.5	94
0	0	0	120	42	9.6	12.4	5.7	3.5	2.8	136
0	0	0	160	50	11.9	15.8	5.7	3.4	3.0	159
Statistical Analysis of Treatments										
P > F:				<0.01	<0.01	<0.01	<0.01	<0.01	0.03	<0.01
LSD (0.05):				13	3.4	5.7	3.0	1.9	1.5	40
LSD (0.10):				10	2.9	4.7	2.5	1.6	1.2	33
CV (%):				29	30	50	45	35	30	25
Contrast Statistics										
P > F: 'Manure vs Fertilizer N'				<0.01	<0.01	<0.01	0.04	0.81	0.88	<0.01
P > F: '2-yr Manure vs 1-yr Manure'				0.53	0.03	0.05	0.02	0.43	0.60	<0.01

SUMMARY

- Grain yields were higher where dairy manure had been applied compared to only fertilizer N (urea).
- Increasing the manure rate from 7500 gal/A to 13800 gal/A did not improve second-year corn yields.
- Applying manure or fertilizer N for first-year corn gave substantially higher NO_3-N concentrations in the soil profile and in the soil water at a 5' depth 12 to 24 months after application. Moreover, first-year corn yields were not affected by the manure or fertilizer N treatments (data not shown).
- Based on these data liquid dairy manure is a superb source of N for second year corn but should not be applied and is not a BMP for first-year corn after alfalfa.

NITRATE LOSSES TO TILE DRAINAGE AS AFFECTED BY NITROGEN FERTILIZATION OF CORN IN A CORN-SOYBEAN ROTATION[1/]
Waseca, 1995

G. W. Randall and J. A. Vetsch[2/]

ABSTRACT: A study was conducted in 1995 to determine the influence of time of N application, N source, and nitrification inhibitor (NI) on the yield and uptake of N by corn and the loss of NO_3 to tile drainage. These second-year results showed a significant yield increase over the control from all N treatments. However, yields were not affected by time of N application, N source, or the nitrification inhibitor (N-Serve). Grain N concentration and relative leaf chlorophyll content were higher with spring preplant-applied AA compared to fall-applied AA. Tile lines flowed from mid-April through mid-June, intermittently in August, and in October through early November. Tile flow averaged 4.70" for corn and 3.84" for soybeans. In the corn plots highest NO_3-N concentration and loss occurred with the fall application of N without NI. Under soybean the highest concentrations occurred with fall-applied AA without N-Serve and spring preplant-applied AA with N-Serve (N applied to the previous corn crop). Nitrate-N concentrations and losses from continuous fallow plots that have not received fertilizer N or a planted crop for nine years were 90% higher than from the fertilized corn. This is due to soil mineralization and lack of crop uptake over the period.

Nitrogen (N) losses to tile drainage water have been directly linked to N additions, crop grown, and soil organic matter level. Research has been conducted on NO_3 losses to tile drainage in Minnesota since 1972. This research has focused primarily on the effects of rate and time of fertilizer N application and tillage in a continuous corn system. The purpose of this study is to determine the influence of time of N application and the use of a nitrification inhibitor on NO_3 movement and accumulation in the soil, NO_3 losses via tile drainage, and yield an N uptake by corn grown in a rotation with soybean.

EXPERIMENTAL PROCEDURES

Thirty-six individual tile line plots were installed on a poorly drained Webster clay loam soil at the Southern Experiment Station in 1976. Each 20 x 30' plot is completely surrounded by plastic sheeting to a depth of 6' to prevent lateral flow and contains a tile line (4' deep) 5 feet from one end. All tiles drain to collection pits where flow rates can be measured and water samples collected for analyses. After completing a research project in 1983 using this tile facility, the plots were cropped to corn with a blanket N rate in 1984 and 1985 to establish uniformity.

Beginning in 1986 corn was planted on one-half of the experimental site while soybean was planted on the other half. Thirty two plots (16 with corn and 16 with soybean) with the most uniform drainage were selected from the 36 for the primary study. The experimental design consists of a 4 x 4 Latin square where the rows and columns were based on the previous (1977-83) tile flow rates from each plot. The four primary N treatments (see Table 1) are applied to the corn phase each year with the residual effects measured in the soybean phase. Three additional N treatments were replicated four times around the edge of the core 16-tile-plot area and were planted to corn. These three treatments were analyzed along with the other four as a completely randomized design.

Fertilizer N was applied at a rate of 120 lb/A for all N treatments. The nitrification inhibitor, N-Serve was applied at 0.5 lb/A. Fall treatments were applied on October 28, 1994. Average soil temperature at the 4" depth on that date was 50°F with an average of 47°F over the following 10-day period. The spring preplant anhydrous ammonia treatments were applied on April 25. The preplant urea treatment (5) was applied on May 3. The sidedress AA treatment was applied at the V4 stage on June 15.

The corn area (1994 soybean area) was field cultivated once before planting, while the soybean area (1994 corn area) was fall chiseled and field cultivated once prior to planting. Because of high soil P and K tests, no broadcast nor starter fertilizer was used.

Corn (Pioneer 3769) was planted at 32,000 seeds/acre on May 4 with a JD Max-Emerge planter. Corn rootworm insecticide was not used. Weeds were chemically controlled with a preemergence application of Lasso (3.5 lb/A) plus Bladex (3 lb/A) on May 11. Soybeans (Sturdy) were planted in 30" rows at 9 beans per foot of row on May 17. Weeds were chemically controlled with 3.0 lb/A Lasso preemergence (May 22) plus a post emergence application of Pursuit (4 oz/A) at the 1st trifoliate stage (July 3).

Two plots within each of the corn and soybean areas were not planted and were fallowed all summer. These four fallow plot areas were located on those tile plots that showed greatest water flow variability (1977-83). The purposes of these plots were to check the NO_3-N concentrations in the tile water in a fallow system and to utilize all 36 of the tiled plots, even though these four historically showed the highest flow variability.

Stand counts were taken at the V-5 stage and plots were not thinned. Chlorophyll content in the ear leaf was measured with a Minolta SPAD meter on July 31 (R-1). Stover and grain samples were taken at physiological maturity by hand harvesting 30' of row for stover yield and 60' of row for grain yield and moisture. Tile line flow rates were determined daily and were recorded when flow exceeded 10 ml/minute (0.01"/day). Samples were collected for NO_3-N analysis on an every-other-day basis. Soil samples for NO_3-N analysis were taken in 1-foot increments to a depth of 8 feet from all plots on November 7. Chemical analyses of plant, water, and soil were performed by the Research Analytical Laboratory, University of Minnesota.

[1/] Partial funding provided by Dow Chemical U.S.A. and Minnesota Agric. Exp. Stn.
[2/] Professor and Assistant Scientist, So. Exp. Stn., Waseca.

RESULTS AND DISCUSSION

Plant

Stover N concentration, yield, and N uptake at physiological maturity were increased over the control by all of the N treatments with no differences among the six N treatments (Table 1). Chlorophyll content of the ear leaf at R-1 stage was increased significantly above the control by all of the N treatments. The two preplant AA treatments showed slightly higher chlorophyll contents than did the two fall-applied AA treatments, however they were not statistically significant at the $\alpha=0.05$ level. Final plant population was excellent and was not affected by the treatments (Table 1).

Table 1. Influence of time of N application, N source and nitrification inhibitor on whole plant N, stover yield, N uptake, leaf chlorophyll, and final population of corn following soybeans.

N Application		Stover			Relative	Final
Time	Inhibitor	N	Yield	N uptake	Chlorophyll	Population
		%	T DM/A	lb/A	%	ppA x 10^3
Primary trts						
AA Fall (10/25)	No	0.51	2.499	25.5	95.0	29.91
AA Fall (10/25)	Yes	0.53	2.648	28.1	96.6	29.86
AA PP (5/11)	No	0.54	2.549	27.5	100.0	29.74
AA PP (5/11)	Yes	0.54	2.483	26.8	98.5	30.13
Additional trts						
Urea PP (5/11)	No	0.51	2.588	26.4	98.2	30.20
AA SD (6/16)	No	0.55	2.362	26.0	98.5	29.96
Check (No N)	- -	0.40	1.715	13.7	69.0	30.01
Statistical Analysis Latin square (Primary trts)						
P > *F*:		0.60	0.85	0.30	0.06	0.40
LSD (0.05):						
CV (%):		7.0	11.3	7.8	2.1	1.0
Statistical Analysis Completely randomized (7 trts)						
P > *F*:		<0.01	<0.01	<0.01	<0.01	0.48
LSD (0.05):		0.07	0.47	6.0	2.9	
CV (%):		8.9	13.2	16.4	2.1	1.1

Grain and silage yields were increased significantly over the control by all of the N treatments (Table 2). However, yields were not different among the six treatments. Grain moisture of the control treatment was significantly higher than all fall and preplant N treatments but was not significantly greater ($\alpha=0.05$) than the sidedress treatment. Grain N concentration was also increased above the control by all six N treatments. In addition, spring preplant-applied AA showed slightly higher grain N ($P > F = 0.10$) compared to the fall-applied AA. Nitrogen uptake in the grain and in the total aboveground portion of the plant was increased by all of the N treatments above the control, but no difference was found among the six N treatments.

The General Linear Model procedure in SAS® was used to "contrast" the four primary treatments and determine if significant differences existed. The significance levels in Table 3 show lower grain moisture at harvest when N-Serve was applied with the fall application. However, grain N concentration and relative chlorophyll content were lower for the fall treatments compared to the spring treatments when averaged across N-Serve. In summary, the plant data show very little difference among times of N application, between sources of N, or between N-Serve applications on corn production in 1995.

Water

Weather conditions during the 1995 growing season were very close to normal except for a wet fall. Greatest tile flow occurred in April and October with much less flow in May and August (Table 4). Drainage from the 16 corn plots averaged 4.70" with a 1.16" range among the four time/method treatments. Soybeans showed slightly less tile drainage compared to corn with an average of 3.84" from the 16 plots and a range of 2.18" among the four time/methods. Ideally, drainage should be uniform among the time/method treatments, however, normal soil and drainage variability exists in these plots and results in these unfortunate differences.

Table 2. Corn grain and silage production as influenced by time of application, N source, and nitrification inhibitor.

N application		Grain				Silage	Total N
Time	N-Serve	Yield	H_2O	N	N Uptake	Yield	uptake
		bu/A	%	%	lb/A	T DM/A	lb/A
Primary trts							
AA Fall (10/28)	No	157.8	26.1	1.19	88.4	6.232	113.6
AA Fall (10/28)	Yes	151.3	24.9	1.23	88.2	6.228	116.5
AA PP (4/25)	No	144.4	25.0	1.25	85.6	5.966	112.9
AA PP (4/25)	Yes	148.9	25.3	1.29	90.6	6.005	117.6
Additional trts							
Urea PP (5/3)	No	150.7	25.6	1.25	89.0	6.153	115.2
AA SD (6/15)	No	146.0	27.1	1.21	83.3	5.816	109.6
Check (No N)	- -	79.4	28.5	0.93	34.8	3.593	48.4
Statistical Analysis Latin square (Primary trts)							
P > *F*:		0.44	0.08	0.10	0.76	0.77	0.71
LSD (0.05):							
CV (%):		7.3	2.3	3.8	7.4	7.5	5.7
Statistical Analysis Completely randomized (7 trts)							
P > *F*:		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
LSD (0.05):		14.2	1.5	0.09	10.2	0.616	11.7
CV (%):		6.9	3.9	5.4	8.6	7.3	7.6

Table 3. Significance levels for differences among the four primary treatments as determined by contrast statistics.

Parameter	Contrast		
	Fall without N-Serve vs Fall with N-Serve	Fall vs Spring	Spring without N-Serve vs Spring with N-Serve
	---------- Probability > *F* ----------		
Stover N Concentration	0.38	0.35	0.78
Grain N Concentration	0.20	0.04	0.36
Grain Moisture	0.02	0.32	0.49
Grain Yield	0.44	0.20	0.59
Stover Yield	0.49	0.70	0.76
Silage Yield	0.99	0.32	0.91
Final Population	0.83	0.78	0.12
Stover N Uptake	0.82	0.70	0.82
Grain N Uptake	0.97	0.96	0.32
Silage N Uptake	0.54	0.95	0.36
Relative Chlorophyll	0.32	0.02	0.34

Annual flow-weighted NO_3-N concentrations in the drainage water for the corn plots were 1.6 mg/l higher for the fall-applied N treatment without N-Serve compared to the fall treatment with N-Serve and the spring preplant AA treatments. (Table 5). Monthly flow-weighted NO_3-N concentrations showed slight temporal variation for all treatments except the spring preplant AA + N-Serve treatment. The fall-applied AA without N-Serve treatment had the highest NO_3-N concentration in April, May, and June and then declined to levels similar to the other treatments. Nitrate-N concentrations for the fall AA + N-Serve and spring preplant AA without N-Serve treatments were lower in April and May, increased about 1.5 mg/l in June and August, and then declined to concentrations similar to the fall AA without N-Serve treatment. Although the differences in the NO_3-N concentrations were not large, these data show a clear trend toward increased concentrations of NO_3^- in tile drainage water with fall-applied AA (October 28) when a nitrification inhibitor was not used, compared to inhibitor use or spring applications.

In the soybean plots, where N had been applied either in the fall of 1993 or spring of 1994, NO_3-N concentrations were consistently higher, especially late in the season, compared to the corn plots and averaged 11.3 mg/l (Table 5). Highest flow-weighted NO_3-N concentrations were found with the fall without N-Serve and spring preplant AA + N-Serve treatments (both early and late in the season). Nitrate-N concentration under a 9-yr continuous fallow system (no fertilizer N applied) was approximately 2 to 2.5 times greater than for the fertilized corn and soybean plots.

Table 4. Tile water discharge from the corn, soybean, and fallow plots in 1995.

N application		Month						Year
Time	Inhibitor	April	May	June	August	October	November	Total
		acre-inches						
		Corn						
Fall (10/28)	No	2.14	0.56	0.06	0.75	1.36	0.40	5.31
Fall (10/28)	Yes	2.00	0.58	0.09	0.55	1.45	0.47	5.16
Spring (4/25)	No	1.80	0.40	0.08	0.46	1.06	0.36	4.15
Spring (4/25)	Yes	1.77	0.44	0.07	0.28	1.18	0.44	4.18
		Soybean						
Fall (10/25/93)	No	1.18	0.46	0.07	0.76	0.68	0.31	3.48
Fall (10/25/93)	Yes	1.87	0.73	0.09	0.81	0.86	0.52	4.90
Spring (5/11/94)	No	1.42	0.82	0.14	0.75	0.72	0.40	4.28
Spring (5/11/94)	Yes	1.12	0.17	0.00	0.74	0.49	0.20	2.72
		Fallow						
NONE		1.12	0.36	0.08	0.90	0.70	0.32	3.50

Table 5. Flow-weighted NO_3-N concentrations for each month from the corn, soybean, and fallow plots in 1995.

N application		Month						Year
Time	Inhibitor	April	May	June	August	October	November	Average
		NO_3-N (mg/l)						
		Corn						
Fall (10/28)	No	11.4	9.4	10.9	9.3	7.0	7.1	9.6
Fall (10/28)	Yes	8.6	8.5	9.9	9.6	7.0	5.7	8.1
Spring (4/25)	No	8.0	7.8	9.0	10.4	7.1	6.8	7.9
Spring (4/25)	Yes	8.3	7.0	7.3	7.7	7.4	8.3	7.9
		Soybean						
Fall (10/25/93)	No	12.3	9.1	8.6	12.4	13.5	12.6	12.4
Fall (10/25/93)	Yes	8.3	8.2	8.0	9.9	10.2	9.6	9.2
Spring (5/11/94)	No	10.3	9.2	9.1	12.0	11.6	11.3	10.8
Spring (5/11/94)	Yes	12.6	7.8	—	12.7	14.6	14.1	12.9
		Fallow						
NONE		23.8	15.9	17.2	22.3	21.9	17.9	21.7

Nitrate-N losses in the drainage water for 1995 were similar for corn and soybean when averaged across N treatments (Table 6). Greatest loss under corn occurred with the fall AA without N-Serve treatment while the lowest loss occurred with the spring preplant AA + N-Serve treatment. Nitrate-N losses under soybean, although not greatly different among treatments, tended to be slightly lower with these two treatments. Nitrate-N losses in the fallow system, when mineralization of the soil organic matter was the NO_3 source, was 90% higher than from the fertilized corn-soybean rotation. This emphasizes the importance of growing a crop to absorb N released from these high organic matter soils.

Nitrate-N losses to the tile drainage water were normalized to tile water flow to minimize the influence of water flow volume among the N treatments on the interpretation of the data (Table 7). Normalized values for corn were highest for both the fall and spring AA treatments that did not include N-Serve. Somewhat lower values were found with the N-Serve treatments with no difference between spring and fall application times. In the year following corn and its associated treatments, normalized losses ranked in the order: fall with N-Serve < spring without N-Serve = fall without N-Serve < spring with N-Serve. Apparently, sufficient N was not utilized by the corn and remained in the soil profile following the spring preplant AA + N-Serve treatment, thus, higher NO_3 losses in the succeeding year. Normalized NO_3-N losses for the corn-soybean system were highest for the spring + N-Serve application, intermediate for the fall and spring applications without N-Serve, and lowest for the fall application + N-Serve. Additional years with adequate drainage losses are necessary to determine if these findings are consistent over time.

Table 6. Nitrate-N loss for each month from the corn, soybean, and fallow plots in 1995.

N application		Month						Year
Time	Inhibitor	April	May	June	August	October	November	Total
		NO_3-N lb/A						
		Corn						
Fall (10/28)	No	4.8	1.2	0.1	1.5	1.9	0.5	10.3
Fall (10/28)	Yes	3.7	1.1	0.2	1.0	2.0	0.6	8.6
Spring (4/25)	No	3.4	0.8	0.2	1.2	2.0	0.6	8.3
Spring (4/25)	Yes	3.1	0.7	0.1	0.4	2.0	0.7	7.1
		Soybean						
Fall (10/25/93)	No	2.8	0.8	0.1	1.9	1.8	0.7	8.2
Fall (10/25/93)	Yes	3.3	1.1	0.1	1.7	1.8	1.0	9.1
Spring (5/11/94)	No	3.0	1.5	0.3	1.9	1.7	0.8	9.2
Spring (5/11/94)	Yes	3.1	0.5	0.0	2.1	1.6	0.6	7.9
		Fallow						
NONE		5.2	1.5	0.3	5.3	3.1	1.3	16.6

Table 7. "Flow-normalized" NO_3-N losses to tile drainage in a corn-soybean sequence in 1995.

	Time/Method of N Application			
Crop System[1]	Fall No Inhibitor	Fall Inhibitor	Spring No Inhibitor	Spring Inhibitor
	NO_3-N lost (lb/A/inch of drainage)			
Corn	1.94	1.67	2.00	1.70
Soybean[2]	2.36	1.86	2.15	2.90
Corn Soybean System	2.10	1.76	2.08	2.17

[1] Continuous fallow (9 years without fertilizer N) = 4.74
[2] N applied for the 1994 corn crop at 120 lb N/A.

Soil

Nitrate-N remaining in the 0-8' soil profile in November was about 2 times greater in the fallow plots compared to the plots that received the six N treatments (Table 8). Although NO_3-N remaining in the 8-ft soil profile after harvest for all of the N treatments was slightly above the check, very little difference existed among the six N treatments. Highest NO_3-N levels were found in the surface foot, while levels throughout the rest of the profile were very low.

Table 8. Residual soil nitrate-N in November 1995 from all fallow and corn plots as influenced by N treatment.

		N Treatment for Corn						
Profile depth	Fallow NO_3-N	Fall AA	Fall AA+NI	PP AA	PP AA+NI	Urea	SD AA	Check (No N)
feet	lb/A	lb/A						
0 - 1	28	16	17	14	22	18	17	18
1 - 2	13	7	8	7	10	7	8	3
2 - 3	11	6	7	6	8	5	10	2
3 - 4	12	3	6	6	8	4	7	2
4 - 5	14	8	7	6	6	6	6	3
5 - 6	14	7	7	6	6	9	5	3
6 - 7	15	8	7	5	7	6	6	5
7 - 8	15	8	7	6	9	7	6	6
Total in								
0 - 5' profile	78	39	45	39	52	40	48	29
0 - 8' profile	122	62	66	56	74	62	65	43

NUTRIENT LOSSES TO TILE LINES AS INFLUENCED BY SOURCE OF N[1/]

Waseca, 1995

G.W. Randall, T.K. Iragavarapu, and M.A. Schmitt[2/]

ABSTRACT: A study was started in 1994 to compare the effects of liquid dairy manure and urea applied at similar N rates on N movement in the soil and into tile lines and corn production. Corn yields and N uptake were statistically similar between the urea and dairy manure treatments. Nitrogen source had no effect on tile flow, NO_3-N concentration and loss in tile water, and NO_3-N content in the 0-5' profile in the fall. Ortho-phosphate was detected in only one of the 71 samples analyzed while total P was detected in only 9% of the 55 samples. Total P concentrations averaged < .10 mg/L and were not different between manure and urea. Ammonium-N was detected in 54% of the 48 samples and the NH_4-N concentration did not differ between the two N sources. Nitrate-N concentrations in porous suction cup samplers tended to be greater in the urea fertilized plots compared to the dairy manure applied plots at the 4 ft depth whereas at the 6 and 8 ft depths, NO_3-N concentrations were slightly greater in the dairy manure treatment compared to urea. More NO_3-N detects were found in the 4 ft. depth piezometers than in the 6 or 8 ft depths. Nitrate-N concentrations in water taken from the piezometers showed much greater variability than in the tile lines or porous cups.

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. Time of application and crop grown have also been shown to influence NO_3-N loss to tile lines. However, little information is available on N losses to tile lines when different sources of N are applied. The purpose of this study was to determine the effect of liquid dairy manure compared to urea on N movement in the soil and into tile lines and on corn production.

EXPERIMENTAL PROCEDURES

A study was initiated in 1975 on a Webster clay loam at Waseca to monitor the movement of N into tile lines installed in plots measuring 45' x 50'. Each plot is enclosed with plastic sheeting to a 6-ft depth. Corn was grown from 1975-1981 with varying rates of fertilizer N. In the fall of 1981, the plot area was converted to a new study where two tillage treatments (fall moldboard plowing and no-tillage) were replicated four times. Corn was grown from 1982 through 1992 and was fertilized at an annual application rate of 180 lb N/A. In the fall of 1992, all 8 plots were moldboard plowed and corn was grown in the residual year (1993).

In the fall of 1993, the same 8 plots used in the previous study were converted to dairy manure and urea treatments. Liquid dairy manure was broadcast-applied on November 7, 1994 at a rate of 10000 gal per acre and the plots were moldboard plowed immediately. On April 28, 1995, urea was broadcast-applied by hand to 4 plots at a rate of 185 lb N/A before field cultivation. The nitrogen rate was selected to match the amount of N "available" from the manure based on calculations from the manure analysis (Table 1). "Available" N was calculated based on the assumption that 90% of the ammonium-N (128 lb) and 25% of the organic N (115 x 0.25 = 29 lb) plus 15% of the total N of the manure that was applied in the fall of 1993 (203 x 0.15 = 30 lb) was available for a total of 185 lb N/A.

Corn (P3578) was planted on April 28 at a population of 32000 plants/A. Starter fertilizer was not used because of the high soil tests. Force was applied at 1 lb ai/A to control rootworms. Weeds were controlled with a preemergence application of Harness (2.75 lb ai/A) and Bladex (3 lb ai/A) applied May 11. Weed and insect control were excellent.

In August 1994, porous suction cup (PSC) samplers and piezometers were installed at 4, 6, and 8 ft depths in the 8 plots that received either urea or dairy manure. The PSC and piezometers were installed 30-in. apart between the corn rows at a distance of 7 ft from the tile line.

Silage yields were taken at physiological maturity. Grain yields were taken by combine from 2-45' rows. When tile lines were flowing, flow rates were measured daily and samples taken on a daily basis for the first week and then on a M-W-F basis thereafter for NO_3 analysis. Ammonium-N, total-P, and ortho-P were determined on samples taken on selected days when all tile lines were running in April, May, October, and November. Tile water samples were collected for fecal coliform bacteria analysis in May and June. Water samples collected on a twice-monthly basis from PSC samplers and piezometers were also analyzed for NO_3. Chloride concentrations were determined in tile water samples

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[1/] Funding provided by the Minnesota Legislature from the MN Future Research Fund as recommended by LCMR.
[2/] Professor and Post-doctoral Research Associate, Southern Experiment Station, Waseca and Assoc. Professor, Dept. of Soil, Water, and Climate, St.Paul, respectively.

collected on two sampling dates in the fall. All analyses were done by the Research Analytical Lab.

Soil NO_3-N in the 0-5' profile was determined from two cores/plot taken in 1-foot increments on November 7, 1995.

RESULTS

Corn grain yield, grain N removal and silage N uptake tended to be greater in the plots that received urea compared to those plots that received liquid dairy manure (Table 2). However, these differences were not statistically significant at the 0.05 P level. The 14 bu/A yield "advantage" for the urea treatment, although not significant at the 95% level, suggests that sufficient N was not provided by the dairy manure treatment. We do not believe this to be the only reason for this yield difference, however. During the season, visual observations indicated a slight color (dark green) and growth/height advantage for the dairy manure treatment. At physiological maturity slightly more stover (data not shown), although statistically insignificant, was harvested from the dairy plots. In a few other studies, we also noted more lush mid-season growth with certain high N treatments but at maturity grain yield was less than from other lower rate N treatments that did not exhibit the same lush growth. Perhaps the very high August temperatures caused a stress that may have affected grain production in these plants with more lush biomass. It should be mentioned, however, that late-season unavailability of N from the manure treatments should not be discounted completely. Although differences were not statistically significant at the 95% level, N concentration in the stover (data not shown) and grain from the manured plots was somewhat less than from the urea plots. Perhaps the assumption that 60% of the total N in the manure applied in Nov. 1994 plus 15% of the total N applied in Nov. 1993 was available to the 1995 crop is an overestimate of N availability from dairy manure. Residual soil NO_3-N was also slightly less with the manured plots. These data indicate that further comparisons between urea and the availability of N from liquid dairy manure need to be made.

Table 1. Nutrient analyses and application rate of liquid dairy manure applied in November, 1994.

Dry matter	Total N	NH_4-N	Organic N	Total P_2O_5	Total K_2O
%			lb/1000 gal		
7.0	25.7	14.2	11.5	13.9	30.8
			lb/acre		
	257	142	115	139	308

Table 2. Influence of nitrogen source on corn production and N utilization at Waseca in 1995.

Nitrogen source	Final Population	Chlorophyll reading	Silage Yield	Silage N uptake	Grain Yield	Grain N	Grain N removal	Grain H_2O
	x10^3	SPAD units	T DM/A	lb N/A	bu/A	%	lb N/A	%
Urea	28.6	57.9	9.37	177.7	156.6	1.46	108.5	23.4
Dairy Manure	28.8	57.4	9.18	157.8	142.6	1.40	94.7	22.8
Check[1/]	29.4	37.3	5.20	59.0	64.3	1.07	32.7	24.1
LSD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	3.8	0.8	5.5	7.7	5.0	3.0	7.7	2.9

[1/] The check plots (0 lb N/A) are not randomized within the replications and do not have the same plot history as the 8 main plots. Therefore, data from these plots are not included in the statistical analysis.

Precipitation exceeded normal by 0.8" in April and by 2.5" October - both months with relatively low ET. As a result, highest tile flow occurred in April followed by October (Table 3). Tile flow, flow-weighted NO_3-N concentration and nitrate-N losses did not differ between the two nitrogen sources.

Table 3. Influence of nitrogen source on tile flow, flow-weighted NO_3-N concentration and NO_3-N loss in 1995.

Month	Tile Flow	NO_3-N Concentration	NO_3-N Loss
	acre-in.	mg/L	lb/A
		Urea	
April	2.46	8.1	4.4
May	0.92	8.5	1.8
June	0.26	8.2	0.5
July	-	-	-
August	0.63	8.7	1.2
September	-	-	-
October	1.90	7.7	3.4
Nov	1.21	8.1	2.2
Total	7.38	Avg = 8.1	13.5
		Dairy manure	
April	2.65	8.8	5.3
May	1.03	9.3	2.2
June	0.32	9.8	0.7
July	-	-	-
August	0.54	9.8	1.2
September	-	-	-
October	2.05	8.9	4.1
Nov	1.34	8.8	2.6
Total	7.93	Avg = 9.0	16.1

Residual NO_3-N in the 0-5 ft. soil profile at the end of the 1995 growing season was slightly greater in the plots that received urea compared to those that received liquid dairy manure (Table 4). This was especially true in the soil layer between 1 and 3 feet.

Table 4. Influence of nitrogen source on residual NO_3-N in the soil profile in November, 1995.

Profile Depth	Nitrogen Source: Urea	Nitrogen Source: Dairy manure
ft	NO_3-N (lb/A)	
0-1	13.3 (2.3)†	12.1 (2.4)
1-2	15.2 (3.5)	10.7 (0.5)
2-3	23.3 (8.8)	10.9 (1.4)
3-4	12.7 (2.9)	11.5 (7.2)
4-5	9.9 (0.6)	10.7 (4.4)
Total (0-5')	74.4	55.9

† Numbers in parentheses represent the standard error around the mean

Ortho-P was detected in only one of the 35 water samples from the plots that received dairy manure and in none of the 36 from plots that received urea (Table 5) indicating that manure application did not contribute to inorganic phosphorus losses in tile lines. Eleven percent of the water samples from the manured plots and 7% from the urea fertilized plots had detectable amounts of total phosphorus, averaging only 0.04 mg P/L. Coliform bacteria (E.Coli) was not detected in any of the 14 samples analyzed. Ammonium-N was detected in 54% of the 24 samples analyzed from each of the dairy manure and urea treatments. Ammonium-N concentrations were identical between the dairy manure and urea treatments.

Chloride content was determined in the fall in eight water samples from each of the dairy manure and urea treatments to measure the impact of manure, a source of chlorides, on the chloride levels in the tile water (Table 6). Chloride concentrations were slightly greater in the dairy manure treatment compared to the urea treatment at both sampling dates.

Table 5. Ortho-phosphorus, total phosphorus, and coliform bacteria detects in tile water samples in 1995.

	Ortho-P		Total P		*E.Coli* Bacteria		NH_4-N	
	Manure	Urea	Manure	Urea	Manure	Urea	Manure	Urea
Number of samples analyzed	35	36	27	28	9	5	24	24
Number of detects[1/]	1	0	3	2	0	0	13	13
% of samples with detects	3	0	11	7	0	0	54	54
Concentration range of detects (mg/L)	0.06	-	0.03-0.04	0.03-0.05	-	-	0.02-0.06	0.02-0.06
Average concentration among detects (mg/L)	0.06	0	0.04	0.04	-	-	0.03	0.03

[1/] Detection level is 0.04 mg/L for ortho-P, 0.02 mg/L for total P, and 0.02 mg/L for NH_3-N.

Table 6. Chloride concentrations in tile water samples from dairy manure and urea treatments

Date	Manure	Urea
	mg/L	
10/30	15.1 (1.3)	12.8 (1.2)
11/06	18.5 (1.4)	14.6 (2.6)

Numbers in parentheses indicate the standard error around the mean.

Nitrate-N concentrations in the PSC samplers at the 4 ft depth were consistently greater at all seven sampling dates in the plots that received urea compared to those that received dairy manure (Fig 1). The reverse was true at the 6 and 8 ft. depths. Nitrate-N concentrations at the 4 ft depth increased from August (23) to October (10) with both treatments, but was most dramatic with urea. This increase was also seen at the 6-ft depth in the urea plots. Concentrations of NO_3-N at the 8-foot depth were low (< 4 mg/L) for both treatments. Water samples were collected four times from the piezometers in 1995. Nitrate-N detects in the piezometer water samples are given in Table 7. Across the four sampling dates between August 8 and October 25, water was found in only 14 of a possible 32 piezometers at the 4 ft. depth whereas at the 6 and 8 ft depths 28 and 27, respectively, of the piezometers had water. However, all the samples from the 4 ft depth piezometers had detectable amounts of nitrates. Average nitrate-N concentrations in the 4 ft depth piezometers were less than those in the 4 ft depth PSC samplers at all sampling dates except the last sampling date (10-25). In general, more detects were found in the urea treated plots compared to the dairy manure applied plots. The variation around the mean nitrate-N concentration was greater for the piezometer samples than those from the tile lines or PSC samplers.

Table 7. Nitrate-N detects in the piezometer water samples in 1995.

	Depth	8-8		8-23		10-9		10-25	
		Manure	Urea	Manure	Urea	Manure	Urea	Manure	Urea
# of samples analyzed	4	2	2	0	3	0	1	3	3
	6	4	4	3	4	3	2	4	4
	8	4	4	4	4	3	2	3	3
# of detects[1/]	4	2	2	-	3	-	1	3	3
	6	1	2	1	2	1	2	4	3
	8	1	1	1	0	1	0	2	0
% of samples with detects	4	100	100	-	100	-	100	100	100
	6	25	50	33	50	33	100	100	75
	8	25	25	25	0	33	0	67	-
Conc. range of detects (mg/L)	4	1.4-1.7	4.0-4.5	-	0.5-12.9	-	7.1	6.8-23.2	12.1-31.3
	6	1.3	4.7-15.9	3.3	2.6-3.3	0.7	0.5-27.5	4-13.4	4.5-8.2
	8	6.1	0.6	5.3	-	9.1	-	6.3-6.4	-
Avg. conc. among detects (mg/L)	4	4.7	4.3	-	5.4	-	7.1	14.0	19.8
	6	1.3	10.3	3.3	3.0	0.7	14.0	7.9	6.5
	8	6.1	0.6	5.3	-	9.1	-	6.4	-

[1/] detection limit is 0.5 mg/L.

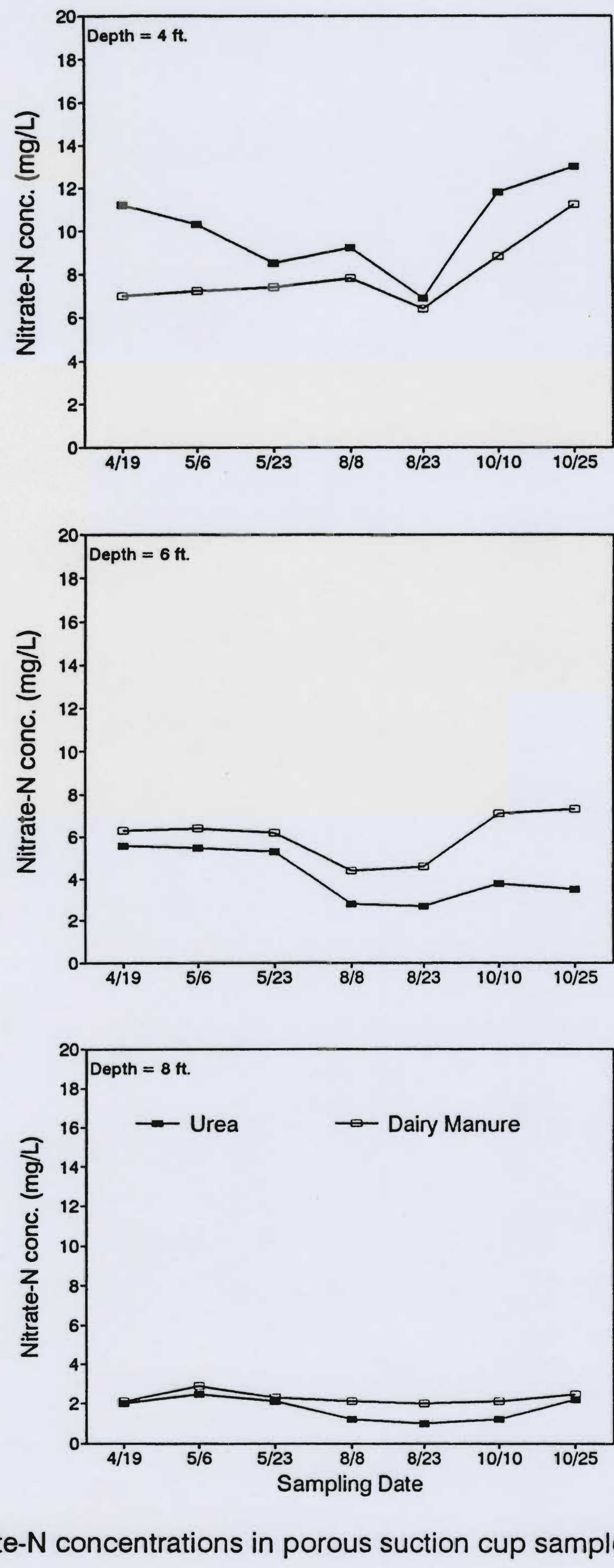

Fig 1. Nitrate-N concentrations in porous suction cup samplers in 1995

EVALUATING SOIL N TEST METHODS ON FIELDS WITH A MANURE HISTORY[1/]

G. W. Randall, M. A. Schmitt, and J. A. Vetsch[2/]

ABSTRACT: Nitrogen can become available to the plant from previous applications of manure. The purpose of this study was to evaluate various soil N test methods to see if Minnesota's new soil N test needs to be modified or an additional test needs to be developed to more accurately predict soil N availability to crops in animal-based systems. Corn yields were optimized with N rates of 30 and 60 lb N/A at the two sites and were related to the residual soil NO_3-N (RSN) indicated by the preplant soil N test. Using the test reduced N recommendations at both sites to more economical and environmentally-sound rates of N. Fertilizer N was not under-recommended at either site by the test. Although further soil N test research appears to be necessary for more accurate prediction of available soil N in these animal-based systems, use of the present N test will provide greater profit while reducing the potential for leaching of excess N to groundwater.

Manure is often applied to the same fields each year by producers because of the proximity of the field to the livestock facility or because of an inadequate land base to facilitate less frequent applications. As a result, manure-N may accumulate over time and can then become available through mineralization to succeeding crops. The amount of N becoming available in any particular field is unknown. Thus, fertilizer N recommendations usually do not take into account these previous applications.

The purpose of this study is to evaluate various soil N tests in animal-based systems to see if our present soil N test needs to be modified or a new test developed to more accurately predict soil N availability to crops. To do this we must obtain experimental sites with a long-term manure history, apply a series of fertilizer N rates, determine the yield response to the fertilizer, and then calibrate this response or lack of response to soil N values obtained by various soil tests.

EXPERIMENTAL PROCEDURES

Two sites were selected for this study in 1995 (Table 1). One was on a fine-textured glacial till soil in south-central Minnesota and the other was on medium-textured loess soil in southeastern Minnesota. Both sites had a history of dairy manure. The previous cropping history is also given in Table 1.

Table 1. Cooperator, field history, soil type, and parent material at each of the 1995 sites.

	Site (County)	
	Waseca	Olmsted
Cooperator:	SES, U of M	Lawler Farm
History:		
Crop	Corn: 1992-94, Alfalfa: 1989-91	Continuous corn
Manure	10000 gal/A of liquid dairy manure in Oct. 1991 and Oct. 1992	8000 gal/A of liquid dairy manure in April of 1994.
Soil type:	Webster cl	Port Byron sil
Parent Material:	Glacial till	Loess

Nitrogen as urea was broadcast-applied and incorporated at rates of 30, 60, 90, 120, 150 and 180 lb N/A just before planting and was compared to an unfertilized check plot at each site. At the glacial till site, three split application treatments were compared to the preplant treatments. Urea was knifed-in 4 inches deep mid-way between the rows when corn was 10 to 12 inches tall at rates of 30, 60 and 90 lb/A on plots that had received a 30-lb preplant N rate. Four replications were used at all sites. Pioneer 3769 and 3861 were planted and thinned to a uniform population at the Waseca and Olmsted sites, respectively. Weeds were controlled very well with a combination of herbicides and cultivation.

Soil samples were taken from the control plots in 1-ft increments to a depth of 3-ft at three times during the season (preplant, emergence, and 10 to 12 inch tall corn). After harvest, samples were taken to a 4-ft depth from the 0, 90 and 180-lb treatments. Samples were analyzed for nitrate-N (NO_3-N) and ammonium-N (NH_4-N).

Grain yields were taken by combine harvesting 89 and 79 ft of row from each plot at the Waseca and Olmsted Co. sites, respectively. Silage yields were determined from 15 ft of row in each plot at all sites.

1/ Partial funding provided by the Minnesota Legislature from the MN Future Resources Fund as recommended by LCMR. Appreciation is extended to Bruce Montgomery and others at the Minn. Dept. of Agriculture for their role in facilitating this research project.

2/ Professor, Southern Experiment Station, Waseca; Assoc. Professor, Dept. of Soil, Water, and Climate, St. Paul; and Assistant Scientist, Southern Experiment Station, Waseca.

RESULTS AND DISCUSSION

Corn yields were quite good at the Waseca site but less than expected and more variable in Olmsted Co. (Table 2). The lower yields in Olmsted Co. were probably due to very strong straight-line winds in early August, which caused severe lodging, and to the hybrid used. Statistical analyses showed that grain yields were optimized with the 30-lb preplant N rate in Waseca Co. and the 60-lb rate in Olmsted Co. Silage yields also were optimized at the 30-lb rate in Waseca, but 90 lb N/A was required in Olmsted Co. A relative chlorophyll content of ≥ 95%, calculated as a percent of the highest chlorophyll treatment, is usually considered optimum. This occurred at the 60 and 90-lb N rates at the Waseca and Olmsted Co. sites, respectively. Contrast statistics showed slightly lower grain and silage yields when the 60, 90 and 120-lb N rates were split applied at Waseca compared to the single, preplant application.

Table 2. Corn grain yield, silage yield, and relative chlorophyll content (R1 stage) as influenced by N applied to fields with a manure history in 1995.

Nitrogen Treatment		Waseca Co.			Olmsted Co.		
Preplant	Sidedress	Grain Yield	Silage Yield	Chlorophyll[1/]	Grain Yield	Silage Yield	Chlorophyll[1/]
--- lb N/A ---		- bu/A -	- T DM/A -	- % -	- bu/A -	- T DM/A -	- % -
0	0	134	6.06	92.2	109	5.11	85.5
30	0	160	6.88	94.7	126	5.31	89.8
60	0	168	7.25	95.4	138	5.54	93.4
90	0	166	7.24	98.5	129	5.90	97.0
120	0	162	6.87	100.0	144	6.08	97.3
150	0	162	7.00	99.9	149	6.58	100.0
180	0	155	6.52	98.7	142	6.60	97.7
30	30	157	6.72	96.4	-	-	-
30	60	156	6.51	96.4	-	-	-
30	90	163	6.85	99.5	-	-	-
Pr. > *F*:		< 0.01	< 0.01	< 0.01	0.01	0.01	< 0.01
LSD (0.05):		13	0.48	2.5	20	0.88	3.3
CV (%):		5.8	4.9	1.8	10.1	10.1	2.3

[1/] Relative to the treatment with the highest chlorophyll content

Soil NO_3-N analysis (Table 3) indicated carryover of RSN throughout the 0 to 3-ft profile at Waseca. Residual N was slightly less in Olmsted and was confined primarily to the top 2 ft. Residual N values form samples taken at emergence and when the corn was about 10 inches tall were similar to the preplant N concentrations at Waseca. At Olmsted, mineralization of N (most likely from the previous manure applications) resulted in much higher NO_3-N concentrations when samples were taken in 10-inch tall corn after soil temperatures had warmed compared to either the preplant or emergence sampling.

Table 3. Soil NO_3-N as influenced by time and depth of sampling in fields with a manure history in 1995.

Sampling		Sites	
Time	Depth	Waseca	Olmsted
	- ft -	-------- ppm --------	
Preplant[1/]	0-1	10.7	7.5
"	1-2	11.3	9.2
"	2-3	10.8	4.9
"	**0-2**	**11.0**	**8.4**
V1 (emergence)	0-1	10.3	9.0
"	1-2	10.7	8.1
"	2-3	11.4	4.4
"	**0-2**	**10.5**	**8.6**
V4-5 (10 inch corn)	0-1	10.8	15.8
"	1-2	10.6	11.5
"	2-3	11.8	6.7
"	**0-2**	**10.7**	**13.6**

[1/] Soil NO_3-N in the 0 to 4-ft profile totaled 172 and 101 lb/A for the Waseca and Olmsted sites, respectively.

Soil N credits determined by Minnesota's preplant soil N test indicate a credit of 65 and 35 lb N/A for the Waseca and Olmsted Co. sites, respectively. Subtracting this credit from our present recommendation of 150 lb N/A for a yield goal of 160 bu/A at these sites provides N recommendations of 85 and 115 lb N/A, respectively. These recommendations are closer to the optimum amounts of N needed as shown by the yields in Table 2, but they are not perfect. At both sites, this reduced rate of N would have lowered fertilizer costs and potential ground water contamination without impacting yield. In fact, about 55 lb N/A in excess of what the plant really needed was applied at both sites even though the test was used. These data suggest that the present U of M preplant soil N test is helpful for improved N management, but it may need some refinement for fields with a manure history if greater profits are to be realized along with less environmental risk.

Residual soil NO_3-N (RSN) in the 0 to 4-ft profile after harvest was significantly different between the two sites (Table 4). At the Waseca site, higher than normal levels of RSN existed throughout the profile in all three treatments, even the control. Apparently mineralization of N from the previous manure applications coupled with corn receiving some fertilizer N in the three years following alfalfa led to the high RSN levels and explains why only 30 lb N/A was needed to optimize yield. Residual soil NO_3-N levels were almost 100 lb N/A higher when excess N was applied with the 180-lb rate compared to the 90-lb rate. In addition, high levels of RSN were found at all depths in the profile when 180 lb N/A was applied.

In Olmsted Co., where the total rate of manure previously applied was lower and alfalfa had not been grown, RSN was considerably lower; especially in the 0 and 90-lb N plots (Table 4). Similar to Waseca, when comparing the 180-lb to the 90-lb N rate, the extra 90-lb resulted in 86 lb more RSN/A and some leaching movement below 3 ft was evident. These data clearly show how high levels of RSN can accumulate in soils when N from previous manure additions becomes available and fertilizer N in excess of crop needs is applied. As a result, the potential for leaching loss of NO_3 is greatly increased.

Table 4. Residual soil NO_3-N (RSN) after harvest by site in 1995.

		Site	
N rate	Depth	Waseca	Olmsted
lb/A	ft	------- lb NO_3-N/A -------	
0	0-1	31	14
"	1-2	27	7
"	2-3	20	7
"	3-4	21	19
"	**0-4**	**99**	**47**
90	0-1	36	21
"	1-2	30	12
"	2-3	21	15
"	3-4	28	14
"	**0-4**	**115**	**62**
180	0-1	49	45
"	1-2	53	48
"	2-3	49	32
"	3-4	62	23
"	**0-4**	**213**	**148**

SUMMARY

- Even though corn yields were quite good, the yield response of continuous corn to fertilizer N was limited in these fields with a manure history.
- The present soil N test provided a N recommendation much closer to the optimum economic rate compared to not using the test. Thus, the test paid economic dividends even though it was not perfect.
- The potential for NO_3^- leaching to the groundwater is greatly increased by high levels of RSN accumulating in soils when fertilizer N is added without taking into account the release of N from previously applied manure.
- Further research appears necessary to more accurately predict the N availability in fields with a long-term manure history.

CORN YIELD RESPONSE TO STARTER PHOSPHORUS ON CLAY LOAM SOILS IN THE MINNESOTA RIVER BASIN

G. W. Randall, S. D. Evans, G. A. Nelson, J. A. Vetsch, and U. Bolliger[1]

ABSTRACT: Knowing the probability of a corn yield response to starter fertilizer as a function of soil test P would help improve fertilizer P management in the Minnesota River Basin. A study was conducted in 1995 to determine the yield response of corn following soybeans to starter fertilizer (10 gal 10-34-0/A) as affected by soil test P and K. Applications of various rates of fertilizer P and K from 1973-1992 had created soil test P ranging from 3 to 35 ppm (Bray P_1) at Waseca and 4 to 28 ppm (Olsen) at Morris. Although early corn growth usually improved with the use of starter fertilizer, regardless of soil test P level, corn grain yield was not increased by the starter fertilizer when soil test P was >10ppm. Grain moisture at harvest was decreased by starter fertilizer at soil tests <10 ppm at Morris but not at Waseca.

Phosphorus from agricultural sources (fertilizer, manure, wastes, etc.) has been identified as a major source of P in surface waters of the Minnesota River Basin. With this increasing concern and with the long-term goal of improving profitability, farmers will be called upon to manage P in a manner that is both environmentally and economically sound. The purpose of this research is to determine the relationship between soil test P level and corn grain yield response to starter (band-placed) P. This information should lead to improved P management practices for corn and soybean farmers.

METHODS

This study was started in the fall of 1973 on a Webster clay loam at Waseca. Fertilizer P rates of 0, 50, and 100 lb P_2O_5/A were broadcast-applied annually each fall from 1973 through 1984. Beginning in 1985 fertilizer P and K was discontinued on some of the plots while annual applications were continued on others. Due to the applications of various rates of P over the 20-year period at both Waseca and Morris, soil test P varied markedly among the plots. Soil test P in October, 1994 ranged from 3 to 35 ppm (Bray P_1) at Waseca and 4 to 28 ppm (Olsen P) at Morris.

Corn was planted in 1995 following a previous crop of soybeans at both locations. Nitrogen was applied prior to planting as anhydrous ammonia at a rate of 150 lb N/A at Waseca and 120 lb N/A at Morris. These rates were about 30 lb/A higher than recommended because we did not want the N in the starter fertilizer to affect yield. At Waseca, corn (Pioneer 3578) was no-till planted using row cleaners at a rate of 32000 plants/A on April 28. At Morris, the site was field cultivated 2X before planting due to very wet conditions. Corn (Pioneer 3861) was planted at a rate of 28000 plants/A on May 18. Starter fertilizer as 10 gal 10-34-0/A was applied to one-half of each plot. Plant population was thinned to a final stand of 30,500 plots/A at Waseca. Grain yields and moisture were obtained by combine harvesting two rows from each starter plot and two rows from each non-starter plot.

RESULTS AND DISCUSSION

Table 1. Corn grain yield, grain moisture, and extended leaf plant heights (measured on July 3) as affected by starter fertilizer applied to soils of varying soil test P and K at Waseca in 1995.

	Fall '94 Soil Test		Grain Yield		Grain Moisture		Plant Leaf Heights	
Trt. No[1/]	P	K	No Starter	Starter[1/]	No Starter	Starter[1/]	No Starter	Starter[1/]
	--- ppm --		--- bu/A ---		--- % ---		--- inch ---	
1	5	103	140a	142a	21.0	20.9	47.4a	52.9b
2	3	150	126a	153b	21.5	21.8	51.2a	58.6b
3	7	143	159a	161a	22.1	20.4	53.6a	57.8b
4	19	136	163a	160a	21.7	21.7	55.9a	59.1b
5	35	145	163a	166a	22.6	21.5	57.8a	60.4b
6	34	112	168a	156a	21.3	20.8	54.1a	57.6b
7	30	110	164a	160a	21.3	20.4	53.9a	57.0b
8	18	104	143a	153a	21.9	21.1	51.3a	54.6b
9	4	113	132a	154b	21.1	21.2	50.6a	55.4b
10	12	104	156a	150a	20.5	21.1	52.9a	55.1b

Statistical analysis of treatment effects for split-plot design	Grain Yield	Grain Moisture	Plant Leaf Heights
Treatment (P > F):	<0.01	0.60	<0.01
LSD (0.05):	12		2.9
Starter Fertilizer (P > F):	0.07	0.14	<0.01
Treatment*Starter (P > F):	0.02	0.68	<0.01
LSD (0.05):	16		3.1
C.V. (%):	5.5	4.8	1.6

[1/] Each 6-row plot was split into 3 rows with starter fertilizer (10 gal 10-34-0/A) and 3 rows without starter fertilizer.

[1] Professor, Southern Experiment Station; Professor and Asst. Scientist, West Central Experiment Station; Asst. Scientist and Plot Technician, Southern Experiment Station, respectively.

Grain yields were affected by starter fertilizer and the interaction between soil test P level and starter fertilizer was signficant at both Waseca (Table 1) and Morris (Table 2). At Waseca, yield responses of >20 bu/A to starter P were obtained when the soil test P (Bray P_1) was 3 and 4 ppm and potassium (K) was not limiting. The lower yields with no response to starter P in treatment 1 (soil test P = 5 ppm) suggests that soil test K may have been limiting. Yield responses to starter fertilizer P were not obtained when soil test P ranged between 7 and 35 ppm and soil test K was adequate. The lack of yield response in treatment 3 (soil test P = 7 ppm) was surprising. Lower yields overall in treatments 8 and 10 with a soil test K of 104 ppm again suggests inadequate K. However, when K was adequate and P was inadequate (treatment 2, soil test P = 3 ppm), the addition of 10 gallons/A of 10-34-0 was still not sufficient to optimize corn yields. Grain moisture at harvest was not influenced by starter fertilizer regardless of soil test P.

At Morris, where soil test K was very high in all treatments, yield responses of >20 bu/A were obtained with starter fertilizer when soil test P (Olsen P) was ≤8 ppm (Table 2). Additionally, grain moisture at harvest was 1.3 to 1.7 points lower when starter fertilizer was used on these low P testing plots. Corn grain yield and grain moisture at harvest responses to starter fertilizer were not obtained when soil test P was >10 ppm.

The yield data collected from these two sites, where no tillage and minimum tillage was used, suggest that yields can be optimized with starter fertilizer (10-34-0) as long as soil test P does not drop to very low levels and soil test K is maintained at a high level. Inadequate soil test K or very low soil P levels limit the potential for starter fertilizer to optimize yields.

Table 2. Corn grain yield, grain moisture, and extended leaf plant heights (measured in June) as affected by starter fertilizer applied to soils of varying soil test P level at Morris in 1995.

Trt. No[1/]	Soil Test	Grain Yield		Grain Moisture		Plant Leaf Heights	
	Olsen P	No Starter	Starter[1/]	No Starter	Starter[1/]	No Starter	Starter[1/]
	- ppm -	--- bu/A ---		--- % ---		--- inch ---	
1	6	104a	130b	20.2a	18.5b	24.8a	30.3b
2	4	108a	132b	20.8a	19.3b	25.5a	30.5b
3	8	112a	143b	20.1a	18.8b	25.8a	29.3b
4	12	132a	135a	18.8a	19.1a	27.3a	29.9b
5	28	142a	143a	19.5a	19.0a	28.3a	31.0b
6	17	137a	131a	17.4a	18.0a	27.1a	28.4a
7	12	136a	134a	18.9a	18.3a	27.3a	29.4b
8	16	143a	136a	17.7a	18.1a	28.5a	30.1a
Statistical analysis of treatment effects for split-plot design							
Treatment (P > F):		0.04		<0.01		0.14	
LSD (0.05):		16		1.1			
Starter Fertilizer (P > F):		<0.01		<0.01		<0.01	
Treatment*Starter (P > F):		<0.01		<0.01		0.03	
LSD (0.05):		19		1.3		2.2	
C.V. (%):		7.2		2.8		4.6	

1/ Each 8-row plot was split into 4 rows with starter fertilizer (10 gal 10-34-0/A) and 4 rows without starter fertilizer.

SUMMARY

- Corn yield responses to starter fertilizer (10-34-0) generally occurred when soil test P was <10 ppm and did not occur when soil test P was >10 ppm even though very little tillage was performed.
- Soil test K must be kept at a high level to optimize the performance of a 10-34-0 starter fertilizer.
- Because P loss to surface water and the resultant algal blooms are a function of sediment loss and soil test P, keeping the test in the 15 to 20 ppm range with application of starter fertilizer P or the incorporation of broadcast P demonstrates environmental stewardship of our natural resources.
- Soil sampling in grids of 200 to 300' along with variable rate fertilizer application technology will be most helpful in maintaining adequate but not excessive P levels throughout the field. However, for this to succeed, it is extremely important to concentrate fertilizer applications on the low and medium P testing soils (with pH <7.5) rather than building soil test P on high or very high soils with "crop removal" applications of P. Variable rate application of starter fertilizer may be an excellent way to accomplish this.

NO-TILL CORN PRODUCTION IN SOUTHERN MINNESOTA AS AFFECTED BY NITROGEN SOURCE, ROW CLEANERS, STARTER FERTILIZER, AND CROP ROTATION.[1]

J.A. Vetsch and G.W. Randall[2]

ABSTRACT: Previous research has shown decreased corn yields in long-term, continuous no-till corn. This research study was initiated in 1994 to evaluate the effects of N source, row cleaners (RC), and starter fertilizer (SF) on corn production in continuous corn (CC) and a corn-soybean (C-Sb) rotation. These single year data (1995) show an 18.3 bu/A yield advantage for the C-Sb rotation, while grain moisture was reduced 2.6 percent, and grain N concentration was increased 0.1 percent, compared to CC. Anhydrous ammonia resulted in greater corn grain yields, grain N concentrations, and grain N removal in the C-Sb rotation. However, in the CC system grain yield and N concentration were not statistically different between AA and UAN. The use of RC enhanced plant emergence, early plant growth, and grain yield, while reducing grain moisture in both crop rotations. Starter fertilizer enhanced early plant growth in both cropping systems, but did not result in a yield advantage in the C-Sb rotation on this high P testing soil (Bray-P_1 =30 ppm). For the CC system RC had the greatest impact on yield, followed by SF, and nitrogen source (AA), respectively. In the C-Sb rotation RC increased yields more than did N source (AA). Injected post-emergence applications of UAN produced 10.0 and 6.8 bu/A greater corn grain yields compared to preplant broadcast applications of UAN for the C-Sb and CC cropping systems, respectively. Inoculation of no-till fields with night crawlers, to improve soil quality, has thus far been successful. Greater numbers of night crawler middens were found in the C-Sb rotation compared to CC.

INTRODUCTION

Long-term continuous no-till corn production has decreased grain yields in some years on wet poorly-drained clay loam soils in southern Minnesota. A research study was initiated in 1994 to evaluate the long-term effects and interactions of N source, (AA vs UAN), row cleaners (RC), and starter fertilizer (SF) on corn grain production in continuous corn (CC) and a corn-soybean (C-Sb) rotation.

EXPERIMENTAL PROCEDURES

A research site was established in the spring of 1994 at the Southern Experiment Station on a Webster-Nicollet-Canisteo complex. The area was cropped to corn in 1993 and was left untilled for 1994. In the spring of 1994 the area was split into three sections. One section will be maintained long-term continuous no-till corn, while the other two sections will rotate between corn and soybean for the corn-soybean rotation.

Treatments were based on current "on-farm" management options for no-till. Individual plots were 10 ft wide by 120 ft long. The treatment combinations were arranged as a complete (2^3) factorial in a randomized complete block design with four replicates. Nitrogen source (AA or UAN), row cleaners (with or without at planting), and starter fertilizer (with or without at planting) were the three treatment main effects (2x2x2=8 treatments). A treatment was added to compare a preplant broadcast application of UAN to a point-injector banded application at the V1-2 stage. Anhydrous ammonia (82-0-0) was injected 15 in. from the row and 7 in. deep with a 5-knife applicator. Urea ammonium nitrate (28-0-0) was injected approximately 3 in. from the row to a depth of 4 in. with a 4-wheel point-injector. Dawn® row cleaners were used on a John Deere Maxi-merge 7100 planter for the RC treatments. Ten gal/A of a 10-34-0 liquid starter were applied with the seed on the SF treatments. All corn plots were planted with the same planter. Anhydrous ammonia and UAN were applied at 160 and 120 lb N/A for the CC and C-Sb rotation, respectively.

Corn (Pioneer 3578) was planted on April 28 at 32,200 seeds/acre. Weeds were controlled with a pre-emergence application (May 11) of Harness (2.75 pt./A) and Bladex (2.5 qt./A), a post treatment (July 11) of Accent (2/3 oz./A), and spot spraying with 2-4 D. The preplant broadcast application of UAN was applied on April 24. The AA and UAN point-injector treatments were applied on May 31 at VE-V1 in the CC and V2 in the C-Sb rotation. Plant emergence counts were taken on selected treatments by daily counting plants emerged in 50 ft of row. Early plant growth was determined by taking extended leaf heights of 10 plants each from rows 2 and 3 in each plot on June 16 and July 14 (49 and 77 days after planting, DAP). Corn grain was combine harvested from the center two rows each 114 ft in length on September 28. Grain yield was calculated from plot weight and grain moisture measured in the combine. A subsample of the grain was saved, dried, ground, and analyzed for total N content at the University of Minnesota Research Analytical Laboratory.

An area (4 ft long and 2.5 ft wide) of each plot was inoculated with 50 night crawlers on May 23. This area was located 25 ft from the end of each plot and was centered in the 10 ft wide plots (between rows 2 and 3). No attempt was made to confine the night crawlers to that area. On September 28 night crawler middens (huts) were counted to estimate the population of crawlers in the each plot. Counts were taken in the inoculated area and just outside the inoculated area.

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[1] Funding provided by the University of Minnesota, Southern Experiment Station.

[2] Assistant Scientist and Professor, respectively, University of Minnesota, Southern Experiment Station.

RESULTS AND DISCUSSION

Corn Grain and Plant Growth Parameters (Corn-Soybean Rotation)

Nitrogen source, row cleaners and starter fertilizer significantly affected corn grain and plant growth parameters (Table 1). Anhydrous ammonia resulted in 4.1 bu/A greater corn grain yield, 0.04 percent greater grain N concentration, and 5.4 lb/A more N in the grain compared to UAN. Plant emergence reached 80% two days earlier in RC plots compared to non-RC plots (Figure 1). Extended leaf plant heights, measured 49 and 77 DAP, were 10 and 3 percent taller where RC were used, respectively (Table 1). Row cleaners produced 6.4 bu/A greater yield and resulted in lower grain moisture compared to non use of RC. Plant emergence was not affected by SF. Starter fertilizer increased plant heights at both 49 and 77 DAP, but did not result in greater yields or reduced grain moisture on this high P testing soil (Bray-P_1 = 30 ppm).

The significant three-way interactions for grain yield, N concentration, and N removal ($P > F$ = 0.06, 0.08, and 0.01, respectively) are intriguing (Table 1). However, because the yield range among the 8 treatments is low (< 15 bu/A) and clear-cut reasons for the phenomena are not evident, we will not attempt to explain these interactions unless they reappear in subsequent years. The agronomic significance of these interactions are not clear at this time and could be hybrid and year dependent.

Table 1. Grain yield, grain moisture, grain N concentration, grain N removal, final plant population, and early plant growth as affected by N source / method of application, row cleaners, and starter fertilizer in a corn-soybean rotation in 1995.

Treatments			Grain				Final	Plant Heights	
N-source	Row Cl.	Starter	Moisture	Yield	N Conc.	N Removal	Plant Pop.	49 DAP	77 DAP
			%	bu/A	%	lb N/A	ppAx10^3	inches	
UAN	No	No	31.7	140.3	1.35	89.5	30.9	18.0	78.1
AA	No	No	32.0	143.5	1.35	91.8	29.0	18.4	78.1
UAN	No	Yes	32.1	137.2	1.31	85.2	30.8	21.9	83.7
AA	No	Yes	31.9	145.4	1.39	95.3	30.8	21.9	82.8
UAN	Yes	No	31.7	146.2	1.29	88.9	32.0	20.2	81.8
AA	Yes	No	31.7	152.1	1.37	98.5	30.8	18.9	78.8
UAN	Yes	Yes	31.4	147.2	1.34	93.3	29.6	24.3	85.1
AA	Yes	Yes	31.2	146.4	1.34	92.9	29.5	24.3	85.2
UAN Bdct.	Yes	No	31.8	136.2	1.29	82.9	28.6	17.9	80.9
Statistical analysis of main effects for 2^3 factorial design (8 treatments)									
N source (N)									
UAN			31.7	142.7	1.32	89.2	30.8	21.1	82.2
AA			31.7	146.8	1.36	94.6	30.0	20.9	81.2
$P > F$			0.93	0.01	0.05	<0.01	0.13	0.47	0.20
Row cleaners (RC)									
No			31.9	141.6	1.35	90.5	30.4	20.0	80.7
Yes			31.5	148.0	1.33	93.4	30.5	21.9	82.7
$P > F$			0.01	<0.01	0.45	0.09	0.84	<0.01	0.01
Starter fertilizer (SF)									
No			31.8	145.5	1.34	92.2	30.7	18.9	79.2
Yes			31.6	144.0	1.34	91.7	30.2	23.1	84.2
$P > F$			0.40	0.35	0.78	0.75	0.35	<0.01	<0.01
Statistical analysis of interaction effects for 2^3 factorial design (8 treatments)									
N x RC ($P > F$)			0.74	0.31	0.93	0.61	0.75	0.18	0.50
N x SF ($P > F$)			0.21	0.77	0.93	0.73	0.16	0.49	0.48
RC x SF ($P > F$)			0.12	0.57	0.69	0.94	0.02	0.13	0.84
N x RC x SF ($P > F$)			0.61	0.06	0.08	0.01	0.68	0.25	0.20
C.V. (%)			1.3	3.0	4.2	5.0	4.8	4.2	2.5
Statistical analysis of treatment effect for randomized complete block design (9 treatments)									
$P > F$			0.14	<0.01	0.15	<0.01	0.19	<0.01	<0.01
LSD (0.05)				6.0		6.4		1.3	2.9
C.V. (%)			1.3	2.9	4.0	4.8	5.8	4.2	2.4
Contrast ($P > F$)									
'UAN Broadcast vs Point Injected'			0.61	<0.01	1.00	0.06	0.01	<0.01	0.55

Comparisons of injected vs broadcast UAN (treatment 5 vs 9) were preformed using contrast statistics (Table 1). Injected UAN at V2 produced 10.0 bu/A greater grain yields compared to preplant broadcast UAN. Early plant growth (plant height) at 49 DAP also benefited from injected UAN. Nitrogen deficiency symptoms were evident in the broadcast treatment during the growing season, but grain N concentration was similar to the injected UAN treatment. However, these treatments resulted in lower grain N concentrations than all other treatments.

Corn Grain and Plant Growth Parameters (Continuous Corn)

Row cleaners and starter fertilizer significantly affected most corn grain and plant growth parameters, while N source had little effect (Table 2). Plant emergence in plots where RC were used reached 80% five days earlier compared to where RC were not used (Figure 1). Grain yield and N removal increased 8.6 bu/A and 5 lb N/A, respectively with RC, while grain moisture decreased by 1.0 percent. Also, final plant population was significantly greater when RC were used ($P > F = 0.09$). Starter fertilizer slightly hastened corn emergence when RC were not used, but had no effect with RC use (Figure 1). Plant heights at 49 and 77 DAP increased by 29 and 14 percent, respectively with SF use. Unlike the C-Sb rotation, SF increased grain yield 7.6 bu/A and decreased grain moisture in the CC system where the soil test P was 28 ppm.

A comparison of injected UAN vs preplant broadcast UAN (treatment 5 vs 9) showed a 6.8 bu/A yield advantage for injected UAN. Although this contrast (Table 2) was not statistically significant ($P > F = 0.11$), it is an agronomically significant yield difference. There were no significant interactions for corn grain in the CC system.

Table 2. Grain yield, grain moisture, grain N concentration, grain N removal, final plant population, and early plant growth as affected by N source / method of application, row cleaners, and starter fertilizer in continuous corn in 1995.

Treatments			Grain				Final	Plant Height	
N-source	Row Cl.	Starter	Moisture	Yield	N Conc.	N Removal	Plant Pop.	49 DAP	77 DAP
			%	bu/A	%	lb N/A	ppAx10^3	inches	
UAN	No	No	35.3	116.8	1.25	68.9	26.5	9.1	51.1
AA	No	No	35.3	120.0	1.25	71.3	29.0	9.6	50.6
UAN	No	Yes	34.2	125.1	1.21	71.8	28.2	11.0	58.0
AA	No	Yes	34.2	127.1	1.23	74.1	28.4	11.9	57.2
UAN	Yes	No	34.1	126.3	1.21	72.4	29.8	11.0	57.9
AA	Yes	No	34.2	127.9	1.27	77.1	29.7	10.1	52.9
UAN	Yes	Yes	33.6	131.6	1.17	72.9	28.6	13.0	62.7
AA	Yes	Yes	33.4	137.6	1.28	83.7	29.5	15.5	64.4
UAN Bdct.	Yes	No	34.5	119.5	1.21	68.7	29.0	10.8	57.3
Statistical analysis of main effects for 2^3 factorial design (8 treatments)									
N source (N)									
UAN			34.3	124.9	1.21	71.5	28.3	11.0	57.4
AA			34.3	128.1	1.26	76.5	29.2	11.8	56.3
$P > F$			0.87	0.11	0.11	0.03	0.29	0.01	0.24
Row cleaners (RC)									
No			34.8	122.2	1.24	71.5	28.0	10.4	54.2
Yes			33.8	130.8	1.24	76.5	29.4	12.4	59.5
$P > F$			<0.01	<0.01	0.98	0.03	0.09	<0.01	<0.01
Starter fertilizer (SF)									
No			34.7	122.7	1.25	72.4	28.8	9.9	53.1
Yes			33.9	130.3	1.22	75.6	28.7	12.8	60.6
$P > F$			<0.01	<0.01	0.46	0.16	0.95	<0.01	<0.01
Statistical analysis of interaction effects for 2^3 factorial design (8 treatments)									
N x RC ($P > F$)			0.75	0.76	0.22	0.24	0.55	0.88	0.60
N x SF ($P > F$)			0.71	0.69	0.54	0.50	0.42	<0.01	0.11
RC x SF ($P > F$)			0.43	0.98	0.82	0.89	0.69	0.01	0.45
N x RC x SF ($P > F$)			0.67	0.47	0.82	0.50	0.32	0.02	0.07
C.V. (%)			1.9	4.3	6.7	8.4	7.9	7.1	4.7
Statistical analysis of treatment effect for randomized complete block design (9 treatments)									
$P > F$			<0.01	<0.01	0.62	0.06	0.51	<0.01	<0.01
LSD (0.05)			0.9	8.2				1.4	4.4
C.V. (%)			1.9	4.5	6.3	8.4	7.4	8.5	5.3
Contrast ($P > F$)									
'UAN Broadcast vs Point Injected'			0.42	0.11	1.00	0.40	0.57	0.83	0.79

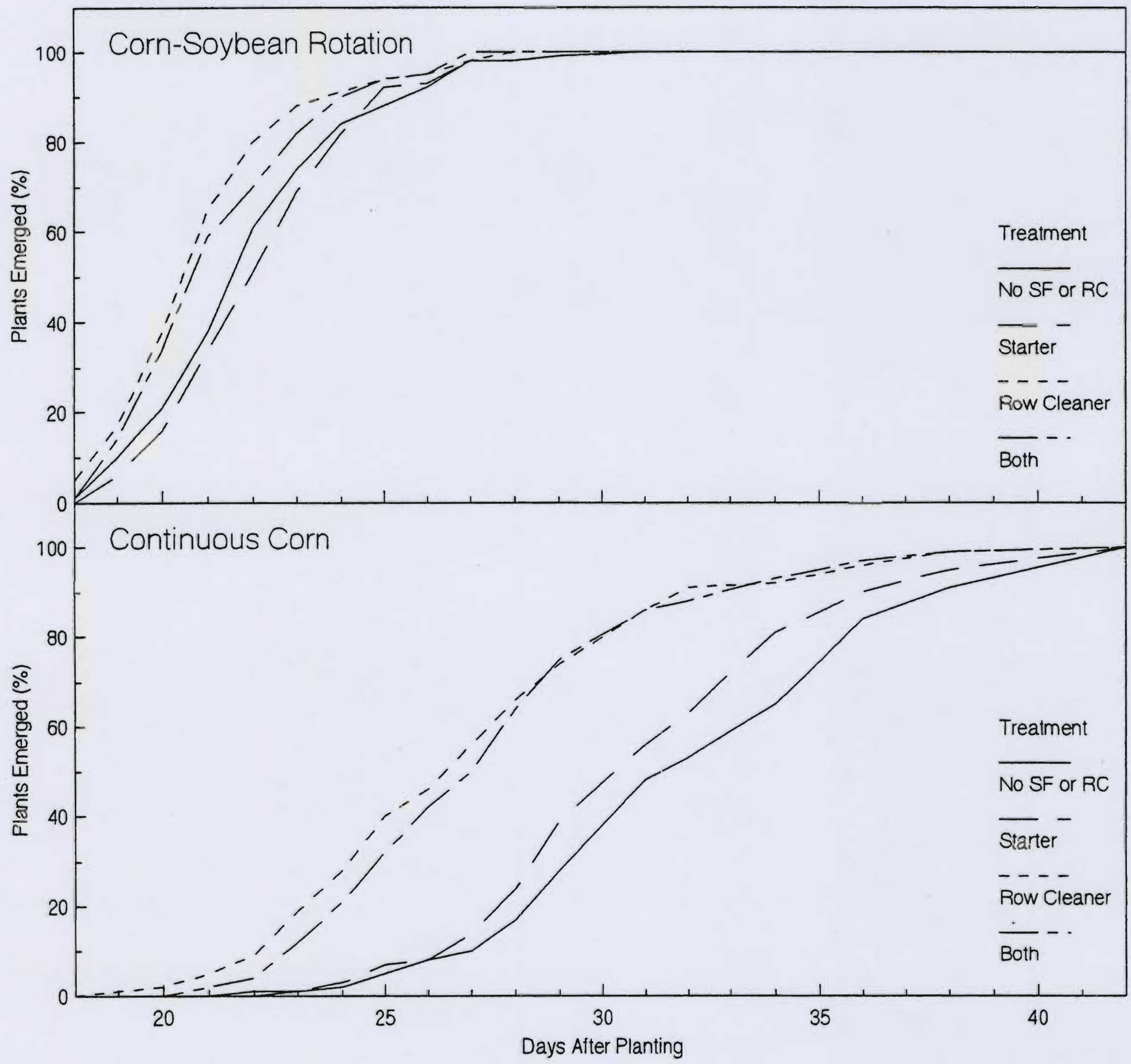
Night Crawlers and Middens

Night crawler middens (huts) were evident in most areas of the CC and C-Sb plots, but were more prevalent in the inoculated areas and in the C-Sb rotation. Variability in midden counts was high. Coefficient of variations (CV) ranged from 27 to 207 percent (Table 3). Generally, plots that received AA had significantly fewer middens compared to UAN.

Table 3. Night crawler middens (huts) in inoculated and non inoculated areas as affected by treatments in 1995.

Treatments			Corn-Soybean Rotation		Continuous Corn	
N-source	Row Cl.	Starter	Inoculated	Non-Inoculated	Inoculated	Non-Inoculated
			------------ middens/meter^2 ------------			
UAN	No	No	13.5	4.8	1.3	0.3
AA	No	No	8.8	4.8	1.0	0.0
UAN	No	Yes	13.8	2.3	4.0	0.5
AA	No	Yes	10.8	3.5	2.3	0.3
UAN	Yes	No	13.3	4.0	4.3	1.0
AA	Yes	No	8.5	3.8	1.3	0.3
UAN	Yes	Yes	13.0	4.5	4.3	0.5
AA	Yes	Yes	9.8	3.8	2.0	0.0
UAN Bdct.	Yes	No	15.0	7.0	2.3	0.0
Statistical analysis of main effects for 2^3 factorial design (8 treatments)						
N source (N)						
UAN			13.4	3.9	3.4	0.6
AA			9.4	3.9	1.6	0.1
P > F			<0.01	0.93	0.01	0.10
Row cleaners (RC)						
No			11.7	3.8	2.1	0.3
Yes			11.1	4.0	2.9	0.4
P > F			0.63	0.79	0.23	0.46
Starter fertilizer (SF)						
No			11.0	4.3	1.9	0.4
Yes			11.8	3.5	3.1	0.3
P > F			0.48	0.25	0.09	0.81
Statistical analysis of interaction effects for 2^3 factorial design (8 treatments)						
N x RC (*P > F*)			0.96	0.42	0.23	0.46
N x SF (*P > F*)			0.48	0.79	0.78	0.81
RC x SF (*P > F*)			0.79	0.14	0.23	0.23
N x RC x SF (*P > F*)			0.96	0.53	0.41	0.81
C.V. (%)			28	50	74	207
Statistical analysis of treatment effect for randomized complete block design (9 treatments)						
P > F			0.06	0.13	0.08	0.50
LSD (0.05)						
C.V. (%)			27	45	73	220
Contrast (*P > F*)						
'UAN Broadcast vs Point Injected'			0.45	0.04	0.14	0.05

Figure 1. Corn plant emergence as affected by row cleaners, starter fertilizer, and crop rotation in 1995.



CONCLUSIONS

1. No-till corn grain yields averaged 14% greater in the corn-soybean rotation compared to the continuous corn monoculture.
2. Corn grain yields in the corn-soybean rotation increased 6.4 bu/A and 4.1 bu/A with row cleaners and anhydrous ammonia use compared to non row cleaners and UAN, respectively.
3. Starter fertilizer improved early plant growth but did not increase corn grain yields in the corn-soybean rotation where the Bray-P_1 soil test was 30 ppm.
4. Continuous corn grain yields increased with row cleaner and starter fertilizer use by 8.6 and 7.6 bu/A, respectively, but were unaffected by nitrogen source / placement method.
5. Injected UAN at V1-2 increased grain yields by 10.0 and 6.8 bu/A compared to preplant broadcast UAN in the corn-soybean rotation and continuous corn monoculture, respectively. However, the difference was not statistically significant in the continuous corn ($P > F = 0.11$).

RESIDUAL EFFECTS OF NITROGEN APPLIED TO ESTABLISHED REED CANARYGRASS

J. A. Vetsch, G. W. Randall, and M. P. Russelle[1]

ABSTRACT: Recently developed low-alkaloid varieties of reed canarygrass are being considered as an alternative forage for dairy enterprises. The objectives of this 4-year study were to determine the effect of single early-season and split applications of fertilizer N on the yield and quality of reed canarygrass. Very high N rates (up to 600 lb/A) were applied in 1994 to examine the effect on yield and to determine the potential for downward movement of excess N in the soil profile. Because substantial soil NO_3-N remained in the 0-4 ft profile in the fall of 1994 (when rates of ≥ 400 lb N/A were applied), we measured reed canarygrass yield and N uptake in 1995 to determine the availability of residual N. Our results showed up to 32 percent recovery in 1995 from the 400-lb rate applied in 1994. The two-year recoveries totaled almost 70 percent for the 300, 350, and 400 lb/A rates. Recovery from the 500 and 600-lb rates was < 60 percent and soil NO_3-N accumulated below the 3 ft depth. These results suggest that residual N can be effectively utilized by reed canarygrass and not all will be lost to ground and surface water when optimum N rates are exceeded.

EXPERIMENTAL PROCEDURES

Ninety-six plots, measuring 10 ft by 20 ft, were laid out on established reed canarygrass (variety Palaton) in April 1994 on a Webster clay loam soil. Plots were fertilized in 1994 with varying rates of N as ammonium nitrate on April 11 and June 20 after first cutting. In 1995 yields were taken from selected N rates (Table 1) to evaluate the residual effects of N fertilization in 1994. A single treatment (300 lb N/A in 1994) also received 300 lb N/A as ammonium nitrate in 1995. Yields were taken by harvesting a 3 ft by 19 ft swath from each plot on June 9, July 24, and September 20. Forage was analyzed for moisture content and total Kjeldahl N. The total N analyses were conducted by Dr. Russelle's Laboratory in St. Paul. Soil samples, three cores per plot to a depth of 5 ft in 1 ft increments, were taken from selected treatments in November of 1995. All soil samples were immediately forced-air dried at 125° F, then ground and analyzed for NO_3-N by the Research Analytical Laboratory, St. Paul.

RESULTS AND DISCUSSION

Dry Matter Yield, Total N Concentration, and N Removal by Harvest

Yield data, obtained in 1995 from selected treatments applied in 1994, were taken to determine the potential for plant recovery of residual N. Nitrogen fertilizer applied in 1994 significantly affected dry matter yields, total N concentration, and N removal in 1995 (Table 1). First and second harvest and total (annual) yields were increased significantly by 1994 rates ≥ 200 lb N/A compared to the control (zero N). Nitrogen rates ≥ 300 lb N/A resulted in a yield increase for the third harvest when compared to the control. Total N concentration and N removal were also affected by 1994 N rates. The 300+300 treatment (300 lb N/A in 1994 and 1995) had significantly greater total N concentration for all three cuts and greater dry matter yield and N removal for the 1st cut. However, total (annual) yield for the 300+300 treatment was not significantly greater than from the 400, 500, or 600 lb N/A rates applied in 1994.

Table 1. Residual effects of N applied in 1994 on dry matter yield, total N, and N removal of reed canarygrass in 1995.

	Dry Matter Yield				Total N Concentration			Nitrogen Removal			
1994 Total N Rate	1st cut	2nd cut	3rd cut	Total	1st cut	2nd cut	3rd cut	1st cut	2nd cut	3rd cut	Total
lb N/A	----- T DM/A -----				----- % -----			----- lb N/A -----			
0	0.56	0.41	0.29	1.26	1.43	1.57	1.72	16	13	10	39
200	0.94	0.56	0.34	1.84	1.47	1.51	1.67	27	17	11	56
250	1.22	0.63	0.38	2.23	1.57	1.55	1.66	38	19	13	70
300	1.68	0.79	0.58	3.05	2.03	1.75	1.64	68	28	19	115
350	1.76	0.82	0.78	3.36	1.96	1.85	1.94	70	30	31	130
400	1.92	0.93	0.94	3.80	2.27	2.15	2.08	87	39	40	166
500	1.92	0.89	1.00	3.81	2.04	2.45	2.25	78	44	45	167
600	1.83	0.99	1.05	3.87	2.05	2.42	2.28	75	48	48	171
300+300[1]	2.12	0.66	0.92	3.70	2.65	3.31	2.86	111	43	52	206
Statistical Analysis											
Pr. > *F*:	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
LSD (0.05):	0.28	0.15	0.20	0.46	0.34	0.30	0.29	16	8	12	23
CV (%):	13	14	20	10	12	10	10	17	17	28	12

[1] 300 lb N/A applied in 1994 and again in 1995.

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Annual N Removal and Apparent N Recovery

Apparent N recoveries were calculated from total N removed for 1994 and 1995 (Table 2). First year (fertilization year) recoveries were lower in 1994 compared to previous years. Therefore, considerable residual N was expected for 1995 plant growth. Recoveries in 1995 increased with increasing N rate up to 400 lb N/A. This rate also optimized yield for 1995 (Table 1). The combined N recovery was calculated by adding the N recoveries from 1994 and 1995. The combined (2-year) recoveries approached 70 percent at N rates between 300 and 400 lb N/A, which is similar to the first-year recovery at 400 lb N/A in 1993. However, these are lower than the 80 to 90 percent recoveries observed in 1992 and 1993 with N rates as high as 300 lb/A, but considerably better than 30 to 40 percent values observed in 1994. Observations in 1995 at N rates ≥ 400 lb/A (lower N recoveries and not significantly greater yields) suggest that some residual N may be available for the 1996 growing season. However, since combined recoveries were considerably lower than first year recoveries in 1992 and 1993, some N was probably leached below the root zone, lost to tile lines, or immobilized.

Table 2. Annual N removal and apparent recovery of fertilizer N by reed canarygrass in 1995 as affected by N rate in 1994.

1994 Total N Rate	Total Annual N Removal 1994	Total Annual N Removal 1995	Apparent N Recovery[1] 1994	Apparent N Recovery[1] 1995	Apparent N Recovery[1] Combined[2]
-- lb N/A --	----- lb N/A -----		--------- percent ---------		
0	84	39	–	–	–
200	187	56	51	8	59
250	202	70	47	12	59
300	216	115	44	25	69
350	230	130	42	26	68
400	230	166	36	32	68
500	241	167	31	26	57
600	246	171	27	22	49

[1] Apparent N Recovery = (Total N removal - N removal from control) ÷ Total N applied in 1994.
[2] Recovery of N applied in 1994 by dry matter in 1994 and 1995.

Soil Nitrate-N

Soil samples were taken in November to determine if substantial quantities of residual soil nitrate remained in the 0-5 ft profile and if the fertilizer N had moved down through the soil profile. When N rates of > 400 lb/A were applied, soil nitrate accumulated below 3 ft (Table 3). Movement of soil nitrate to depths below 3 ft suggests the potential for leaching losses to ground and surface drainage waters. The 300+300 treatment also shows accumulation of residual soil nitrate in the profile and the potential for movement below the root zone or loss to tile drainage. This suggests that annual applications of 300 lb N/A may exceed crop requirement and can result in leaching losses from the soil profile.

Table 3. Nitrate-N remaining in the 0-5 ft profile in November 1995 as influenced by N rates applied to Reed Canarygrass.

N Rate 1994	N Rate 1995	Soil Profile Depth 0 - 1'	1 - 2'	2 - 3'	3 - 4'	4 - 5'	0 - 5'
---- lb N/A ----		------------------- lb NO_3-N/A -------------------					
0	0	8	2	1	2	2	15
400	0	8	2	2	10	9	31
500	0	7	1	15	28	23	74
600	0	9	2	9	35	29	84
300	300	14	8	23	19	10	74

Recommendation

This report concludes four years of research in N fertilization of reed canarygrass at Waseca. Based on this research the following recommendations for nitrogen fertilization of reed canarygrass can be made. Single early-season (April) applications of N are as effective as split applications for dry matter production. A single early-season application of 200 lb N/A is recommended for optimum yields. If growing conditions are excellent and a first cut yield > 2.3 T DM/A is obtained, then an additional 50 to 100 lb N/A may be warranted after first cutting. Nitrate concentration in the forage can reach toxic levels when single applications of N exceed 200 lb/A. Thus, forage nitrate concentrations need to be monitored and feed rations may have to be adjusted. At these recommended N rates for optimum production, we would not expect N loss from the soil profile.

IMPACT OF ADDING WHEAT TO A TRADITIONAL CORN-SOYBEAN STRIP SYSTEM ON CROP YIELDS AND EROSION CONTROL[1/]

T. K. Iragavarapu and G. W. Randall[2/]

1995

ABSTRACT: Four single crop production components (ridge tillage; three-crop wheat-corn-soybean rotation; narrow, alternate strips (15' wide); and legume interseeding) were integrated into a complete cropping system. Studies were started in 1991 at two locations in southern Minnesota on Webster clay loam soil. The rotations compared were: a) continuous corn; b) corn-soybean; c)corn-soybean-wheat with and without interseeded legumes (berseem clover or crimson clover). Each corn strip following wheat or soybeans was fertilized at four N rates (0, 60, 100, and 150 lb N/A) to determine N contribution of legumes. Results from 1995 indicate that the narrow-alternate strips of corn, soybean, and wheat in a ridge-till system provide excellent surface residue coverage and satisfy erosion control goals. Strip yields of corn were enhanced by about 6% in both E-W and N-S row orientations while soybean yields were increased by 6% in E-W rows and were unaffected in N-S rows compared to conventional systems. Wheat yields in strips were reduced slightly (1%) compared to conventional systems in E-W rows. Wheat introduced into the traditional corn-soybean strip system reduced the negative border effects of corn on soybeans.

Narrow, alternate strip cropping systems have been receiving much attention in the farm press the last few years. These aesthetically pleasing cropping systems are touted as sustainable systems that reduce chemical inputs and pest activity while improving net profit and erosion control.

Studies show that in traditional corn-soybean strip crop systems improved corn yields in the border rows are offset by reduced soybean yields. Adding wheat to this two-crop strip system should reduce border effects on soybeans without sacrificing wheat yields. Wheat planted north of corn and south of soybeans in east-west rows will allow adequate sunlight for soybeans. Wheat, a cool-season crop, will not be shaded as it heads out before corn gets tall enough to shade it. Addition of wheat to the corn-soybean system will not only facilitate interseeding of legumes that provide nitrogen to the following corn, but also will break corn root worm diapause and reduce soybean cyst nematode infestation.

The objective of this study was to evaluate the potential of a three-crop (wheat-corn-soybean) system on crop yields and erosion control.

PROCEDURE

Studies were started in 1991 at the Southern Experiment Station with east-west rows and on the Lynn Sorenson farm in Freeborn Co. with north-south rows. Soybean strips were located on the south side and wheat strips on the north side of corn in E-W rows. In N-S rows, wheat was located on the east side and soybean on the west side of the corn strips. All crops were planted in 15' wide by 120' long strips on ridges. Corn (Pioneer 3751) was planted in 30" rows at a rate of 30,200 plants/A in rows 2-5 and 36,000 ppA in the outside rows (1&6) at Freeborn and at a rate of 32000 ppA in rows 2-5 and 38400 ppA in rows 1 and 6 at Waseca. Nitrogen rates were changed to 0, 60, 100, and 150 lb N/A in 1995. Individual plots are 6 rows wide x 30' long within each strip. Weeds were controlled with broadcast application of Lasso (3 lb ai/A) and Bladex (2.5 lb ai/A) and ridge till cultivation. Hand-harvest grain yields were obtained from a 25-foot section within each row of each plot.

Soybean variety, "Sturdy", which was planted in 1991-1994 was replaced with a cyst nematode resistant variety, "Bell" in 1995. Soybean was planted at a rate of 9 to 10 beans/foot of row in 30" rows. Weeds were controlled with a preemergence, broadcast application of Lasso (3 lb ai/A), and postemergence, broadcast application of Pursuit (4 oz ai/A), and by ridge cultivation. Each individual row was harvested with a plot combine.

"Grandin" spring wheat was planted at a rate of 94 lb/A with a minimum-till drill in 8" rows following broadcast-application of 65 lb N/A and field cultivating the ridges. In 1991-1993, annual alfalfa, "Nitro" was companion seeded with wheat at 10 lb/A and hairy vetch was planted after wheat harvest at a seeding rate of 30 lb/A. Starting in 1994, alfalfa was replaced with berseem clover (10 lb/A) and hairy vetch was replaced with crimson clover (15 lb/A). Broadleaf weeds, when present, were controlled with a broadcast-application of Bromoxynil in wheat strips when no legume was planted.

[1/] Funding provided by USDA-LISA and Minnesota Department of Agriculture.
[2/] Post-doctoral Research Associate and Professor, respectively, Univ. of Minnesota.

RESULTS

Corn grain yield following wheat without interseeded legumes was greater in 1995 than the 4-yr average (1991-94) in all rows at both sites. The only exception is the west outside row in N-S rows. Hail in the first week of August caused damage to the corn plants, especially the west outside row at the Freeborn site. As a result, the west outside row yielded only 11% greater than the center two rows in 1995 when compared to a 28% yield advantage in 1991-94. The increase in the fertilizer N rate from 120 lb N/A to 150 lb N/A combined with better growing conditions may have resulted in greater yields in 1995 compared to the previous years. The yield advantage of the narrow strips for corn in the 3-crop (wheat-corn-soybean) rotation was 10 bu/A (6%) in the E-W system and 8.7 bu/A (6%) in the N-S row orientation compared to the whole-field averages (Table 1). The greater yield advantage for the E-W strips in 1995 compared to previous years may be due to increase in: a) fertilizer N rate by 30 lb N/A and b) seeding rate of corn by 1800 ppA in rows 2-5 and by 2400 in rows 1 and 6. On the other hand, at the Freeborn site with N-S rows, yield advantage for the strips was 8.7 bu/A (6%) compared to a 12.2 (9%) advantage in 1991-94 due mainly to the west outside rows suffering hail damage.

Grain moisture of the strip was 0.8 points greater than the center two rows in E-W rows because of greater moisture content in the outside rows. In N-S rows, corn grain in the strip had 0.5 points more moisture compared to the center two rows.

Similar to corn yields, soybean yields were greater in all rows at both sites in 1995 compared to the 1991-94 averages. Unlike the previous years, soybean yields were increased by 2.7 bu/A (6%) in the strip in E-W rows (Table 3), due mainly to the second row from north yielding 29% greater than the center two rows in 1995. The north row (next to corn) yielded 2.3 bu/A (5%) less while the south row (next to wheat) yielded 1.8 bu/A (4%) more than the center two rows in the E-W row orientation. In N-S rows, yield of row 6 (next to wheat) was 8.9 bu/A (15%) more while the row bordering corn (row 1) suffered a 8.8 bu/A (22%) yield loss compared to the center two rows. This suggests that including wheat resulted in increased yields in the adjacent soybean row compared to the row next to corn. Root competition for moisture and nutrients between adjacent corn and soybean rows is a possible explanation for yield loss in the north soybean row in E-W rows where shading is not a problem and the east row in N-S rows.

Soybean yields in the two-crop alternate strips were comparable to the conventional systems at both sites in 1995 (Table 4) mainly due to the second row yielding the highest at both locations. Outside rows (rows 1 & 6) bordering corn yielded 15% less (6.1 bu/A) than the center two rows in the E-W system and 15% less (5.6 bu/A) in the N-S system. The soybean row on the north side of corn (E-W rows) and east side of corn (N-S rows) yielded 25 and 19% less, respectively, than the center two rows. Wheat yields were affected slightly (0.9 bu/A) in the E-W system by the soybean borders (Table 5).

Surface residue coverage before planting was ideal for all crops (Table 6). Residue coverage before planting corn in the wheat alone strips dropped from 83% in 1992-94 to 61% in 1995. Liquid hog manure was injected into the ridges of the wheat alone strips and the ridges were rebuilt in the fall of 1994. This resulted in reduced surface coverage in 1995. After planting, residue coverage was still > 30% following corn and wheat. Residue coverage after soybean was only 17% due to field cultivating the ridges before planting spring wheat, but this was offset by mid-May with a well-established stand of wheat capable of providing excellent erosion control.

Table 1. Corn grain yield in a C-Sb-W rotation as influenced by row position and direction[†].

Row Direction	Year	Row/Position 1	2	3&4	5	6	Yield Adv.of 6-row strip[‡]
		bu/A					
E-W Rows	1995	194.8	170.4	171.8	171.0	211.8	10.0
	1991-94	154.3	139.9	148.8	142.0	170.8	2.0
N-S Rows	1995	182.9	162.8	151.9	145.4	168.4	8.7
	1991-94	168.8	140.0	136.3	135.4	174.1	12.2

[†] 5-yr (1991-1995) averages for corn fertilized at 120 lb N/A annually during 1991-94 and at 150 lb N/A in 1995.
[‡] Yield advantage of 6-row strip compared to the center two rows, which are assumed to represent a whole-field yield.

Table 2. Corn grain moisture at harvest in a C-Sb-W rotation as influenced by row position and direction[†].

Row Direction	Year	Row/Position 1	2	3&4	5	6	Moisture Adv.of 6-row strip[‡]
		%					
E-W Rows	1995	27.7	25.0	24.9	25.0	27.0	-0.8
	1991-94	33.7	32.5	31.5	31.5	29.5	-0.2
N-S Rows	1995	23.9	22.5	22.2	22.5	22.7	-0.5
	1991-94	23.4	23.5	24.2	23.5	22.7	0.6

[†] Corn fertilized at 120 lb N/A annually in 1991-94 and at 150 lb N/A in 1995.
[‡] Moisture advantage of 6-row strip compared to the center two rows, which are assumed to represent a whole-field.

Table 3. Soybean seed yield in a C-Sb-W rotation as influenced by row position and direction.

Row Direction	Year	Row/Position 1	2	3&4	5	6	Yield Adv.of 6-row strip[†]
		bu/A					
E-W Rows	1995	40.5	55.1	42.8	47.5	44.6	2.7
	1991-94	32.1	36.4	39.1	40.0	35.1	-2.1
N-S Rows	1995	30.9	40.5	39.7	40.5	45.8	-0.2
	1991-94	27.7	34.5	35.4	35.5	33.9	-1.7

[†] Yield advantage of 6-row strip compared to the center two rows, which are assumed to represent a whole-field yield.

Table 4. Soybean seed yield in a C-Sb rotation as influenced by row position and direction.

Row Direction	Year	Row/Position 1	2	3&4	5	6	Yield Adv.of 6-row strip[†]
		bu/A					
E-W Rows	1995	40.0	47.6	41.7	42.5	31.2	-0.9
	1991-94	35.2	38.5	39.8	38.0	26.3	-3.5
N-S Rows	1995	31.3	42.1	38.6	37.4	34.6	-1.5
	1991-94	27.5	32.2	35.5	32.7	28.0	-3.6

[†] Yield advantage of 6-row strip compared to the center two rows, which are assumed to represent a whole-field yield.

Table 5. Wheat yields in strips as influenced by row direction[†].

Row Direction		N⅓ or E⅓	Center⅓	S⅓ or W⅓	Yield Adv. of 15' strip[‡]
		bu/A			
East-West	1995	54.4	56.5	55.8	-0.9
	1991-94	43.6	42.1	41.1	0.2
North-South	1991-94	42.1	38.6	35.9	0.3

[‡] Relative yield advantage of the 15'strip compared to the center 5', which is assumed to represent a whole-field.

Table 6. Surface residue coverage as influenced by previous crop at Freeborn Co. (1992-95).

Previous crop[‡]	Before planting 1995	Before planting 1992-94	After planting 1995	After planting 1992-94
	----------	%	----------	
Corn	44	63	39	37
Soybean	53	51	17	21
Wheat	61	83	42	35
Wheat + berseem clover	85	88	70	56
Wheat + crimson clover	76	90	64	48

[‡] In 1992-93 wheat was interseeded with either alfalfa or hairy vetch. In 1994, alfalfa and hairy vetch were replaced with berseem clover and crimson clover, respectively.

CONCLUSIONS

1. Incorporating a wheat strip between corn and soybean strips resulted in reduced negative border effects on soybean without affecting wheat yields.

2. Unlike previous years, soybean yield was highest in row 2 for both three- and two-crop systems in E-W rows in 1995 for reasons unknown.

3. Contrary to previous years, corn benefitted more in E-W strips than in N-S strips due to greater yield advantage for the strip compared to the whole-field averages.

4. Hail damage, especially to the west outside corn row resulted in less yield advantage for the N-S strips in 1995 than in the previous years compared to the whole-field averages.

5. Narrow alternate strips of corn, soybean, and wheat satisfy erosion control goals.

6. Economic analyses of all inputs and outputs from these cropping systems are needed before we can compare the profitability of these narrow strip systems to conventional systems.

FERTILIZER AND MANURE NITROGEN MANAGEMENT IN SOUTHEASTERN MINNESOTA[1/]

G. W. Randall and J. A. Vetsch[2/]

1995

ABSTRACT: A 4-yr study has been conducted on a Port Byron sil in Olmsted Co. to develop best management practices (BMPs) for fertilizer N and manure for corn in southeastern Minnesota. Four-year results indicate corn yields and profitability to be optimized at the 120-lb N rate applied in the spring prior to planting. Split and sidedress N applications did not consistently increase yield or profitability above that from preplant applications. Nitrate-N concentrations in the soil and the soil water increased markedly with increasing fertilizer N rate and clearly indicate the environmental impact of over-application of fertilizer N. Although the high rate of manure applied every-other-year resulted in highest yields in the year of application, residual effects on yield in the year after application were minimal in 1993 but substantial in 1995. Thus, 4-year average yields were slightly higher with the biennial applications. Nitrate-N concentrations in the soil water at 5' and 7.5' were not greatly different between the two manure application treatments. Additional years will be needed to more clearly distinguish the long-term differences among treatments for the establishment of more precise BMPs.

Management of nitrogen from both fertilizer and manure is vitally important to the economic profitability of southeastern Minnesota crop producers and the environmental quality of this region's resources. The overall purpose of this study is to develop best management practices (BMPs) for fertilizer N and manure for corn grown on well-drained, silt loam soils of southeastern Minnesota. Sub-objectives include determining: a) the optimum profitability associated with various rates and times of N application and b) the downward movement and distribution of nitrates through the soil profile as influenced by rates and times of N application and annual vs every-other-year application of dairy manure.

MATERIALS AND METHODS

A 5-year study (1987-91) at this site (Richard Lawler & Sons Farm) showed the optimum rate of fertilizer N to be between 75 and 150 lb N/A applied in the spring prior to planting. Thus, this study was started in 1992 to determine more precisely the optimum rate of fertilizer N for continuous corn and whether split or sidedress applications would be advantageous. The fertilizer treatments were applied as urea and were compared to liquid dairy manure treatments. The spring preplant fertilizer treatments were broadcast-applied and field cultivated in while the sidedress treatments were knifed in about 4" deep. The nutrient analyses of the liquid dairy manure used each year are given in Table 1 while the nutrient amounts added each year are given in Table 2. The manure was sweep-injected about 4" deep prior to planting. All plots were chisel plowed each fall.

Corn (Pioneer 3751 in 1992 and 1993 and Pioneer 3861 in 1994 and 1995) was planted at 32000 plants per acre without starter fertilizer. Force was used to control corn rootworm. Yields were taken by combine harvesting the center two rows in 1992, 1994, and 1995 and by hand-harvesting in 1993.

Soil water samples were obtained periodically throughout the season (May - Oct.) from porous cup samplers installed at the 5 and 7.5' depths. Soil samples were taken to an 8-foot depth from each plot each fall.

RESULTS

Yields

Grain yields shown in Table 3 were rather low in 1992 and 1993, slightly below average in 1995, and were quite respectable in 1994. Optimum yield each year and the greatest economic return to the fertilizer during the 4-yr period was obtained with the 120-lb preplant N rate. Splitting the N applications into preplant and sidedress application at the 7 to 8-leaf stage (corn 12 - 15" tall) did not consistently improve the 4-yr yield or profit; although the split-applied 90-lb rate was 4 bu/A and $6/A better than the single preplant 90-lb rate. Applying all of the N at the 8-leaf stage resulted in slightly poorer grain yields in the first two years, but not in 1994 and 1995 compared to the same N rate applied preplant. This emphasizes the point that sidedress N needs to be applied before the V4 stage (6-leaf) in continuous corn if yields and fertilizer efficiency are to be optimized consistently.

In 1992, grain yield was 23 bu/A higher with the 8650-gal manure treatment (no. 10) compared to the 3700-gal treatment (Table 3). However, the residual effect of the high manure rate was minimal in 1993 when yields were 19 bu/A lower than the annual average 4100-gal rate (trt. no. 9). Four annual applications averaging 4550 gal/A (152 lb total N/A/yr) (trt. no. 9) produced 4-year average corn yields which were similar to those from the 90-lb fertilizer N rate. Four-year average yields for the every-other-year (biennial) manure treatment were slightly higher compared to the annual application. This was largely due to the substantial residual effect in 1995 from the manure applied in 1994.

[1/] Support for this project has been provided by the Center for Agricultural Impacts on Water Quality and the Southern Experiment Station.

[2/] Professor and Asst. Scientist, respectively, Southern Experiment Station, Waseca.

Table 1. Nutrient analyses of the liquid dairy manure used in 1992, 1993, 1994, and 1995.

Year	Total N	NH_4-N	P_2O_5	K_2O
	lb/1000 gal			
1992	45.0	18.2	14.2	21.2
1993	28.0	18.4	15.9	23.3
1994	28.4	16.0	12.0	30.2
1995	34.8	16.6	16.4	35.4

Table 2. Nutrient application rates as liquid dairy manure in 1992, 1993, 1994, and 1995.

Year	Trt. No.	Applc'n rate	Total N	NH_4-N	P_2O_5	K_2O
		gal/A	lb/A			
1992	9	3700	166	67	52	78
	10	8650	389	157	123	183
1993	9	4500	126	83	72	105
	10	0	0	0	0	0
1994	9	5000	142	80	60	151
	10	10000	284	160	120	302
1995	9	5000	174	83	82	177
	10	0	0	0	0	0
1992-93 Total	9	8200	292	150	124	183
	10	8650	389	157	123	183
1992-95 Total	9	18200	608	313	266	511
	10	18650	673	317	243	485

Table 3. Corn grain yield and economic return to N as influenced by nitrogen and manure treatments.

Treatment			Year				Four-Yr	Return[1]
No.	N rate	Time of Application	1992	1993	1994	1995	Avg.	to fert.
	lb/A		Yield (bu/A)					$/A
1	0	Spr. preplant (PP)	33	58	63	86	60	-
2	60	"	82	95	139	108	106	95
3	90	"	103	96	147	123	117	116
4	120	"	113	106	165	127	128	136
5	150	"	112	108	157	131	127	128
6	60 + 30	Spr. PP + SD (8-leaf)	100	105	153	126	121	122
7	60 + 60	"	105	105	155	134	125	126
8	90	SD (8-leaf)	89	100	150	124	116	113
9[2]	Liq. dairy manure, annually	Spring injected	113	99	144	126	120	-
10[2]	Liq. dairy manure, every other year	Spring injected	136	80	167	124	127	-
	Treatment Statistical Analyses							
	P > F:		<0.01	<0.01	<0.01	<0.01		
	LSD (0.05):		11.0	8.2	14.4	16.9		
	LSD (0.10):				12.0	14.0		
	CV (%):		8.5	6.5	6.9	9.6		

[1] Economics based on the following prices: Corn = $2.40/bu, N = $0.20/lb, and $3.00/acre/application.
[2] See Table 2.

Stover and silage yields were optimized at the 90-lb N rate in 1995 (Table 4). Stover production was slightly but not statistically (P = .10 level) lower when all of the N was sidedressed. Stover N concentration was optimized with the 120-lb N rate while grain N was optimized with the 60-lb N rate. Grain N concentration for the biennial manure treatment was not different from the 0-lb control, which suggests that available N in these plots ran out before N uptake and translocation to the grain had been completed. Nitrogen uptake in the stover, grain, and silage (total N uptake) was optimized at N rates of 90 and 120 lb/A. Nitrogen uptake for the manure treatments averaged slightly lower than for the 90-lb fertilizer N treatment. Chlorophyll content was optimized at the 120-lb N rate. Sidedressing all of the N gave slightly lower chlorophyll readings compared to the preplant application. This was likely due to the short 18-day period between N application (June 30) and the time the chlorophyll measurements were taken (July 18). Chlorophyll content was quite low for the biennial manure treatment, which indicates available N carrying over from the 1994 application was insufficient to meet the early-season N needs. Grain moisture and final plant population were not affected by the fertilizer N or manure treatments.

Table 4. Grain moisture, yield, N concentration, N uptake, final plant population and chlorophyll content as influenced by fertilizer and manure treatments in 1995.

Trt.	Grain Moisture	Yield		N Concentration		N Uptake			Final Plant Pop	Chlorophyll V13 (Jul 18)	
		Stover	Silage	Stover	Grain	Stover	Grain	Silage			
#	%	- - - - TDM/A - - -		- - - - - % - - - - - -		- - - - - - - - lb N/A - - - - - - - -			ppA*1000	SPAD	Rel. %
1	26.0	1.249	3.289	0.43	1.11	10.6	45.1	55.7	30.79	43.8	80.2
2	25.9	1.980	4.539	0.51	1.23	20.1	62.7	82.8	30.59	49.7	91.0
3	25.5	2.239	5.153	0.57	1.24	25.1	72.0	97.1	30.86	52.3	95.8
4	25.7	2.210	5.219	0.61	1.24	26.7	74.8	101.5	31.26	53.4	97.8
5	26.5	2.213	5.314	0.65	1.28	28.6	79.7	108.3	30.73	54.6	100.0
6	25.9	2.029	5.017	0.60	1.26	24.5	74.9	99.4	31.03	51.9	95.0
7	26.3	2.116	5.283	0.66	1.26	27.9	79.7	107.6	30.76	52.0	95.2
8	26.5	1.967	4.900	0.61	1.23	24.1	72.2	96.4	30.96	50.4	92.2
9	26.4	2.252	5.300	0.48	1.20	21.4	71.5	92.9	30.39	50.6	92.7
10	25.8	2.120	5.065	0.56	1.11	24.0	65.9	89.9	30.66	47.5	86.9
Treatment Statistical Analysis											
P > F:	0.91	<0.01	<0.01	<0.01	0.03	<0.01	<0.01	<0.01	0.86	<0.01	<0.01
LSD (0.05):		0.378	0.486	0.09	0.11	5.4	12.3	12.9		1.8	3.2
LSD (0.10:		0.314	0.403	0.08	0.09	4.5	10.2	10.7		1.5	2.7
C.V. (%):	4.1	12.8	6.8	11.4	6.3	16.0	12.1	9.5	2.2	2.4	2.4
Contrasts 'PP vs Split, 90 PP vs 90 Split, 90 PP vs 90 SD, 90 Split vs 90 SD'											
PPvsSp,P>F:	0.35	0.25	0.83	0.21	0.63	0.89	0.36	0.35	0.63	0.13	0.13
90PPvs90Sp,P>F	0.62	0.26	0.57	0.48	0.68	0.81	0.64	0.72	0.74	0.58	0.59
90PPvs90SD,P>F	0.20	0.15	0.29	0.33	0.93	0.71	0.98	0.90	0.84	0.03	0.03
90Spvs90SD,P>F	0.42	0.74	0.62	0.79	0.62	0.90	0.65	0.63	0.90	0.09	0.09

Soil Nitrogen

Residual soil nitrate (RSN) prior to fertilization at the preplant stage was low (Table 5). Higher NO_3-N concentrations at the VE and V4 stages for treatment 7 show the effect of the first (preplant) application of 60 lb N/A. The value of 21.5 exceeded the commonly acknowledged critical value of 21 for the PSNT test. However, yield responses of 18 and 26 bu/A were obtained with the second additions of 30 and 60 lb N/A in these split treatments compared to single 60-lb preplant treatment. This suggests a PSNT value >21 is needed for optimum corn production on these soils. In treatment 8, RSN approximately doubled between the PP and V4 stages due to mineralization prior to the sidedress application of N. Soil NH_4-N did not change consistently between the PP and V4 stages.

Table 5. Early-season soil NO_3-N and NH_4-N concentration as influenced by time of N application in 1995.

Trt.	Treatment			Time of Sampling[1/]		
No.	N rate	Time	Depth	Preplant	VE	V4
	lb/A		feet		NO_3-N	
7	60 + 60	Split	0-1	5.2(1.9)[2/]	13.8 (1.5)	21.5 (1.4)
	60 + 60	Split	1-2	6.3 (0.3)	10.3 (1.1)	17.7 (2.1)
8	90	SD	0-1	4.0 (0.3)	6.6 (0.4)	10.1 (0.6)
	90	SD	1-2	5.7 (0.2)	5.6 (0.5)	8.9 (1.2)
					NH_4-N	
7	60 + 60	Split	0-1	8.6 (1.1)	8.3 (0.7)	10.1 (0.4)
	60 + 60	Split	1-2	5.0 (0.8)	5.0 (1.0)	7.1 (0.5)
8	90	SD	0-1	8.4 (0.8)	7.1 (0.4)	9.7 (0.8)
	90	SD	1-2	5.2 (0.4)	4.2 (0.4)	8.2 (0.5)

[1/] Preplant = 5/2, VE = 6/2, and V4 = 6/22.
[2/] ( ) = Standard error of the mean.

Residual soil NO_3-N (RSN) in the soil profile in early November, 1995 was greatly affected by the fertilizer and manure treatments (Table 6). RSN in the 0-8' profile ranged from 45 lb/A for the 0-lb N rate to 186 lb/A for the 150-lb rate. Much of the increase in RSN at the 150-lb N rate was due to consistently higher NO_3-N concentrations at each depth throughout the 8-foot profile compared to the 120-lb rate. Accumulation of RSN below the 4-foot depth is significant because of a higher potential for leaching to the groundwater. Very little difference in RSN was found between the 90 and 120-lb N rates.

The RSN remaining from the two manure treatments was similar to that remaining for the 60 and 90-lb fertilizer N treatments (Table 6). Even though more total N had been applied with the biennial treatment (673 lb/A vs 608 for the annual treatment) during the 4-year period, consistently less RSN remained throughout the soil profile. This would suggest greater loss of N, perhaps by leaching from the soil profile, but the soil water data shown in Table 7 does not indicate this to be the case in 1995.

Nitrate-N in Soil Water

Even though NO_3-N concentrations in the soil water at the 5 and 7.5-foot depths were quite variable, the concentrations were increased consistently at the 5-foot depth from about 2 to 3 mg/L for the 0-lb N rate to about 20 mg/L for the 150-lb rate (Table 7). Little difference in NO_3-N concentration was found between the PP, split, and sidedress N treatments. Nitrate-N at 5 feet was consistently higher for the biennial application of manure compared to the annual application. The opposite was true at 7.5'. At the 7.5' depth, NO_3-N ranged from about 1.5 to 2 mg/L for the 0-lb N rate to about 17 mg/L for 120-lb N rate. Nitrate-N concentrations for the two manure treatments at the end of four years fell between the concentrations found for the 60 and 90-lb fertilizer N rates.

Table 6. Soil NO_3-N concentrations in the 0-8' soil profile after harvest as influenced by fertilizer N and manure treatments in 1995.

Trt.	Treatment		Depth (ft)								
No.	N rate	Time	0-1'	1-2'	2-3'	3-4'	4-5'	5-6'	6-7'	7-8'	0-8'
	lb/A		- - - Nitrate N-Conc (ppm) - - -								lb/A
1	0	0	3.0	1.0	0.7	0.9	1.2	1.3	1.6	1.8	45
2	60	PP	4.5	2.6	1.8	2.7	2.5	2.4	2.1	1.9	82
3	90	PP	5.4	3.0	2.4	3.0	3.4	2.7	2.8	3.2	103
4	120	PP	4.7	3.4	4.1	4.0	4.0	3.4	3.1	3.1	119
5	150	PP	7.2	5.4	7.4	6.5	5.2	4.9	4.5	5.4	186
6	60 + 30	Split	6.0	2.8	2.2	2.9	3.5	3.0	2.7	3.0	104
7	60 + 60	Split	5.8	3.6	4.1	4.9	4.6	4.3	4.0	3.5	138
8	90	SD	5.5	4.0	3.5	3.6	3.1	3.1	2.6	2.9	113
9	Annual	PP	5.4	2.6	2.2	2.9	3.6	3.3	3.0	3.0	104
10	Biennial	PP	4.5	2.0	1.2	2.2	2.9	3.0	2.6	2.0	81
Treatment statistical analysis											
P > F:			0.04	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
LSD (.10):			1.7	1.3	1.8	1.5	1.3	1.1	0.9	0.6	31
CV (%):			28.	36.	50.	37.	31.	30.	26.	18.	24.

Table 7. Nitrate-N concentration in the soil water at the 5' and 7.5' depths as influenced by nitrogen and manure treatments in 1995.

Trt.	Treatment		Date			
No.	N rate	Time	5/26	7/18	8/10	10/13
	lb/A					
			- - - NO_3-N (mg/L) at 5' - - -			
1	0	-	2.6 (1.0) [1/]	3.6 (0.7)	3.5 (0.8)	2.2 (1.1)
2	60	PP	7.0 (1.4)	7.5 (1.3)	-	7.7 (0.2)
3	90	PP	8.5 (0.6)	11.1 (1.8)	10.6 (2.0)	13.4 (3.2)
4	120	PP	18.1 (6.8)	26.3 (4.7)	17.9 (4.9)	14.9 (3.2)
5	150	PP	20.1 (9.4)	17.9 (5.3)	18.5 (5.0)	-
6	60 + 30	Split	-	21.4 (7.4)	19.6 (6.6)	-
7	60 + 60	Split	16.8 (5.6)	12.3 (4.9)	17.9 (6.2)	-
8	90	SD	12.2 (4.8)	12.4 (4.8)	12.6 (4.5)	9.3 (0.8)
9	Annual	PP	12.1 (7.3)	10.2 (6.1)	13.5 (9.2)	11.6 (3.4)
10	Biennial	PP	15.4 (5.3)	13.6 (4.7)	15.8 (5.0)	19.2 (2.9)
			- - - NO_3-N (mg/L) at 7.5' - - -			
1	0	-	1.8 (1.1)	-	1.7 (0.5)	1.5 (0.9)
2	60	PP	5.6 (1.4)	5.1 (1.1)	5.6 (1.3)	5.9 (0.2)
3	90	PP	14.0 (1.9)	14.0 (2.8)	13.6 (2.9)	-
4	120	PP	18.3 (2.8)	17.4 (2.9)	16.2 (2.0)	16.6 (3.0)
9	Annual	PP	8.8 (5.8)	9.4 (6.8)	13.8 (8.8)	9.3 (6.4)
10	Biennial	PP	5.9 (1.9)	7.0 (1.0)	5.8 (0.8)	5.8 (0.6)

[1/] ( ) = Standard error of the mean.

MUNICIPAL SOLID WASTE COMPOST USE ON IRRIGATED COARSE TEXTURED SOILS[1]

M. MAMO, C.J. ROSEN, T.R. HALBACH, AND J.F. MONCRIEF[2]

ABSTRACT

Two field experiments were conducted at Becker to assess corn yield and nitrate leaching on soils amended with municipal solid waste (MSW) compost. The MSW composts (Truman and Swift) were applied in the spring of 1992. The compost rates were 0, 20, 40, and 80 dry T/A with either 0, or 220 lbs N//A split applied as urea. In 1993 at Becker, MSW compost was also applied on new plots to evaluate the effect of split vs one time application. The compost rate was 40 T/A (yearly application) and 120 T/A (one time application) with either 0, 110, or 220 lbs N/A split applied as urea. In 1995, yield in the 1992 established plots was relatively higher on residual MSW compost plots compared to the control. The 1993 established plot gave a significantly higher grain yield at all compost rates compared to the nonamended control. In the nonamended control plots, response to N fertilizer was significant up to 220 lbs N/A. Providing N at a rate higher than 110 lbs N/A on compost amended soil did not significantly increase grain yield. Without N application, the yearly compost application gave significantly higher grain yield compared to the one time compost application. In 1995, nitrate leaching did not increase on compost amended soils compared to nonamended fertilized control.

INTRODUCTION

Limited storage capacity of landfills, failure to meet regulatory guidelines, and increasing operating costs has prompted research into alternative methods of waste management. Composting of municipal solid waste (MSW) has been considered as one alternative to landfilling. In addition, composting involves resource conservation and recycling and the final product can be marketable. The benefits of adding organic matter to maintain soil productivity and soil quality are well known. Thus, MSW compost can be used in soil as a potential source of organic matter. Composting transforms organic materials into a stabilized organic matter which can be applied to agricultural land to improve soil fertility. However, improvements in soil fertility from compost is dependent on the quality and quantity of compost.

Compost supplies essential plant nutrients such as nitrogen, phosphorus, and sulfur, of which nitrogen is of main interest. Since, a large fraction of the nitrogen in the compost is organic, the release of the nitrogen into the inorganic form is necessary before plants can use it. If a large amount of inorganic nitrogen is released from the compost, the potential for nitrate to contaminate the ground water is high unless the commercial inorganic fertilizer application rate is adjusted accordingly. Therefore, the estimation and prediction of nitrogen release potential are key factors for the efficient use of compost nitrogen with respect to environmental quality and crop profitability.

The overall goals of this project were: 1) to determine residual effects of MSW compost on corn production, and soil chemical and physical properties 2) to compare annual split with one time MSW compost application, 3) to monitor levels of nitrate in soil water, and 4) to assess if any water stress is induced by compost amendments on plants.

MATERIALS AND METHODS

To accomplish the above goals, two field experiment were established at the Sand Plain Research Farm in Becker on a Hubbard loamy sand. The first experiment was established in 1992, and the second in 1993.

1995 Becker Compost Utilization Project (established in 1992)

- The treatments for the 1992 established experiment are listed in Table 1. MSW compost was applied only in the first year. Nitrogen fertilizer was applied every year.

[1] Support for this project was provided by the Minnesota Pollution Control Agency (MPCA) and Prairieland Composting Facility. Their support is greatly appreciated.

[2] M. Mamo, C.J. Rosen, T.R. Halbach, and J.F. Moncrief are Graduate student, Professor, Extension Specialist, and Professor, respectively.

- Corn variety 3921 Pioneer (85 day) was planted May 10, 1995 at a planting rate of 30,700 kernels per acre in 30" rows with starter fertilizer banded at 160 lbs N/A (8-10-30).
- Granular fertilizer urea 46-0-0 was split applied: one-half on 5/25/95 and the other half on 6/16/95. The urea was sidedressed with a Gandy applicator on either sides of each row and irrigated in with 0.5-1" of water for incorporation.
- Solid set irrigation was provided according to the check book method.
- Four whole plant samples were taken from each plot for chemical analysis on 6/21/95.
- Ear leaf samples were taken on 7/28/95 for chemical analysis.
- Soil water samples from suction cups at 3 feet were taken weekly throughout the season.
- The middle two 20 feet of row were harvested for grain and stover on 10/5/95 and 10/12/95, respectively.

1995 Becker Compost Utilization Project (established in 1993)

- The treatments for the 1993 established experiment are listed in Table 2. MSW compost was applied either annually for three consecutive years (1993-1995) or at one cumulative rate the first year (1993). Nitrogen fertilizer was applied every year at 0, 110, and 220 lbs N/A.
- Corn variety 3921 Pioneer (85 day) was planted May 10, 1995 at a planting rate of 30,700 kernels per acre in 30" rows with starter fertilizer banded at 160 lbs N/A (8-10-30).
- Granular fertilizer urea 46-0-0 was split applied: one-half on 5/25/95 and the other half on 6/16/95. The urea was sidedressed with a Gandy applicator on both sides of each row and irrigated with 0.5-1" of water for incorporation.
- Solid set irrigation was provided according to the check book method.
- Four whole plant samples were taken from each plot for chemical analysis on 6/21/95.
- Ear leaf samples were taken on 7/28/95 for chemical analysis.
- Soil water samples from suction cups at 4 feet were taken weekly throughout the season.
- The middle two 15 feet of row were harvested for grain and stover on 10/5/95 and 10/12/95, respectively.

Plant Water Stress Measurement

- The plant water status console was used to measure water stress. The console measures the negative pressure or tension with which water is held in the plant. The console is equipped with a gauge, a cylinder containing compressed N_2 gas, and a chamber with a lid where leaf is placed.
- Leaf facing direct solar radiation was excised and held between wet paper towel (to avoid water loss). Leaf was placed in pressure bomb chamber with the end tip exposed to the outside. Pressure was exerted until the end tip of the leaf withdraws or loses droplets of sap. A magnifying glass was used to help detect the first sap droplets from the leaf. The pressure at which the first water droplet was detected corresponded to the tension at which water was held by the plant.

RESULTS

1992 established experiment-residual effect (Becker , MN):

YIELD

When N fertilizer was not applied, grain yield was higher at all compost rates compared to the control (Table 3). The residual effect of MSW compost still remained in 1995. Grain yield of residual compost with optimum N rate was higher than the control at the same N rate. The highest grain yields were obtained when compost rate was supplied with optimum N fertilizer rate (220 lbs N/A). Stover yield was also increased when fertilizer was applied with the compost treatments.

SOIL WATER NITRATE

Soil water NO_3-N was generally high for the 20 T/A Truman compost with no N application (Figs. 1a, and b). Unlike 1994, all compost rate at the 220 lbs N/A did not result in higher NO_3-N loss than the 0 lbs N/A. However, Compared to the control with N, the compost rates at 20, 40, and 80 T/A did not increase the leaching losses of NO_3-N. Figure 1c shows NO_3-N leaching of Swift compost amended with or without fertilizer N. Addition of N fertilizer increased NO_3-N leaching throughout the growing season. The Swift compost without N fertilizer had much lower NO_3-N leaching. The latter suggests that most of the N lost comes from the added commercial fertilizer.

1993 established experiment-residual effect and annual application (Becker, MN)

YIELD

Grain and stover yields were much higher for all compost rates with no N application compared to yield from the control with no compost and N application (Table 4). The higher grain and stover yield of the compost with no N suggests residual compost effect. Without N applied, grain yield at a rate of 120 T/A compost was similar for both composts. With no N application, the split application of MSW compost improved yield for both compost sources compared to the one rate of 120 T/A. The addition of inorganic fertilizer in the split compost application rate did not improve the yield significantly. With the exception of the nonamended control, the 220 lbs N/A did not improve yield significantly compared to the 110 lbs N/A.

SOIL WATER NITRATE

All rates of Truman and Wright composts at 0 lbs N/A had lower leaching losses compared to the 110 and 220 lbs N/A treatments (Figs. 2a, b, c, d, e, and f). Truman compost amended at 120 T/A with 110 lbs N/A generally gave higher NO_3-N losses compared to the annual rate of 40 T/A and the control. Wright compost amended in split at 40 T/A with 110 and 220 lbs N/A gave higher NO_3-N losses throughout most of the growing season compared to the Truman compost at the same rate.

PLANT MOISTURE STRESS

Water stress measurements were made on two clear and warm days (air temperature: A.M. = 75-80 °F, and P.M.= 85-95 °F). Unless of rain events, irrigation was not made before stress measurements. The mean leaf water potential with compost as the main effect is presented in Table 5. In the 1993 established experiment, compost type and measurement date were not significant. Plant moisture stress was significantly different between morning and afternoon measurements. None of the compost treatments were significantly different from the control.

Table 1. MSW compost treatments for the 1992 established experiment, Becker, MN.

Compost type	N rate LBS/A	Compost rate T/A
Control	0	0
Control	220	0
Control§	440	0
Truman	0	20
Truman	220	20
Truman	0	40
Truman	220	40
Truman§	440	40
Truman	0	80
Truman	220	80
Swift	0	40
Swift	220	40

§ The 440 lbs N/A was applied only in 1992 and 1993. In 1994 and 1995 0 lbs N/A was applied.

Table 2. MSW compost treatments for the 1993 established experiment, Becker, MN.

Compost type	**N rate LBS/A**	**Compost rate T/A**			
		1993	1994	1995	Total
Control	0	0	0	0	0
Control	110	0	0	0	0
Control	220	0	0	0	0
Truman	0	40	40	40	120
Truman	110	40	40	40	120
Truman	220	40	40	40	120
Truman	0	120	0	0	120
Truman	110	120	0	0	120
Truman	220	120	0	0	120
Wright	0	40	40	40	120
Wright	110	40	40	40	120
Wright	220	40	40	40	120
Wright	0	120	0	0	120
Wright	110	120	0	0	120
Wright	220	120	0	0	120

Table 3. Residual effect of compost type, compost rate, and nitrogen rate on grain yield, stover yield, and plant population on the 1992 field site in Becker, MN. 1995.

Compost type	**N rate LBS/A 1995**	**Compost rate T/A 1992**	**Grain Yield BU/A**	**Stover Yield T/A**	**Plant/A Population x 1000**
Control	0	0	68.6	3.54	23.6
Control	220	0	128.8	5.07	25.5
Control§	440	0	66.0	3.14	25.1
Truman	0	20	98.4	3.71	25.3
Truman	220	20	146.4	6.02	26.5
Truman	0	40	98.7	3.54	25.6
Truman	220	40	139.4	5.44	25.5
Truman§	440	40	83.0	3.71	24.3
Truman	0	80	113.8	4.25	24.4
Truman	220	80	142.4	5.54	24.9
Swift	0	40	115.0	4.36	25.3
Swift	220	40	142.8	5.55	25.6
Significance			**	**	††
LSD			28.9	1.51	2.4

§ The N rate at 440 lbs/A was applied only in 1992 and 1993.
†† Significant at 10% **Significant at 1% NS= Not significant

Table 4. Effect of compost type, compost rate, and nitrogen rate on grain yield, stover yield, and plant population at the 1993 established site-1995.

Compost type	**N rate LBS/A**	**Compost rate T/A**	**Grain Yield BU/A**	**Stover Yield T/A**	**Plant/A Population x 1000**
Control	0	0	78.2	1.63	21.1
Control	110	0	127.0	2.34	23.1
Control	220	0	149.5	3.09	25.4
Truman	0	40+40+40	136.0	2.42	22.5
Truman	110	40+40+40	142.8	2.78	22.5
Truman	220	40+40+40	147.0	3.19	24.4
Truman	0	120	116.8	1.66	21.1
Truman	110	120	145.2	2.75	23.7
Truman	220	120	153.2	2.89	24.3
Wright	0	40+40+40	145.3	2.70	23.7
Wright	110	40+40+40	142.5	2.92	23.1
Wright	220	40+40+40	152.9	3.10	24.8
Wright	0	120	117.7	1.89	22.4
Wright	110	120	152.7	3.06	24.1
Wright	220	120	166.8	2.84	24.4
Significance			**	**	**
LSD			14.8	0.39	2.4

**Significant at 1% NS= Not significant

Table 5. Plant moisture stress measured during the 1995 growing season on the 1993 established experiment, Becker, MN.

Compost type	**N rate LBS/A 1995**	**Compost rate T/A 1993-95**	**Leaf Water Potential⇑ MPa**	
			Date: 8/9/95	
			8:15-9:27 A.M.	1:10-2:20 P.M.
Control	220	0	0.69(0.09)	0.89(0.35)
Truman	220	40+40+40	0.75(0.16)	0.95(0.13)
Truman	220	120	0.67(0.12)	0.83(0.10)
Wright	220	40+40+40	0.74(0.11)	1.08(0.17)
Wright	220	120	0.75(0.07)	0.88(0.08)
			Date: 8/18/95	
			8:10-9:10 A.M.	12:00-1:05 P.M.
Control	220	0	0.51(0.11)	1.02(0.05)
Truman	220	40+40+40	0.52(0.12)	1.10(0.15)
Truman	220	120	0.52(0.07)	1.03(0.04)
Wright	220	40+40+40	0.56(0.08)	1.06(0.09)
Wright	220	120	0.51(0.08)	1.06(0.13)
Compost			NS	
Time			**	
Time*Compost			NS	
Date			NS	
Time*Date			**	
Compost*Date			NS	
Time*Compost*date			NS	

⇑Number in parentheses is standard deviation. Measurements made on clear days void of irrigation and precipitation.

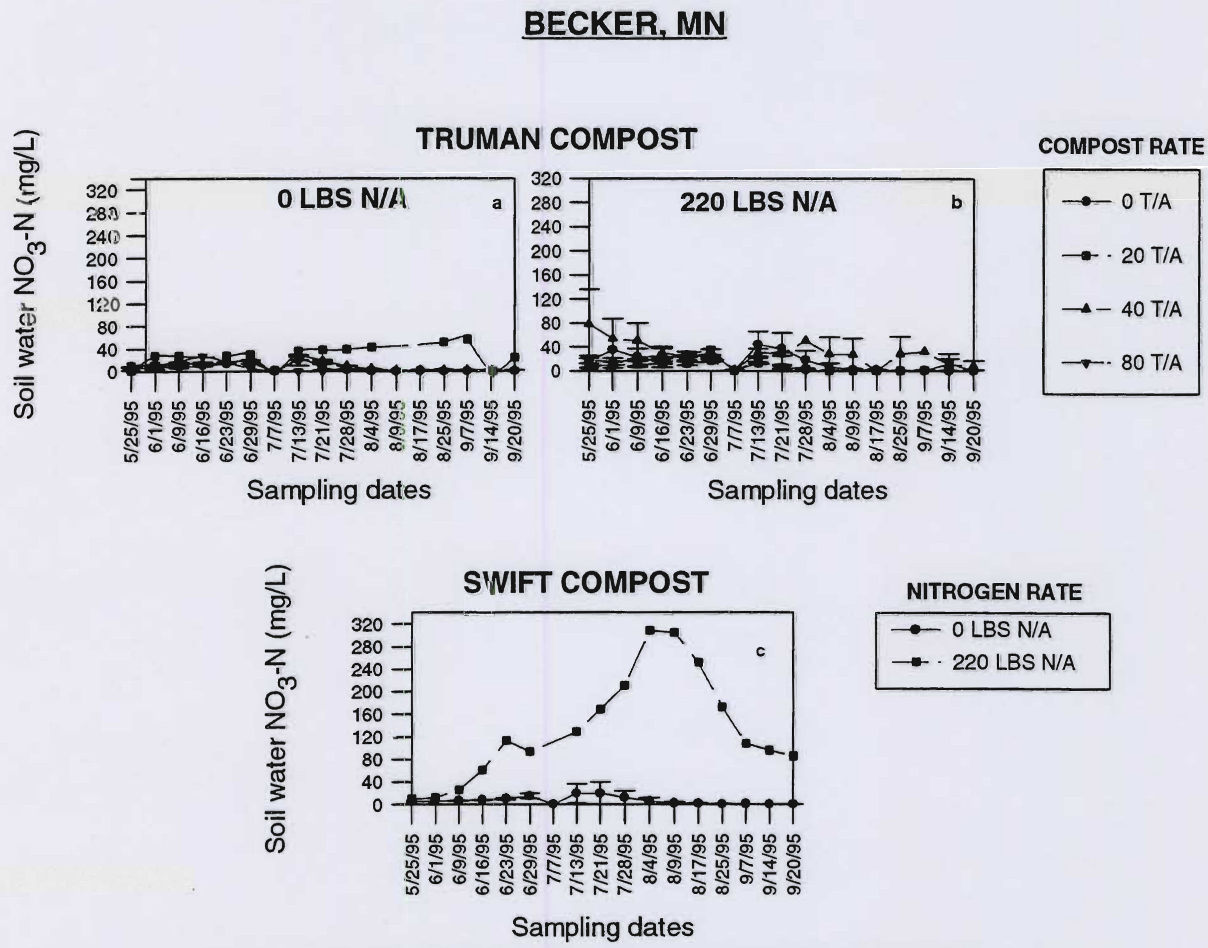
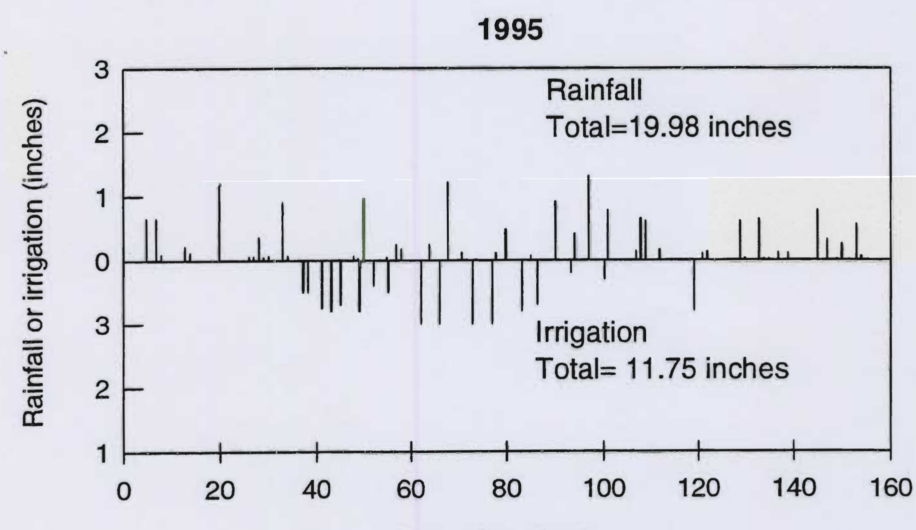


Fig. 1- SOIL WATER NITRATE-1995 GROWING SEASON Compost utilization plots established in 1992



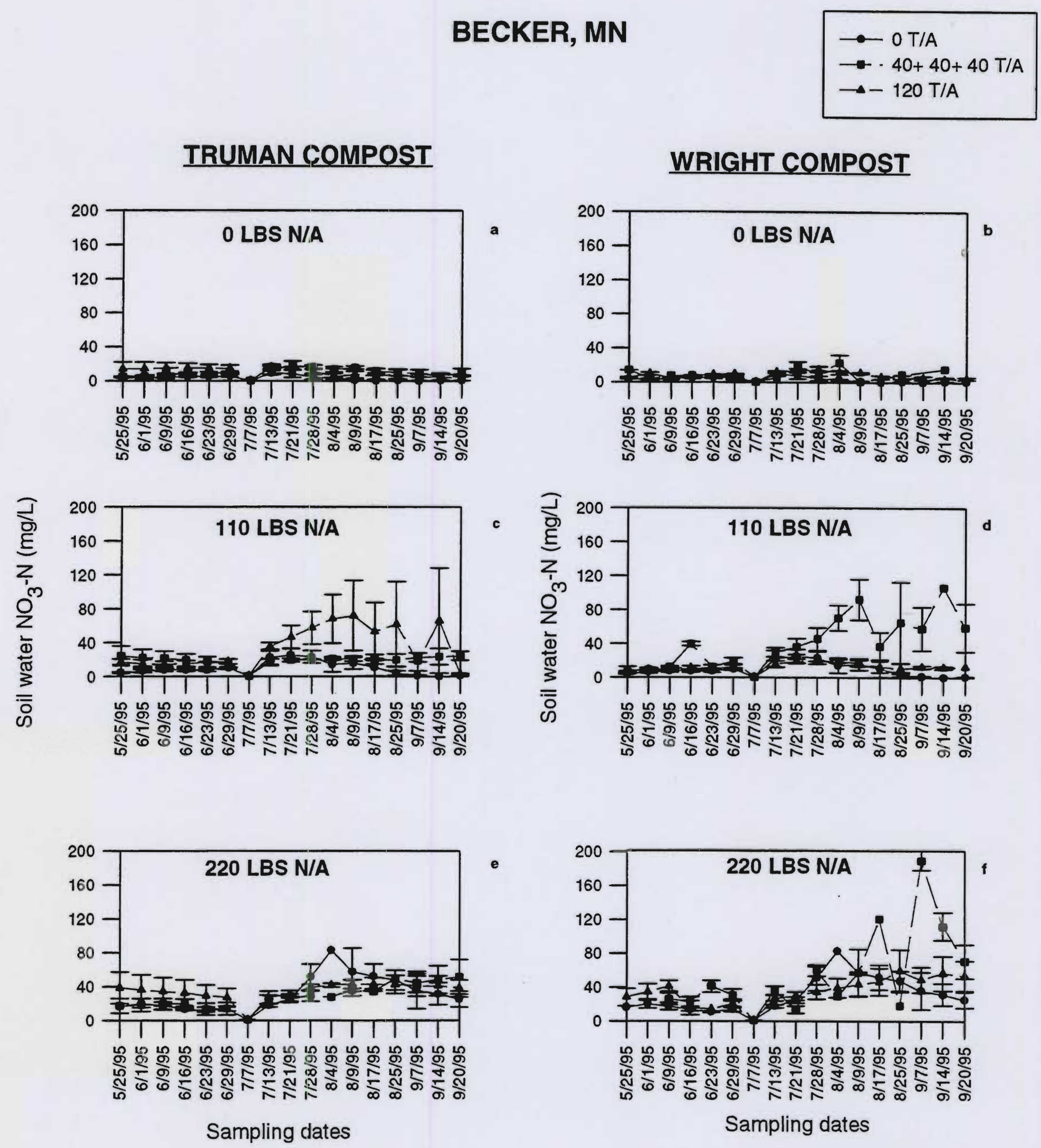


Fig. 2- SOIL WATER NITRATE- 1995 GROWING SEASON
Compost utilization plots established in 1993

LAND SPREADING OF YARD WASTE: RESIDUAL EFFECTS - 1995[1]

Carl Rosen, Thomas Halbach, Dave Birong, and Wenshan Wang[2]

ABSTRACT: The fourth year of a field experiment at the Sand Plain Research Farm in Becker, Minn. was conducted to determine the residual effects of land applied yard waste, primarily tree leaves, on corn production and soil nitrate movement. Four yard waste treatments (0, 20, 40, and 80 dry T/A) were applied during the fall of 1991. In 1995, treatments included the four rates of yard waste that were applied in 1991 with 0, 100, and 200 lbs N/A applied during the growing season. During the first year of the study, 1992, yard waste application initially inhibited growth and depressed tissue nitrogen concentration in the corn plants. The inhibitory effect diminished by the middle of the 1992 growing season and final grain yields were similar to 0 T/A yard waste treatment (with 200 lb N/A) when 200 lb N/A was applied to the yard waste treatments. During the second and third years of the study, 1993 and 1994, increases in growth and yield were greater with increasing yard waste application rates than with applied fertilizer N. Results in 1995 were similar to those in 1993 and 1994. In 1993 and 1994, 1 - 2 lbs of N per dry ton were supplied by the yard waste. In 1995, 0.5 lb N per dry ton was supplied by the yard waste. Yields in 1995 were optimized with a 40 ton/A yard waste application plus 100 lb N/A. Nitrate leaching tended to increase with fertilizer N application and yard waste application. Residual soil nitrate-N increased with increasing yard waste application and to a lesser extent with fertilizer N application. These results suggest: 1) Soil N was initially immobilized during the first year after yard waste application; and 2) Yard waste decomposition increased available N during the second, third, and fourth year after application.

Until recently, yard wastes (tree leaves and grass clippings) accounted for 15-20% of the bulk in landfills. In 1990 (metro counties) and in 1992 (greater Minnesota), regulations were passed that prohibited dumping of yard wastes in landfills. Because of this legislation, alternatives to landfilling yard waste need immediate attention. Some options for using or recycling the yard waste include: 1) backyard composting and application of the compost to gardens; 2) municipal composting followed by land application of the compost; and 3) direct land application of noncomposted yard waste. While backyard composting is a desirable way to handle yard waste, not all homeowners desire to compost their own yard waste. Several problems with municipal yard waste composting include finding an acceptable site, controlling nutrient runoff, and controlling odors. Direct land application of noncomposted yard waste may be more efficient than composting and does not have the same problems associated with composting. Land application of yard waste may require an adjustment of nitrogen requirements, because of its high carbon to nitrogen ratio. The effects of nitrogen application on crop production also needs to be ascertained. Therefore, the objectives of this study were to: 1) Determine the residual effects of direct application and incorporation of noncomposted yard waste (primarily tree leaves), with and without fertilizer nitrogen, on the productivity of irrigated field corn, and 2) Characterize nitrogen release from the yard waste during the growing season in terms of availability for crop needs and movement through the soil profile.

PROCEDURES

The experiment was conducted at the Sand Plain Research Farm in Becker, MN on a Hubbard loamy sand soil. This was the fourth year of the study, to determine the residual effects of applied yard waste. The yard waste was collected and applied to 15' x 35' plots with a front end loader in October of 1991. The yard waste primarily consisted of tree leaves, although some garden plants and grass clippings were also present. Twelve treatments were tested: 0, 20, 40, and 80 dry tons/A yard waste with 0, 100, and 200 lbs N/A. The experimental design was a randomized complete block with 4 replications.

The field was plowed to a depth of 8-10 inches two days prior to planting. In addition, 200 lbs/A 0-0-22 and 200 lbs/A 0-0-60 were broadcast and incorporated prior to planting. Pioneer hybrid 3751 (100 day maturity) was planted on May 10, 1995 at a population of 32,000 seeds/A (2.5 feet between rows). At planting, starter fertilizer was banded 2 inches to the side and 2 inches below the seed at a rate of 185 lbs/A 0-14-42. The nitrogen treated plots received split N applications as urea with half of the N applied on May 24 and the remainder on June 14, 1995. Irrigation was used to supplement rainfall (Figure 1).

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[1]Funding for this project was provided by the Legislative Commission for Minnesota Resources
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Suction tubes with ceramic cups were installed in the row at a depth of 4 feet in three replications of each treatment. Water samples were collected, after significant irrigation or precipitation events (greater than 0.5 inches), and analyzed for nitrate. Whole plant samples (4 per plot) were collected at the 8-12 leaf stage on June 21 after all fertilizer N was applied. Ear leaf samples were collected on July 28 at 50% silking. Two, 20 foot rows were harvested for grain and stover yield from each plot on October 5 and October 12, respectively. Subsamples of stover and grain plus cob were taken for moisture determinations and nitrogen analyses. Plant tissue samples were dried and then ground through a 30 mesh screen. Dried samples were digested in concentrated sulfuric acid and Kjeldahl nitrogen was determined using conductimetric procedures. After harvest, soil samples were collected from 0-6, 6-12, 12-24 and 24-36 inch depths. Soil nitrate was determined using 2 N KCl extracts.

RESULTS

Corn Growth and Yield: Initial corn growth increased with increasing rates of yard waste and nitrogen fertilizer (Table 1). The addition of yard waste also increased total yield indicating a significant release of nutrients during the fourth year after incorporation. Without added fertilizer nitrogen, each ton of yard waste increased yield by 0.75 to 1 bu/A. When nitrogen fertilizer was applied, the increase in yield per ton of yard waste was 0.25 to 0.5 bu per A. Yields were optimized when 40 ton/A yard waste and 100 lb N/A were applied. Yields with 40 ton/A yard waste and 100 lb N/A were greater than those with 200 lb N/A without yard waste. Reasons for this yield increase with yard waste over the fertilized controls appear to be due to more than a simple nitrogen response. Neither nitrogen application nor yard waste amendment affected the final stand count. Kernel moisture at harvest decreased with the addition of yard waste and nitrogen.

Tissue Nitrogen Concentrations and Total Nitrogen Uptake: At the 8-12 leaf stage, yard waste application tended to decrease tissue N concentration, presumably due to a dilution effect (Table 2). At the silking stage, yard waste amendment had no effect on ear leaf N concentrations. At harvest, yard waste application increased concentrations of N in stover and grain. Nitrogen uptake increased with increased rates of yard waste. Yard waste application supplied approximately 0.5 lbs N/dry ton over the growing season to the corn crop. The addition of N fertilizer also increased N uptake although the contribution from yard waste was about the same regardless of N rate. Except for cob tissue at harvest, N fertilizer increased tissue N concentrations at all growth stages with the application of fertilizer nitrogen.

Soil Nitrate-Nitrogen Content: Yard waste application increased residual nitrate-N in the soil (Table 3). The 80 T/A yard waste amendment, with or without fertilizer N, resulted in the highest residual nitrate-N content in the upper 3 ft of the soil. Fertilizer N application also increased residual nitrate-N content in the soil, but to a lesser extent than yard waste application. With leaching rainfall or over-irrigation the higher residual nitrate N content in the yard waste treatments may result in higher nitrate leaching losses.

Soil Water Nitrate Concentrations: Concentrations of nitrate-N in soil water, as affected by treatments, are presented in figures 2 - 13. Initial levels of nitrate-N in the water increased with increasing yard waste application. In most treatments, peak nitrate-N concentrations at the four foot depth occurred at about 10 weeks after planting, which corresponded to a week of high amounts of irrigation and rainfall. Yard waste application tended to increase nitrate-N concentrations in soil water at the four foot depth when fertilizer N was not applied. Variation in nitrate-N concentration within treatments, became more pronounced as fertilizer application rates increased. Fertilizer application had a greater effect on increasing nitrate-N concentrations than yard waste application. Yard waste applications with 0 or 100 lb N/A applied resulted in lower nitrate-N concentrations compared to the treatment where no yard waste applied with 200 lb N/A. Nitrate concentrations in soil water from treatments receiving yard waste and 200 lb N/A were similar to those in the 200 lb N/A treatment without yard waste. Higher levels of nitrate-N earlier in the season with the yard waste application may result in higher risk of nitrate leaching; however, concentrations of nitrate in the soil water with the fertilized control at the recommended rate were higher than those with 40 ton/A yard waste with 100 lb N/A (the optimized yield treatment). These results suggest that if N rate is adjusted to yard waste application, leaching losses would be no greater than the fertilized control.

Table 1. Effect of yard waste and nitrogen application on whole plant dry matter at the 8-12 leaf stage, final stand count, grain yield, and kernel moisture.

Yard waste rate	Nitrogen application	Whole plant dry matter (8-12 leaf)	Final stand count	Grain yield	Kernel moisture
-tons/A-	--lbs/A--	-grams/plant-	-plants/A-	-bu/A-	- % -
0	0	3.4	25918	42	32
20	0	5.9	25700	65	29
40	0	7.0	25918	90	28
80	0	8.3	26463	102	26
0	100	8.5	25156	126	25
20	100	11.3	25809	145	25
40	100	12.8	26027	166	25
80	100	13.0	25483	164	25
0	200	9.5	25374	140	24
20	200	11.3	25156	158	24
40	200	12.4	24720	164	24
80	200	13.1	26245	167	24
Significance		**	NS	**	**
BLSD (5%)		2.0	--	15	2
Main effects					
	Yard Waste Rate				
	0	7.1	25483	103	27
	20	9.5	25555	123	26
	40	10.7	25555	140	26
	80	11.5	26063	145	25
	Significance	**	NS	**	++
	BLSD (5%)	1.1	--	9	2
	Linear	**	NS	**	**
	Quadratic	**	NS	**	NS
	Nitrogen Application				
	0	6.1	26000	75	29
	100	11.4	25619	150	25
	200	11.6	25374	157	24
	Significance	**	NS	**	**
	BLSD (5%)	1.0	--	7	1
Interaction					
	Yard Waste x Nitrogen	NS	NS	NS	++

NS = nonsignificant, ++ = significant at 10%, ** = significant at 1%.

Table 2. Effect of yard waste and nitrogen application on nitrogen concentrations, dry matter accumulation, and nitrogen content.

Yard waste rate	Nitrogen application	Whole plant N 8-12 leaf stage	Ear leaf N silking stage	Nitrogen Concentration Cob	Nitrogen Concentration Stover	Nitrogen Concentration Grain	Dry Mass Cob	Dry Mass Stover	Dry Mass Grain	Dry Mass Total	Nitrogen Content Cob	Nitrogen Content Stover	Nitrogen Content Grain	Nitrogen Content Total
-tons/A-	--lbs/A--	-------- % Nitrogen --------		--- % Nitrogen ---			--------- Ton/A ---------				-------- lb N/A ---------			
0	0	3.29	1.43	0.78	0.34	0.93	0.15	0.89	1.18	2.32	2.4	6.1	22.0	30.5
20	0	3.05	1.80	0.66	0.32	0.95	0.21	1.14	1.82	3.17	2.8	7.4	34.5	44.7
40	0	3.11	1.50	0.62	0.29	0.99	0.29	1.46	2.52	4.27	3.5	8.5	50.1	62.1
80	0	3.01	1.63	0.53	0.35	0.99	0.26	1.81	2.87	4.94	2.8	13.0	57.1	72.9
0	100	3.98	2.30	0.55	0.38	1.05	0.36	2.30	3.52	6.18	4.0	18.2	74.9	97.1
20	100	3.87	2.62	0.54	0.37	1.21	0.43	2.51	4.06	7.00	4.4	19.1	98.6	122.1
40	100	3.88	2.70	0.51	0.41	1.27	0.50	3.04	4.65	8.19	5.2	25.7	118.7	149.6
80	100	3.84	2.51	0.43	0.50	1.30	0.50	2.90	4.59	7.99	4.2	29.6	119.1	152.9
0	200	4.03	3.01	0.54	0.64	1.31	0.43	2.48	3.92	6.83	4.7	31.5	103.1	139.3
20	200	3.96	3.10	0.52	0.56	1.40	0.46	2.61	4.42	7.49	4.8	29.3	123.9	158.0
40	200	4.01	3.09	0.49	0.62	1.40	0.53	2.44	4.60	7.57	5.1	30.5	129.0	164.6
80	200	3.82	2.98	0.48	0.65	1.39	0.56	3.20	4.69	8.45	5.4	43.0	130.6	179.0
Significance		**	**	**	**	**	**	**	**	**	**	**	**	**
BLSD (5%)		0.17	0.44	0.07	0.10	0.10	0.06	0.52	0.42	0.78	0.9	9.4	14.5	19.8
<u>Main effects</u>														
<u>Yard Waste Rate</u>														
0		3.77	2.24	0.62	0.46	1.10	0.31	1.89	2.87	5.07	3.7	18.6	66.7	89.0
20		3.63	2.51	0.57	0.42	1.19	0.37	2.08	3.43	5.88	4.0	18.6	85.7	108.3
40		3.67	2.43	0.54	0.44	1.22	0.44	2.32	3.92	6.68	4.6	21.6	99.2	125.4
80		3.56	2.37	0.48	0.50	1.23	0.44	2.64	4.05	7.13	4.1	28.5	102.3	134.9
Significance		**	NS	**	++	**	**	**	**	**	**	**	**	**
BLSD (5%)		0.11	--	0.04	0.07	0.06	0.04	0.31	0.24	0.46	0.5	5.8	8.5	11.6
Linear		**	NS	**	++	**	**	**	**	**	++	**	**	**
Quadratic		NS	NS	NS	++	*	**	NS	**	*	**	NS	**	*
<u>Nitrogen Application</u>														
	0	3.12	1.59	0.65	0.33	0.97	0.23	1.33	2.10	3.66	2.9	8.7	40.9	52.5
	100	3.89	2.53	0.51	0.42	1.21	0.45	2.69	4.20	7.34	4.5	23.1	102.8	130.4
	200	3.96	3.04	0.51	0.62	1.38	0.49	2.68	4.41	7.58	5.0	33.6	121.6	160.2
Significance		**	**	**	**	**	**	**	**	**	**	**	**	**
BLSD (5%)		0.08	0.21	0.04	0.05	0.05	0.03	0.25	0.21	0.39	0.4	4.5	7.2	9.8
<u>Interaction</u>														
Yard Waste x Nitrogen		NS	NS	++	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS = nonsignificant, ++ = significant at 10%, * = significant at 5%, ** = significant at 1%.

Table 3. Effect of yard waste and nitrogen application on soil nitrate-N (lbs/A) in the top three feet at the end of the growing season.

Yard waste rate	Nitrogen application	Sample depth (inches) 0 - 6	6 - 12	12 - 24	24 - 36	Total
-tons/A-	--lbs/A--	lbs nitrate-N/A				
0	0	2.15	1.61	2.95	2.54	9.25
20	0	2.62	1.59	2.61	2.18	9.00
40	0	3.61	2.61	4.57	3.46	14.25
80	0	4.62	3.54	5.76	3.43	17.35
0	100	3.45	3.31	4.49	2.13	13.38
20	100	3.90	3.29	6.48	3.21	16.88
40	100	4.30	5.15	7.48	3.12	20.05
80	100	6.92	9.40	11.14	4.16	31.62
0	200	3.73	3.66	5.39	4.04	16.82
20	200	4.00	7.45	15.68	9.55	36.68
40	200	4.32	6.57	14.89	10.19	35.97
80	200	8.27	10.03	15.02	9.93	43.25
Significance		**	**	**	**	**
BLSD (5%)		1.83	4.11	6.44	2.76	12.87
Main effects						
Yard Waste Rate						
0		3.11	2.86	4.28	2.90	13.15
20		3.51	4.11	8.26	4.98	20.86
40		4.08	4.78	8.98	5.59	23.43
80		6.60	7.66	10.64	5.84	30.74
Significance		**	**	**	**	**
BLSD (5%)		1.00	2.25	3.77	1.70	7.34
Linear		**	**	**	**	**
Quadratic		++	NS	NS	*	NS
Nitrogen Application						
0		3.25	2.34	3.97	2.90	12.46
100		4.64	5.29	7.40	3.15	20.48
200		5.09	6.92	12.74	8.43	33.18
Significance		**	**	**	**	**
BLSD (5%)		0.90	1.86	2.92	1.31	6.01
Interaction						
Yard Waste x Nitrogen		NS	NS	NS	++	NS

NS = nonsignificant, ++ = significant at 10%, * = significant at 5%, ** = significant at 1%.

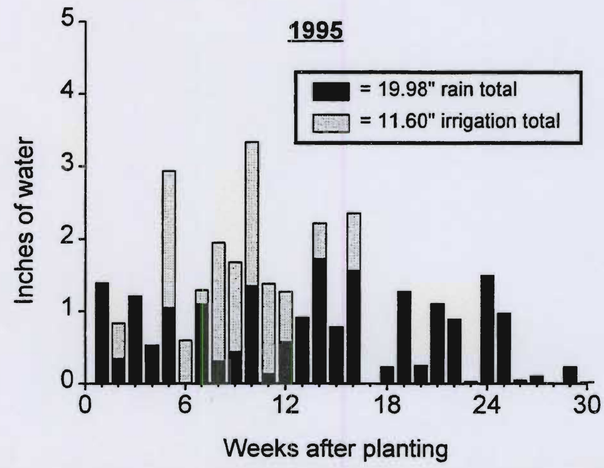

Figure 1. Rainfall and irrigation during the 1995 growing season.

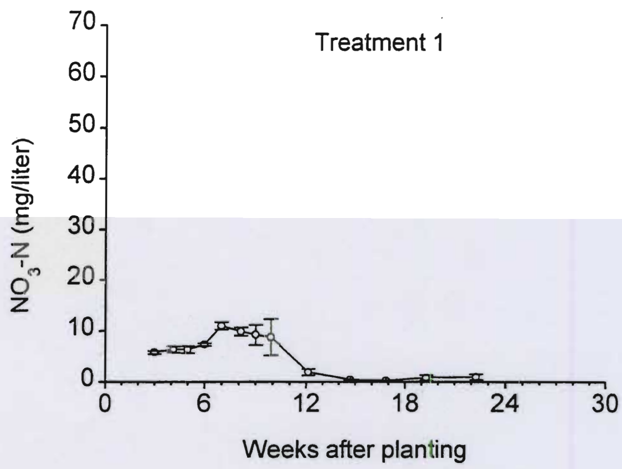

Figure 2. Nitrate-N concentration in soil water sampled at the 4 ft. depth over the 1995 growing season. Treatment 1: no leaves, no nitrogen applied. Error bars represent SE of the mean.

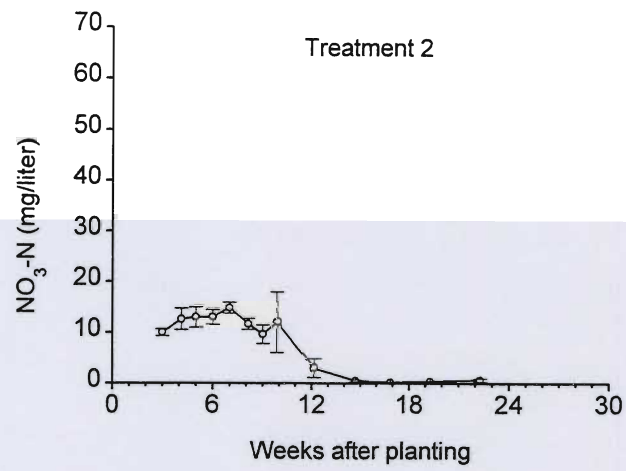

Figure 3. Nitrate-N concentration in soil water sampled at the 4 ft. depth over the 1995 growing season. Treatment 2: 20 tons/A leaves, no nitrogen applied. Error bars represent SE of the mean.

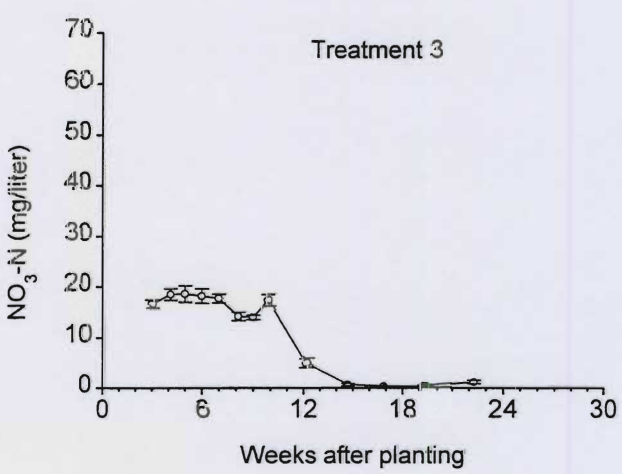

Figure 4. Nitrate-N concentration in soil water sampled at the 4 ft. depth over the 1995 growing season. Treatment 3: 40 tons/A leaves, no nitrogen applied. Error bars represent SE of the mean.

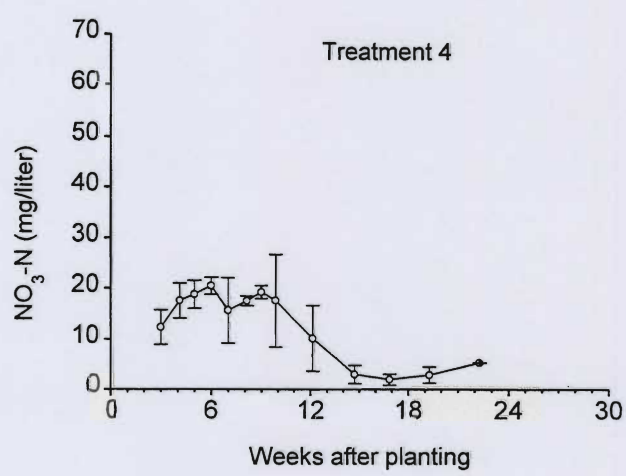

Figure 5. Nitrate-N concentration in soil water sampled at the 4 ft. depth over the 1995 growing season. Treatment 4: 80 tons/A leaves, no nitrogen applied. Error bars represent SE of the mean.

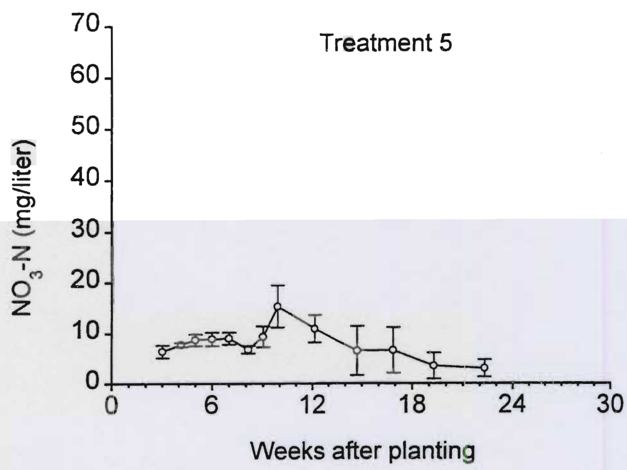

Figure 6. Nitrate-N concentration in soil water sampled at the 4 ft. depth over the 1995 growing season. Treatment 5: no leaves, 100 lbs/A nitrogen applied during the growing season. Error bars represent SE of the mean.

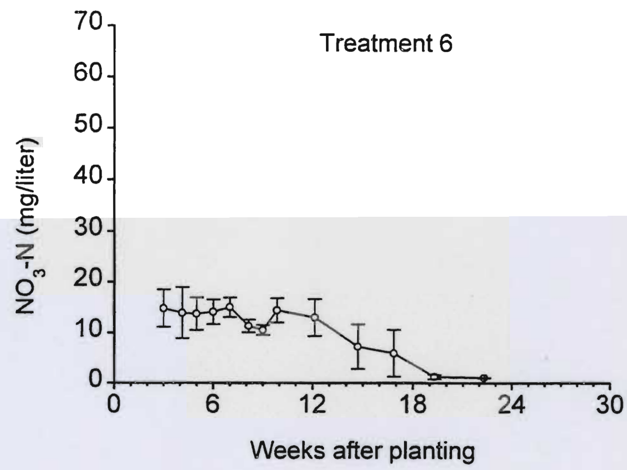

Figure 7. Nitrate-N concentration in soil water sampled at the 4 ft. depth over the 1995 growing season. Treatment 6: 20 tons/A leaves, 100 lbs/A nitrogen applied during the growing season. Error bars represent SE of the mean.

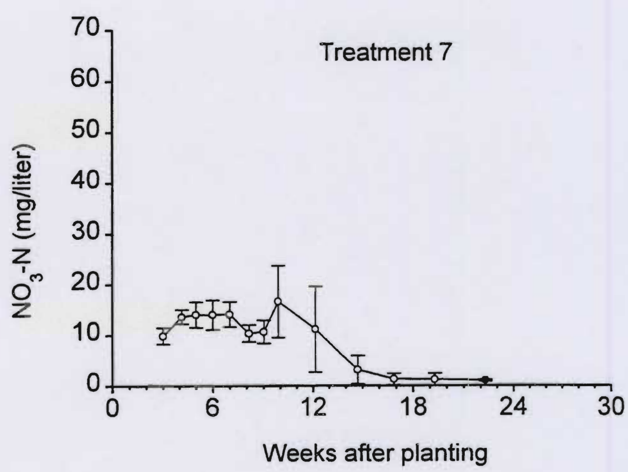

Figure 8. Nitrate-N concentration in soil water sampled at the 4 ft. depth over the 1995 growing season. Treatment 7: 40 tons/A leaves, 100 lbs/A nitrogen applied during the growing season. Error bars represent SE of the mean.

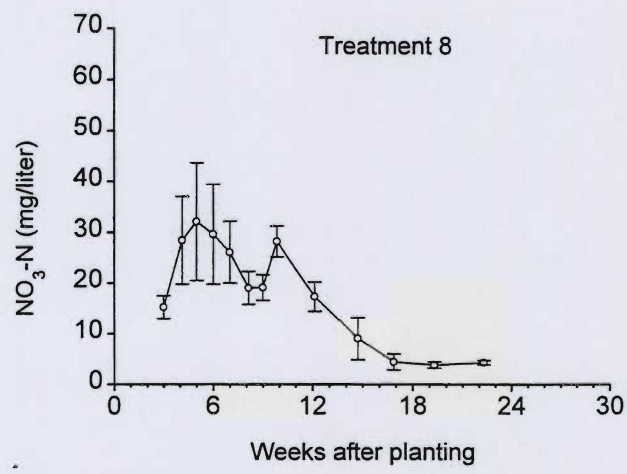

Figure 9. Nitrate-N concentration in soil water sampled at the 4 ft. depth over the 1995 growing season. Treatment 8: 80 tons/A leaves, 100 lbs/A nitrogen applied during the growing season. Error bars represent SE of the mean.

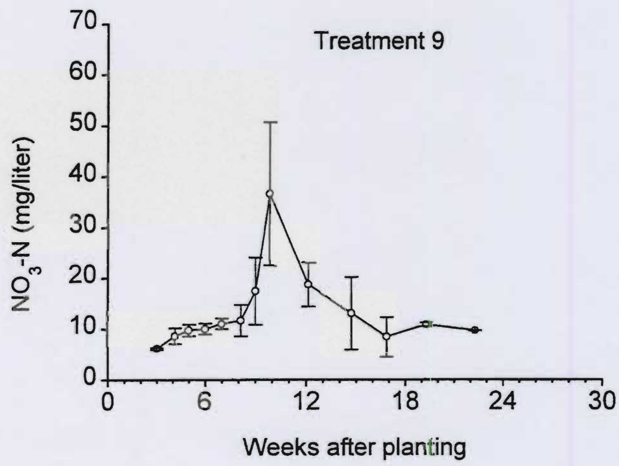

Figure 10. Nitrate-N concentration in soil water sampled at the 4 ft. depth over the 1995 growing season. Treatment 9: no leaves, 200 lbs/A nitrogen applied during the growing season. Error bars represent SE of the mean.

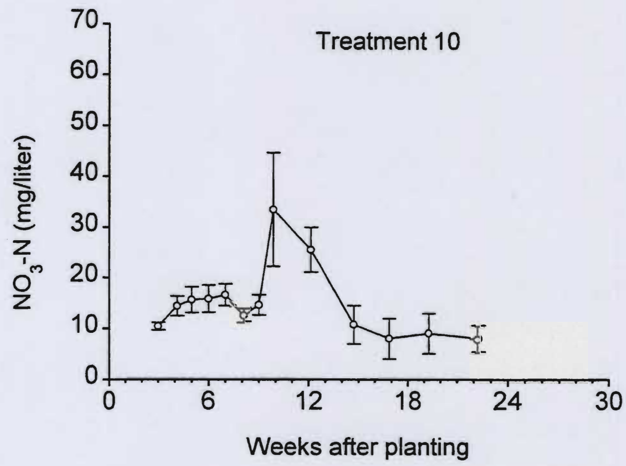

Figure 11. Nitrate-N concentration in soil water sampled at the 4 ft. depth over the 1995 growing season. Treatment 10: 20 tons/A leaves, 200 lbs/A nitrogen applied during the growing season. Error bars represent SE of the mean.

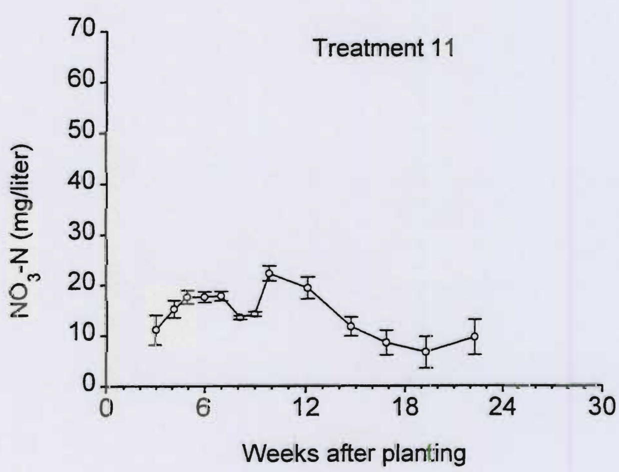

Figure 12. Nitrate-N concentration in soil water sampled at the 4 ft. depth over the 1995 growing season. Treatment 11: 40 tons/A leaves, 200 lbs/A nitrogen applied during the growing season. Error bars represent SE of the mean.

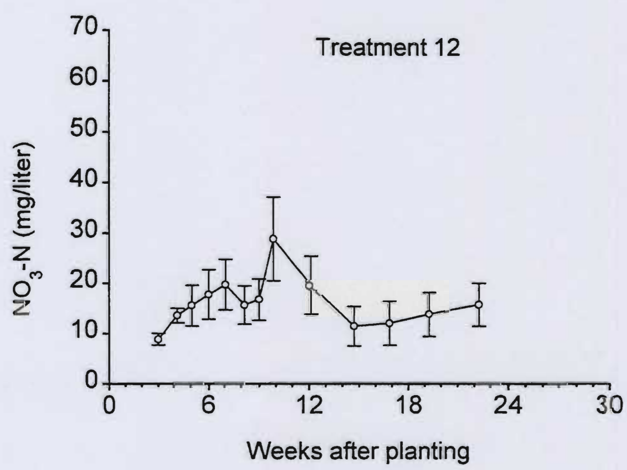

Figure 13. Nitrate-N concentration in soil water sampled at the 4 ft. depth over the 1995 growing season. Treatment 12: 80 tons/A leaves, 200 lbs/A nitrogen applied during the growing season. Error bars represent SE of the mean.

EVALUATION OF MUNICIPAL SEWAGE/PAPER MILL SLUDGE AS A SOIL AMENDMENT IN CROPPING SYSTEMS

Russell D. Mathison[1]

Abstract

Research was conducted at Grand Rapids, MN to evaluate the agronomic benefits and environmental impact of applying municipal sludge (in this case essentially paper mill sludge) to cropping systems. Sludge appears to reduce oat, alfalfa and weed seedling germination and seeding year plant growth if the material is applied immediately prior to seeding. However, sludge applied one year ahead of seeding did not adversely affect seedling performance. Municipal sludge seems to benefit crop production on coarse-textured soils during dry periods by increasing moisture holding capacity via the addition of organic matter. Municipal sludge also elevates soil pH which is especially useful in the production of pH sensitive crops, such as alfalfa. This study did not appear to identify any adverse environmental impacts associated with applying municipal sludge to cropping systems.

Introduction

Grand Rapids municipal sludge, a mixture of approximately 90 percent paper mill sludge from Blandin Paper Company and 10 percent municipal sludge from the city of Grand Rapids is currently being landfilled. This disposal method may not be the best use of a potentially beneficial organic product or a sound disposal method from an environmental or economic perspective. Sludge may benefit cropping systems because it contains a high percentage of organic matter that could benefit crop production, especially on coarse textured soils such as found in northeast Minnesota, by increasing soil tilth and nutrient and water holding capacity. Sludge also contains some plant nutrients, primarily nitrogen, phosphorous and potassium.

This research study was initiated at the North Central Experiment Station in 1994 to evaluate the agronomic benefits and environmental impacts of applying Grand Rapids municipal sludge to agricultural cropping systems. Funding for this project was provided by the city of Grand Rapids. Establishment of the study, data collection and analysis of results were a joint effort between Environmental Land Management, Eagan, MN and the North Central Experiment Station, University of MN, Grand Rapids, MN.

Materials and Methods

A randomized complete block experiment with four replications was established 24 May, 1994 at the North Central Experiment Station, University of Minnesota, Grand Rapids. Sludge application rates were determined by calculating available N using formulas developed by the Minnesota Pollution Control Agency (MPCA). Sludge application rates based on available N were used because the nitrogen economy of soils to which sludge has been added will likely affect crop production the most for two reasons: N is needed to fuel the decomposition of organic compounds in the sludge and is also a nutrient frequently added to nonleguminous cropping systems to achieve maximum yield. The sludge application rates used should add approximately 27, 53 and 106 lb/a of N to the soil with the 53 lb/a rate being a common amount in normal small grain production systems. The lower and higher sludge rates were included to develop a response curve. Also included was a treatment containing ash from Blandin's Co-Generation facility because it is currently being successfully used in alfalfa cropping systems and the mixture of sludge and ash may be superior to either component alone.

Treatment materials were hand-applied to 10 x 20 ft plots, then incorporated with a field cultivator and spike-toothed harrow. Valley oats @2.5 bushels per acre and Oneida alfalfa @ 20 lb/acre were seeded 26 May. Prior to seeding, check plots in the oat area received 300 lb/a of 11-5-40 and 100 lb/a of 46-0-0. Check plots in the alfalfa area received 300 lb/a of sul-po-mag (22-18-22). All commercial fertilizer was applied using a 10 ft Gandy broadcast fertilizer spreader. Eptam pre-emergence herbicide was applied at 3 lb/a to the alfalfa area on 25 May. The alfalfa seeding was not uniform due to an equipment malfunction, so the area was reseeded 10 June. Data collected on oats included: percent stand, percent weeds and plant height. Alfalfa data included: percent stand, percent weeds, dry matter yield, soil and plant tissue analysis. In 1995, the plot area containing oats in 1994 was reseeded to an oat/alfalfa mixture to investigate the effects of applying sludge one year prior to planting. Troy oat and Oneida alfalfa were seeded 18 May at 2 bu/a and 15 lb/a, respectively. Plant height and forage dry matter yield data was taken 18 July when oat was in the boot stage. No alfalfa forage dry matter yield data from the new seeding was collected in 1995, however forage yield and plant tissue elemental analysis data was collected from the 1994 alfalfa seeding. Statistical analysis of data was performed using MSTAT statistical software. Statistical differences, when detected, were separated using Fisher's LSD and Duncan's multiple range test.

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1994 Results

Oats

Plant response Oat plant height (Table 1) and general plant vigor were adversely affected by the presence of sludge, but only the highest sludge rate negatively affected final percent stand. Environmental conditions for oat growth were less than optimum during seedling germination, emergence and early growth stages, as evidenced by the poor performance of the check treatment. Sludge apparently magnified the adverse effects of weather on oat growth. The addition of ash from Blandin's co-generating plant increased oat height compared to sludge treatments containing no ash. All sludge treatments significantly reduced percent weeds compared to the check.

Alfalfa

Plant response Alfalfa seedling emergence and early growth were reduced by the presence of sludge. Consequently, seasonal forage dry matter yield was significantly less for all sludge only treatments compared to the check (Table 1). Blandin ash increased alfalfa dry matter yield. Treatment five, containing Blandin ash and sludge, yielded significantly more dry matter than treatment four, which contained the same amount of sludge but no ash. Sludge did not affect final alfalfa percent stand, and the two highest sludge rates significantly reduced the percentage of weeds present in the final alfalfa stands compared to the control.

Plant tissue response Major plant nutrients necessary for alfalfa production were at sufficient levels in alfalfa plant tissue from all treatments and the check except boron (Table 2), which was only at the sufficient level in the ash/sludge treatment. Levels of heavy metals (Pb, Ni, Cr, and Cd) in alfalfa plant tissue were not affected by any of the treatments.

Soil response Soil pH is a critical factor in alfalfa production with a pH level of 6.5 considered the minimum level necessary for successful production. Soil pH of this research site was initially 6.6 (Table 3). Soil pH in the fall following spring treatment application was highest for the sludge/ash treatment. The 20 and 30 ton/acre sludge rates also raised soil pH to higher levels than the control, but the increase was not statistically significant.

Soil levels of the plant nutrients phosphorous (P) and boron (B) were similar for all treatments and the check. Soil levels of potassium (K) and magnesium (Mg) in the ash/sludge treatment were higher than the other treatments and the check. Soil levels of sulfur (S) in the check and ash/sludge treatments were higher than for all sludge-alone treatments. Soil levels of zinc(Z) were higher in the ash/sludge and 20 and 30 ton/acre sludge treatments than in the check and 5 ton/acre sludge treatment. Soil levels of iron (Fe), manganese (Mg) and the heavy metals were similar for all treatments and the check.

1995 Results

Oat/Alfalfa Mixture (Seeded in 1995)

Unlike 1994, oat or alfalfa seedling emergence in 1995 was not inhibited nor was early seedling growth reduced in treatments containing municipal sludge compared to plants in the control. Oat plant height (Table 4) at harvest was greater for all treatments which contained municipal sludge. Oat forage dry matter yield was greater for treatments containing sludge at application rates of 20 or 30 ton/acre, compared to the control. The sludge/ash combination did not affect either oat plant height or dry matter yield differently than sludge-alone treatments. The weed control benefit of sludge in the application year was not as readily apparent in 1995, one year after sludge application. Weed species invasion was of primarily grass species rather than broad leaves, which may or may not be a direct effect of the presence of sludge. Growth of alfalfa was not visibly inhibited by municipal sludge, as visual stand ratings of all treatments and the control were not different.

Alfalfa (Seeded in 1994)

Treatments containing sludge at application rates of 20 or 30 ton/acre had significantly higher alfalfa forage dry matter yields (Table 4) at cut one, whereas only the treatment containing a sludge/ash combination had higher total season forage dry matter yield.

Plant tissue elemental analysis

Plant tissue (Table 5) from treatments containing sludge alone consistently differed from the control only by containing higher concentrations of zinc (Zn). Plant tissue from the treatment containing a sludge/ash mixture had lower concentrations of phosphorous (P), calcium (Ca), magnesium (Mg) and sodium (Na) and higher concentrations of potassium (K), zinc and boron (B). No differences in sulfur (S), aluminum (Al), iron (Fe), copper (Cu) or heavy metal [lead (Pb), nickel (Ni), chromium (Cr) or cadmium (Cd)] concentrations were measured between any treatments and the control.

Soil elemental analysis

Soil from treatments containing sludge alone consistently differed from the control only in having lower concentrations of magnesium (Table 6). Treatments containing the sludge/ash mixture had higher soil pH and higher potassium, sulfur, boron, calcium and magnesium concentrations than the control and sludge/alone treatments. Treatments containing sludge at application rates of 20 and 30 ton/acre had higher zinc concentrations than the control and the 5 ton/acre sludge treatment. Heavy metal (lead, nickel, chromium and cadmium) concentrations of treatments did not consistently differ from the control. The sole exception was the control had a higher nickel concentration than the treatment containing the sludge/ash mixture.

Discussion

1994 data indicated municipal sludge may inhibit seedling emergence and reduce vigor resulting in reduced plant performance. The precise mechanism of this inhibitory factor is beyond the scope of this study, however, it could involve a significant alteration in the nutrient status of soil resulting from sludge application, and/or the sludge may present some type of physical barrier. 1995 data seem to show reduced seedling emergence and vigor as a result of municipal sludge application occurs only in the year of sludge application. Oat and alfalfa seeded in 1995 were not affected by the presence of municipal sludge applied in 1994.

Oat plant height and forage DM yield in 1995 were higher for all treatments containing sludge compared to the control. Growing conditions during May and early June 1995 were drier than optimum for seedling emergence and growth. It seems likely this increased plant growth response during dry conditions was due to an increase in the water holding capacity of the soil resulting from addition of organic matter via the sludge. It is also possible the same phenomenon was partially responsible for the greater alfalfa forage dry matter yield at cut one of the alfalfa established in 1994.

Plant tissue and soil elemental analysis data from established alfalfa indicate forage dry matter yield differences were probably related to available potassium (P) and boron (B) because concentrations of these elements in alfalfa tissue were generally sufficient (potassium and boron are 20,000 and 30 ppm, respectively) for only the treatment containing ash, even though fertilizer was applied at recommended rates.

Municipal sludge appears to have a generally beneficial effect on soil chemistry if applied and incorporated well in advance of seeding, although the benefit is not always statistically measurable. Specifically, the soil pH increase observed with the addition of sludge could be more beneficial than observed in this study to pH sensitive crops, such as alfalfa, in situations where the existing soil pH is well below the required minimum of 6.5. Other crops potentially could benefit from increases in soil pH as well because many plant nutrients become generally more available as soil pH becomes closer to neutral (pH of 7). Additionally, zinc (Zn) concentrations in both soil and plant tissue, appears to be elevated to favorable levels by the addition of municipal sludge.

Conclusions

Results thus far do not appear to indicate any adverse environmental effects of municipal sludge application to cropping systems. Municipal sludge application appears to have both beneficial and detrimental effects on plant growth. Detrimental effects associated with sludge application are reduced seedling germination and early plant vigor, both of which likely can be avoided by applying the sludge well ahead of seeding, i.e., in the fall previous to a spring seeding. Beneficial effects of sludge application on plant growth are associated with an increase in soil pH, especially for pH sensitive crops, and an increase in the moisture holding capacity of coarse-textured soils during periods of reduced soil moisture.

Table 1. Plant responses to sludge applications.

	Oat			Alfalfa		
Treatment	Stand	Weeds	Height	Stand	Weeds	Yield
	----------%----------		In.	----------%----------		T/A
1. Check	94 a*	24 a	35 a	94 a	6 a	1.02 a
2. Sludge, 5 tons/A	88 a	2 b	15 b	80 a	4 ab	0.53 c
3. Sludge, 20 tons/A	86 a	2 b	13 b	88 a	2 bc	0.58 c
4. Sludge, 30 tons/A	73 b	1 b	13 b	78 a	1 c	0.46 c
5. Sludge, 30 tons/A + Blandin ash, 10 tons/A	85 a	2 b	14 b	92 a	1 c	0.82 b

* Means within the same column followed by the same letter do not differ statistically at the 0.05 level of significance.

Table 2. Effect of sludge application on alfalfa plant tissue.

Treatment	S	P	K	Ca	Mg	Na	Al	Fe
	%	---------------	---------------	---------------	ppm	---------------	---------------	---------------
1. Check	0.35 b*	3090 c	26870 b	18540 a	2021 a	94.5 c	16.63 a	63.8 a
2. Sludge, 5 tons/A	0.30 c	3431 bc	26580 b	17840 a	1948 a	155.3 bc	19.92 a	87.6 a
3. Sludge, 20 tons/A	0.36 b	3620 ab	28580 b	16170 a	1987 a	330.5 ab	16.35 a	88.4 a
4. Sludge, 30 tons/A	0.37 b	3892 ab	27740 b	17140 a	2125 a	518.3 a	17.45 a	95.6 a
5. Sludge, 30 tons/A + Blandin ash, 10 tons/A	0.45 a	4037 a	39980 a	13340 a	2047 a	209.8 bc	13.38 a	100.1 a
Alfalfa sufficient nutrient level	30	2500	24000		300-1000			

Treatment	Zn	Cu	B	Pb	Ni	Cr	Cd
	---------------	---------------	---------------	ppm	---------------	---------------	---------------
1. Check	22.1 c	7.63 a	15.40 c	1.96 ab	1.39 ab	0.40 ab	0.38 a
2. Sludge, 5 tons/A	33.6 b	7.52 a	22.53 b	1.68 b	1.66 a	0.36 b	0.14 a
3. Sludge, 20 tons/A	33.0 b	7.96 a	16.73 bc	1.88 b	1.18 bc	0.41 ab	0.18 a
4. Sludge, 30 tons/A	35.1 ab	8.33 a	16.33 c	1.95 ab	1.17 bc	0.43 a	0.18 a
5. Sludge, 30 tons/A + Blandin ash, 10 tons/A	39.0 a	9.92 a	40.01 a	2.22 a	0.98 c	0.43 a	0.30 a
Alfalfa sufficient nutrient level	20-50		31-80				

*Means within the same column followed by the same letter do not differ statistically at the 0.05 level of significance.

Table 3. Effect of sludge application on soil nutrient and heavy metal concentrations.

Treatment	pH	P	K	S	B	Ca	Mg	Fe
	---------------	---------------	---------------	---------------	ppm	---------------	---------------	---------------
1. Check	6.63 bc*	73 a	71 b	18.8 a	0.15 a	1072 b	32.0 b	52.0 a
2. Sludge, 5 tons/A	6.55 c	77 a	68 b	4.8 b	0.35 a	827 c	24.0 c	59.8 a
3. Sludge, 20 tons/A	6.90 b	72 a	67 b	5.3 b	0.18 a	980 bc	27.5 bc	50.3 a
4. Sludge, 30 tons/A	6.90 b	78 a	68 b	6.0 b	0.18 a	1009 bc	28.3 bc	53.3 a
5. Sludge, 30 tons/A + Blandin ash, 10 tons/A	7.25 a	77 a	281 a	29.0 a	0.73 a	1492 a	57.8 a	48.8 a

Treatment	Mn	Zn	Cu	Pb	Ni	Cd	Cr
	---------------	---------------	---------------	ppm	---------------	---------------	---------------
1. Check	5.25 a	0.93 c	0.48 b	0.58 a	0.52 ab	0.049 a	0.028 a
2. Sludge, 5 tons/A	8.70 a	2.55 c	0.56 a	0.81 a	0.61 a	0.055 a	0.028 a
3. Sludge, 20 tons/A	7.03 a	5.40 b	0.54 ab	0.61 a	0.44 b	0.052 a	0.028 a
4. Sludge, 30 tons/A	7.84 a	7.48 a	0.55 a	0.67 a	0.44 b	0.053 a	0.028 a
5. Sludge, 30 tons/A + Blandin ash, 10 tons/A	7.15 a	8.43 a	0.59 a	0.60 a	0.42 b	0.082 a	0.028 a

*Means within the same column followed by the same letter are not statistically different at the 0.05 level of significance.

Table 4. Oat plant height and forage dry matter yield for oats and alfalfa seeded in 1995 and forage dry matter yield for alfalfa seeded in 1994.

	-----------Oats/Alfalfa----------		-------------Alfalfa-------------		
Treatment	Plant Ht	Forage DM Yld	Cut 1	Cut 2	Total
	--in--	-----------------------TDM/A-----------------------			
Check	22 d*	0.64 c	1.76 bc	1.02 a	2.78 a
5	26 c	0.98 b	1.66 c	0.95 a	2.61 a
20	29 ab	1.23 a	1.90 bc	1.05 a	2.95 a
30	29 a	1.20 a	2.03 b	1.05 a	3.07 a
20 + 10	27 bc	1.26 a	2.37 a	0.98 a	3.35 a

*Means within the same column followed by the same letter are not statistically different at the 0.05 level of significance.

Table 5. Grand Rapids Municipal Sludge Study - 1995 Plant tissue elemental analysis. Alfalfa seeded in 1994.

Treatment	S	P	K	Ca	Mg	Na	Al	Fe
	%	---------------------------ppm---------------------------						
1. Control	0.29 a*	2844 a	19060 b	15850 a	2341 a	535 a	17.0 a	61 a
2. Sludge, 5 tons/A	0.25 a	2639 bc	19910 b	15600 a	2048 ab	436 ab	21.0 a	63 a
3. Sludge, 20 tons/A	0.26 a	2780 ab	20230 b	15900 a	2002 b	511 a	18.1 a	63 a
4. Sludge, 30 tons/A	0.28 a	2783 ab	18850 b	16720 a	2127 ab	666 a	18.4 a	66 a
5. Sludge, 30 tons/A + Ash, 10 tons/A	0.26 a	2476 c	26840 a	12140 b	1518 c	205 b	25.3 a	63 a

Treatment	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd
	---------------------------ppm---------------------------							
1. Control	39.5 ab	20.2 d	5.47 a	19.6 b	<1.68 a	3.27 a	0.41 a	<1.20 a
2. Sludge, 5 tons/A	43.0 a	24.0 c	5.47 a	21.5 b	<1.68 a	3.00 a	0.42 a	<1.20 a
3. Sludge, 20 tons/A	35.4 abc	26.7 b	5.12 a	20.5 b	<1.68 a	2.89 a	0.37 a	<1.20 a
4. Sludge, 30 tons/A	34.7 bc	29.0 a	5.49 a	20.8 b	<1.68 a	2.93 a	0.38 a	<1.20 a
5. Sludge, 30 tons/A + Ash, 10 tons/A	28.1 c	25.7 bc	4.77 a	31.8 a	<1.68 a	2.08 a	0.37 a	<1.20 a

*Means within the same column followed by the same letter are not statistically different at the 0.05 level of significance.

Table 6. Grand Rapids Municipal Sludge Study - 1995 Soil elemental analysis of treatments established in 1994.

Treatment	pH	P	K	S	B	Ca	Mg	Fe
	ppm							
1. Control	6.5 bc*	71 a	69 b	4.25 bc	0.10 b	849 bc	34 b	45 ab
2. Sludge, 5 tons/A	6.3 c	71 a	66 b	1.75 c	0.10 b	777 c	23 c	50 a
3. Sludge, 20 tons/A	6.7 b	69 a	62 b	7.75 b	0.10 b	958 b	24 c	40 bc
4. Sludge, 30 tons/A	6.8 b	74 a	68 b	5.25 bc	0.13 b	978 b	24 c	40 bc
5. Sludge, 30 tons/A + Ash, 10 tons/A	7.3 a	75 a	149 a	14.8 a	0.35 a	1262 a	42 a	34 c

	Mn	Zn	Cu	Pb	Ni	Cd	Cr
	ppm						
1. Control	4.6 a	0.99 b	0.48 a	0.57 a	0.52 ab	0.05 a	<0.03 a
2. Sludge, 5 tons/A	5.8 a	3.38 b	0.56 a	0.75 a	0.62 a	0.06 a	<0.03 a
3. Sludge, 20 tons/A	3.8 a	6.71 a	0.55 a	0.55 a	0.44 bc	0.05 a	<0.03 a
4. Sludge, 30 tons/A	4.3 a	8.23 a	0.54 a	0.60 a	0.40 bc	0.05 a	<0.03 a
5. Sludge, 30 tons/A + Ash, 10 tons/A	4.0 a	7.81 a	0.53 a	0.56 a	0.30 c	0.07 a	<0.03 a

*Means within the same column followed by the same letter are not statistically different at the 0.05 level of significance.

SEED-PLACED FLUID FERTILIZER FOR CORN PRODUCTION

George Rehm, Gyles Randall, Dave Huggins, Thor Sellie, Andy Scobbie, and Jeff Vetsch[1/]

Abstract

Banded fertilizer becomes an important placement option for immobile nutrients as soil test levels increase. Seed-placed (pop-up) fertilizer is one option. This study evaluated the effect of three fluid fertilizers applied in contact with the seed at three rates on emergence, early growth, and yield of corn grown at two locations. This placement method had no effect on emergence, increased early growth, and had mixed effects on corn yield.

Introduction

The placement of fertilizer with the seed (pop-up) has been used by some corn producers for several years. Limits for use have not been well defined. This practice may become a more important option as soil test levels for P and K continue to increase. Therefore, the impact of this fertilizer management practice needs to be studied in more detail.

Experimental Procedure

This study was conducted at the Waseca and Lamberton Experiment Stations. Three fluid fertilizers (7-21-7, 4-10-10, 10-34-0) were applied at rates of 5, 10, and 15 gallons per acre in contact with the seed (pop-up). A control (no fertilizer with the seed) was also used. Corn was planted in both early and mid-May at the Waseca location. The corn was planted in mid-May at the Lamberton site. The soil to a depth of 6 inches was wet at both locations.

Stand counts were taken at approximately four weeks after emergence at both sites. Whole plants were harvested at this time, dried, and weighed. These plant samples were ground and analyzed for P and K. Grain yields were measured in October.

Summary of Results

Fertilizer applied in contact with corn seed had no negative effect on emergence at all sites. The soil moisture in the seed zone was high and this may have eliminated any negative effects caused by this practice.

This placement practice increased the early growth of corn at both locations. Even though soil test values for P and K were in the high range at all sites, this practice was positive because of the cold, wet conditions at planting.

The effect of "pop-up" fertilization on yield was mixed. For the early planting at Waseca, yields were reduced slightly when this practice was compared to the control. This effect was not observed for the mid-May planting at both the Waseca and Lamberton locations.

This study will be repeated in 1996.

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EFFECT OF ANHYDROUS AMMONIA APPLICATION PATTERNS AND TIMING ON CORN STAND AND YIELDS

M.A. Schmitt, and D.R. Hicks[1/]

Abstract

Earlier corn planting could occur in many farming operations if it wasn't for delays due to nitrogen fertilizer applications. This study was designed to evaluate the effects of applying anhydrous ammonia after corn planting--yet before emergence--using various application patterns. Applying anhydrous ammonia parallel to and in-between corn rows resulted in no stand loss and optimum yields. Other application patterns resulted in varying degrees of stand loss that was correlated with grain yield loss.

Introduction

In the northern Corn Belt, corn producers are annually challenged with completing all the necessary field work to ensure planting by the optimum dates. Factors such as seedbed tillage operations, wet soil conditions due to soil frost and/or rainfall, and chemical and fertilizer applications all contribute to delay in planting. One management strategy that may allow for earlier corn seeding is to apply anhydrous ammonia (AA), which is the most popular nitrogen (N) form used, after planting yet before emergence. The objectives of this study were to determine the feasibility of this practice by evaluating corn stands and yield as affected by AA application patterns, N rate, and time of application.

Experimental Procedure

This study was conducted for four site-years in eastern Minnesota. An AA application rig was used to apply the treatments in four configurations: 1) with the knives centered down the middle of the corn rows; 2) the rig driving at an angle through the plots; 3) the rig driving at the same angle through the plots twice; and 4) with the knives centered on the seeded rows of corn. The application treatments were applied either within 24 hr of corn planting or a week after planting. Nitrogen was applied at rates of 0 or 150 lb N per acre, with the 0 N rate still having the application rig and knives going through the plots. Corn stands in the plots were measured approximately 3, 4, 5, and 6 wk after planting, with stand quality parameters, such as gaps and delayed plants, quantified at 6 wk after planting. Grain yields were measured at physiological maturity.

Summary of Results

Corn stands were reduced when both angled treatments or the in-row treatments were applied, regardless of whether AA was being applied or not. Compared to the between row treatment, stands were reduced 6, 14, and 31% with the angle, angle-twice, and in-row treatments, respectively. The reduction in stand was highly correlated to gaps (>12 in.) in the rows. Yields were 96, 92, and 81% of the between row treatment, which had an average yield of 176 bu/acre for the four site-years. The N rate (0 or 150 lb N/acre) did not have a significant effect on stand, except with the in-row treatment, which indicates that seed displacement from the knives is just as important as AA injury. There were minor negative effects on stand and injury with treatment applications one week after planting.

Status

This project consisted of two site-years in 1994 and two site-years in 1995.

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ANNUAL MEDICS AS A SOURCE OF NITROGEN AND MEANS OF WEED CONTROL IN CORN

C.C. Sheaffer, M.A. Schmitt, and G.W. Randall[1/]

Abstract

Annual medics, which are legumes that provide rapid ground cover early in the season and then senesce by the middle of the season, may be grown with corn in an effort to reduce herbicide and nitrogen inputs. This study was designed to evaluate the weed control and nitrogen sufficiency of this dual-crop system. Research results indicated that the weed control properties were questionable and that nitrogen contributions were not realized by the corn. In summary, medic was a significant competitor with the corn.

Introduction

Annual medics establish and grow quite rapidly in the spring of the year, and by mid-summer they have completed their vegetative growth cycle. Previous research has shown that medics can fix significant quantities of nitrogen (N) in their growth cycle. Also, due to their growth habit, they can have a weed suppression effect. The objective of this study was to evaluate medics grown with corn as contributors to weed suppression and N sufficiency for corn.

Experimental Procedure

This study was conducted in Waseca and Olmsted counties in 1995. Three different medic/N main effect treatments were established. One treatment consisted of broadcast application of N and broadcast seeding of medic immediately preceding corn planting. The second treatment consisted of band application of N directly in-between the corn rows and band seeding of medic directly over the corn rows. The third treatment used banded N (in-between corn rows) with no medic being grown. Each of these main effect treatments were established using N rates of 0, 50, 100, and 150 lb N/acre. In addition, a preplant herbicide treatment was used with each of the main effect treatments at the 100 lb N/acre rate. Soil N and plant (corn, medic, weed) N were measured in June and July and grain yield was measured at maturity.

Summary of Results

Results between the two locations were similar. There was a significant effect of N rate for each of the medic/N application methods. Averaged across N rates, the broadcast medic/N treatments provided the lowest corn biomass during the season and lowest grain yield at the end of the season. The banded medic/N treatments provided intermediate results between the broadcast treatments and the no medic treatments. The greatest yields were observed when a preplant herbicide was used. These results indicate the need for effective weed control strategies and an understanding of the competitive nature of plants, even a legume, for inorganic N.

Status

This project was started in 1993 and was conducted at two sites in 1994 and again in 1995.

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EFFECT OF ALFALFA STAND AGE ON N CREDITS FOR SUBSEQUENT CORN N RECOMMENDATIONS

M.A. Schmitt, C.C. Sheaffer, G.W. Randall, and D.R. Huggins[1/]

Abstract

Age of alfalfa stand is not considered in providing N credits for a subsequent non-legume crop. This study was designed to evaluate the effect of alfalfa stand age on corn's N responsiveness. One-, two-, and three-year old stands of alfalfa were killed and seeded to corn. Nitrogen fertilizer rates ranging from 0 to 150 lb/acre were applied. In 1995, grain yield responsed up to 50 lb N/acre with the 1-year old stands. No corn response to N was measured when grown on 2- or 3-year old stands of alfalfa.

Introduction

It is not unusual for alfalfa producers to be forced into plowing-up a stand of alfalfa much earlier than expected. Winterkill, changes in the government program, or poor stands all provide opportunities for producers to rotate out of alfalfa early. This study was designed to evaluate the effect of stand ages on corn response to fertilizer N.

Experimental Procedure

This study was located at three locations in Minnesota--Rosemount, Waseca, and Lamberton. Alfalfa was established in 1992, 1993, and 1994 so that in 1995, when corn was to be grown, there were 1-, 2-, and 3-yr old stands of alfalfa. The alfalfa was chemically killed in the fall of 1994. On each of these plots, N rates of 0, 25, 50, 75, 100, and 150 lb/A were applied shortly before corn seeding, which was accomplished without any tillage. Plant and soil samples were collected regularly throughout the growing season in the control plots to monitor soil N and, hence, N uptake. At harvest, grain and stover yields were measured.

Summary of Results

At the Rosemount site, corn grain yields were reduced throughout the entire study; possibly due to a combination of poor stands, poor weed control, and/or compacted soils. As a result, there were no treatment responses caused by the applied N rates or the age of alfalfa stand. Waseca and Lamberton data were quite similar. The 1-year old stand of alfalfa resulted in a yield response with the 25 and 50 lb N/A treatments. There was no yield response to fertilizer N with the 2- or 3-yr old stands.

Status

Identical protocols were used for the 1994 and 1995 corn crops and will continue with the 1996 crop.

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THE IMPACT OF STARTER FERTILIZERS ON ROOT ACTIVITY AND PRODUCTION OF POPULAR BUT DIFFERENT CORN HYBRIDS

George Rehm, Deborah Allan, Diane Knight, Andy Scobbie, and Thor Sellie[1/]

Abstract

Previous studies in recent years had shown that various corn hybrids show differences in root architecture. Little is known about the impact of fertilizer use on distribution and activity of corn roots. This study evaluated the impact of various rates of K_2O and placement on root activity of three popular, but different, corn hybrids. The study was conducted at two sites. One had a high soil test value for potassium. The other had a medium soil test value for potassium. Neither hybrid nor potash fertilization affected yield at the site with the medium soil test. Hybrid, but not potash fertilization, affected yield at the site having the high soil test for potassium.

Introduction

Root growth and root activity is not the same for all hybrids. Past research has shown that corn hybrids respond differently to potash use and placement. These differences have been attributed to differences in the way that roots grow with root development being different among hybrids. In addition, very little is known about differences in root activity among hybrids. Therefore, this study was conducted to measure the effect of potash fertilizer on the distribution and activity of roots of three popular corn hybrids.

Experimental Procedure

This study was conducted in fields of cooperating farmers in Goodhue County. Selection was based on soil test values for potassium. One site had a very high soil test for potassium. The potassium level at the second site was in the medium range. Three popular, but different, hybrids were grown at each site. Three rates of potash (20, 40, 60 lb. K_2O per acre) were applied in a starter fertilizer with 100 lb. 18-46-0 per acre. Other treatments were: 1) no starter, 2) 100 lb. 18-46-0 per acre in a starter (no potash), and 3) 200 lb. K_2O per acre broadcast with 100 lb. 18-46-0 per acre in a starter.

Three non-essential cations (strontium, rubidium, lithium) were injected to various depths at two distances (4 and 8 inches) from the row at both 30 and 40 days after planting. Injections were made perpendicular to corn plants. Whole plant samples were taken ten days after each injection. These plant samples were analyzed for potassium, rubidium, and strontium in an effort to measure root growth and activity.

Grain yields were measured in October and corrected to 14.5% moisture.

Summary of Results

Results recorded in 1995 were inconsistent. Neither hybrid nor use of potash fertilizer had a significant effect on yield at the site with a medium soil test for potassium. An early growth response to potash use was clearly visible at this site. These differences in early growth, however, were not reflected in yield.

Yield was affected by hybrid, but not potash use, at the site where the soil test for potassium was in the high to very high range. The lack of response to potash would be expected at this site.

Uptake of non-essential cations was quite variable in 1995. Therefore, definite comments about root geometry and root activity cannot be made at this time.

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FIELD SCALE USE OF A CHLOROPHYLL METER FOR NITROGEN FERTILIZER APPLICATION

J.A. Lamb, D.S. Onken, and K.I. Ault[1/]

Abstract

A chlorophyll meter was used to schedule nitrogen fertilizer applications for irrigated corn grown on a Zimmerman fine sand. After three years results have been mixed. Grain yields reductions from scheduled applications compared to sufficiently fertilized corn ranged from 0 to 11 percent. The N fertilizer reductions were 30 % of the sufficiently fertilized corn. Use of this technique on sandy soils in Minnesota will require top management.

Introduction

Chlorophyll meters have been developed to schedule in-season nitrogen applications for corn under irrigated conditions. Nebraska researchers found that using a relative nitrogen status (RNS) of 95 % (comparing an adequately fertilized area to a scheduled area) on silt loam soils would result in a 6 % reduction in corn grain yield while reducing fertilizer N inputs. This reduction has implications for reduced nitrate-N losses into the ground water. The objective of this study was to use a chlorophyll meter to schedule in-season N applications for irrigated corn in Minnesota.

Materials and Methods

This study was conducted as part of the Northern Cornbelt Sand Plains Management Systems Evaluation Area (MSEA) project from 1993 to 1995. A ridge-till corn-soybean rotation was used with each crop present in each year. The cropping areas are 4.4 acres in size with the predominant soil being a Zimmerman fine sand. Nitrogen was applied as 20 pound N per acre in the starter at planting and 60 to 70 pounds N per acre at the V4 corn growth stage. The rest of the fertilizer N (about half) was applied according to the chlorophyll meter scheduling. To schedule N applications, well fertilized reference strips consisting of the outside 8 rows on each side of the cropping area were established each year. The reference strips received an additional 50 to 70 pounds N per acre at corn growth stage V8. This operation occurred before the ridging operation. Relative nitrogen status (RNS) was calculated by comparing the chlorophyll meter readings from the scheduled area with the reference strip chlorophyll readings. RNS is expressed as follows: (Chlorophyll number scheduled/ Chlorophyll reference strip) X 100. The chlorophyll numbers were determined by a Minolta SPAD meter periodically after the V8 corn growth stage. When the RNS went below 95 %, 20 to 30 pounds N per acre was applied as Urea Ammonium Nitrate solution (28-0-0) injected into the irrigation system. Hand harvested grain yields were determined from both the reference and scheduled areas each year.

Results and Discussion

The use of the chlorophyll meter for N fertilizer scheduling requires a considerable amount of management. Sampling must be done on at least a weekly basis. There was a grain yield reduction between the reference and scheduled areas in 1993 and 1995 of 10 and 11 percent, respectively. In 1994, no grain yield reduction occurred. The N inputs were approximately 70 % for the scheduled area compared to the reference strips. In 1993, some of the grain yield reduction was caused by the newness of the technique to the researchers. In 1995, we were unable to make up the loss after the 95 % threshold was reached. Future use will require the RNS threshold to be increased to 97 % on sandy low organic matter soils.

This is the third year of an on-going study.

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PRECISION SOIL SAMPLING FOR IMMOBILE NUTRIENTS

J.A. Lamb, G.W. Rehm, G.L. Malzer, and J.G. Davis[1/]

Abstract

A study to evaluate the best grid cell size and best soil sample system for immobile nutrients was conducted in South-Central Minnesota from 1993 to 1995. A corn-soybean cropping system was used. The soils at the research sites were formed in glacial till. Three grid cell sizes, 60 X 60 ft., 180 X 180 ft., and 300 X 300 ft. were evaluated. The sampling patterns included a mid-plot sample, a 60 X 60 ft. grid all-point pattern, and five to nine sample pattern. The smaller the grid cell the better the characterization of the soil for P and K. Economics of the cropping system will dictate the grid cell size used in most situations. The sampling pattern results indicate that a single mid-point soil sample is not a good characterization of soil P and K in a grid cell. The use of any pattern with at least five sample locations in the cell is as good as using soil from 25 locations. To get the most out of grid soil sampling, the person taking the sample should use their knowledge of soil science and of the field being sampled to get a sample which "best" reflects the grid cell.

Introduction

Precision soil sampling has become an issue in Minnesota. Many fertilizer dealers and consultants have invested in the variable rate technology (VRT) for application of phosphorus (P) and potassium (K) fertilizer. The variable rate application equipment require a condition map of the field to provide information on how much and where to apply fertilizer. As the use of VRT grows more questions arise about how to develop the condition map. Most consultants have adopted a grid system of soil sampling a field to meet this need.

As more grid soil sampling is done the following questions have been asked: 1. What is the best grid cell size for P and K soil testing? 2. What is the best soil sampling pattern within a grid cell? and 3. How does the time of the year affect the soil test results?

Materials and Methods

A study was started with three locations in Southern Minnesota to answer questions about using grid soil sampling. These locations were established in farmer's fields in the soybean year of a corn-soybean rotation. One location (SB) was started in June 1993 and the others (RA and RM) in June 1994. For this report only SB and RA locations will be discussed. Soil samples to a six inch depth were taken on a 60 X 60 ft. grid and analyzed for pH, organic matter, Bray-P, sodium bicarbonate-P (Olsen-P), and potassium. The SB location was 360 feet wide and 1320 feet long accounting for an area of 10.9 acres which forms 132 - 60 X 60 ft. grid cells. The RA site was 360 feet wide and 1140 feet long which is 9.4 acres in area and has 114 - 60 X 60 ft. grid cells. Soybean and corn were grown by the farmer cooperators as part of their bigger fields. At the end of the second year corn grain yields were determined in 60 foot segments by a plot combine.

Soil data from one sampling time at each location was evaluated at three different grid cell sizes; 60 X 60 ft., 180 X 180 ft., and 300 X 300 ft. To compare grid cell sizes, similar areas of the sites were used. At the RA location 12 - 180 X 180 ft. grid cells and 3 - 300 X 300 ft. grid cells were used for acres of 360 X 1080 ft. and 300 X 900 ft., respectively. At the SB site, 21 - 180 X 180 ft. grid cells were used making the site size 360 ft. X 1260 ft. Four 300 X 300 ft. grid cells were used or an area 300 ft. X 1200 ft. Fertilizer recommendations for P and K were derived from University of Minnesota recommendation for a 150 bushel per acre corn yield goal.

Results and Discussion

Optimum Grid Cell Size

From an academic prospective, the smaller the grid cell sizes will provide a better documentation of the variation in a field. Current University of Minnesota research at two sites has looked at three grid cell sizes: 60 X 60 ft. (0.1 acre), 180 X 180 ft. (0.75 acre), and 300 X 300 ft. (2 acre). For the actual soil test values, there are some differences in average values with changing grid cell sizes. At the RA location, when using a standard single mid-point sample, the Bray-P test was affected by

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cell size (16.4 ppm for 60 X 60 ft., 20.1 ppm for 180 X 180 ft., and 9.7 ppm for 300 X 300 ft.). The 300 X 300 foot soil test was less than the smaller two grid sizes. At the SB location, Bray-P soil test values decreased with increasing grid cell size (27.7 ppm for 60 X 60 ft., 26.9 ppm for 180 X 180 ft., and 21.0 ppm for 300 X 300 ft.). The phosphate fertilizer recommendations for a 150 bushel per acre corn crop based on the Bray-P soil test are quite different when comparing a 60 X 60 foot grid cell to a 300 X 300 foot grid cell (23.3 vs 30.0 pounds phosphate per acre). At both locations, the average recommended rate for all cells increased with increased cell size: (35 pounds phosphate per acre at RA and 7.9 pounds phosphate per acre at SB). For recommendation purposes, we suggest using the smallest grid cell size that is economically practical. Large cells should be used where there is a small amount of variability in a field. If substantial variability is expected, use smaller grid cells.

Sampling Pattern Within a Grid Cell

The sampling pattern used within the cell seems to make a substantial difference in the fertilizer recommendations. The use of a mid-point location produced different fertilization recommendations that if multi-point (5 to 9 sampling locations in the grid cell) were used. In this study, the multi-point and all points sampling systems produced the same Bray-P test. The all point system required collection from within the 300 X 300 ft. grid on 60 X 60 ft. intervals for at total of 25 soil samples. If possible a sampling pattern which would include at least five separate location in the grid cell, should be used. Again this would increase the number of soil samples taken but the increased precision in the fertilizer recommendations may be worth it. The mid-point sampling system allows an individual to return to a specific location each time a cell is sampled. With the improvement of global positioning system technology (GPS), the ability to return to the same place using 5 to 9 sampling areas should also be possible.

The RA location had three 300 X 300 ft. cells while SB was larger with four cells. The comparison of sampling patterns at RA indicates that in two of the three cells the single mid-point soil test Bray-P value was less than the all points value which utilized 25 individual soil samples taken in the 300 X 300 ft. cell. Because of this the phosphate recommendations are different between the two sampling systems at the RA site. At the SB site in three of four cells the mid-point Bray-P value was less than the all point value. Again the phosphate recommendations reflect these differences. In both locations, the Bray-P soil test value derived from a multi-point sampling pattern which involved five to nine soil samples was similar at the all point value. In this study multi-point patterns involved separate soil samples which were mathematically averaged and not composited.

Effect of Time of Sampling of pH, Bray-P, Olsen-P, and Potassium

The increase use of grid sampling has caused some concern about the increased amount of time involved in taking and analyzing the added soil samples. For immobile nutrients and pH, the "window" for soil sampling could be longer than the current practice. Part of this study was to determine soil test variability over time. Soil samples were taken at the RA site June 1994, October 1994, June 1995, and October 1995. The samples were taken at the SB site June 1993, October 1993, June 1994, and October 1994. At the RA site, phosphorus measurements were relatively similar during the sampling dates. The pH mean values were similar between sampling dates but the minimum value increased in the October 1994 sampling. The potassium soil test means increased with time. At the SB site the mean and minimum values for Bray-P and Olsen-P remained similar between sampling dates. The Bray-P and Olsen-P maximum values were decreased in 1995 from the 1994 values. All pH values decreased in 1995 compared to 1994. Again potassium soil test values changed more erratically between sampling times.

In general the phosphorus soil tests and pH are stable over time if they are taken from the same location in the field. In most cases, the differences between sampling times are within the accuracy of the analytical lab. Potassium is erratic. This is a concern. This variability can be from several different factors. First the soil moisture status at sampling time can cause variability. At lower soil test values, soil test K will increase when soils are dry causing release of fixed K from the clays in the soil. At high soil test values, the analytical methods do not allow enough time to extract the K released by the clays. The way the sample is handled in terms of drying temperature and the length of time it is dried at the soil testing laboratory can also cause considerable variability. Our recommendation to minimize the variability of K soil test is to sample a field in the same place during the same time of the year and use the same laboratory. At this time we believe that the "window" of time when soil sampling for immobile nutrients can be increased to make it a more manageable activity.

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EFFECT OF TIME OF APPLICATION ON MINERALIZATION OF MANURE N , CORN YIELD, AND SOIL NITRATE CONCENTRATIONS

G.W. Randall, M.A. Schmitt, and B. Montgomery[1/]

Abstract

There is often more available labor and time in the fall of the year for manure applications. However, there are several concerns associated with early manure applications. This study was designed to evaluate the agronomic and environmental aspects of various times of manure applications. In 1995, the time (and rate) of application had important effects on yield.

Introduction

The issue of when to apply manure can be a controversial issue. While producers realize that earlier applications are most convenient and labor efficient, environmental and agronomic concerns need answers. The objectives of this project are twofold. First is the determination of N mineralization rates of manure as affected by time of manure application and nitrification inhibitors. Second, the effects of these factors will be evaluated on crop N uptake, grain yield, and leaching potential.

Experimental Procedure

Studies were established at two sites in 1995 in south central Minnesota. At each site, three fall manure applications were scheduled (September, October, and November) along with a spring, preplant application. At each application date, two rates (3,000 and 6,000 gal./acre) of manure were applied, with each rate being applied with and without nitrapyrin (N-Serve). Commercial fertilizer N rates were used as reference treatments. Soil samples were collected in approximately two week intervals from the date of manure application through June of the crop year, excluding winter. These samples were analyzed for nitrate and ammonium. Soil water samples were collected from selected treatments and analyzed for nitrate. Grain and stover yields along with plant N concentrations were measured at maturity.

Summary of Results

Results indicate that spring soil nitrate-N and grain yields are strongly related to the fall application date--the earlier the manure was applied, the less available N and yield were measured the following season. For the two sites in 1995, there were no differences measured among the fall application dates. However, grain yields from all fall-applied treatments was slightly less than from spring-applied treatments. The higher rate of manure for all treatments resulted in higher soil N concentrations at all sampling times, and resulted in greater yields at the 1995 sites. Inclusion of nitrapyrin had the greatest effect in slowing nitrification with the September/October applications, and resulted in yield increases at one site when averaged across all treatments.

Status

This project was started in 1993 at two sites. Three sites were used for the study in 1994. Only residual yield affects will be measured in 1996 at the 1995 sites.

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MANAGEMENT TO IMPROVE ROOT HEALTH OF SOYBEANS GROWN IN NO-TILL PLANTING SYSTEMS

George Rehm, Ward Stienstra, Andy Scobbie, Thor Sellie, and Sandra Gould[1/]

Abstract

Root diseases are a concern when soybeans are planted in no-till systems. The effects of tillage system, variety, Ridomil use, and either potash or phosphate fertilization practices on soybean root health and subsequent yield were evaluated in this study. Experimental sites were selected in Dakota, Olmsted, and Swift Counties. The sites selected had been planted to soybeans in 1994 using no-till planting techniques. Results were varied. The effects of treatments on root health and yield were not consistent across all sites. In general, yields were lower where no-till was used. Incidence of Phytophthora Root Rot was more evident where the susceptible variety was planted with no-till techniques without the use of Ridomil.

Introduction

There is a substantial interest in no-till soybean production in Minnesota. Yet, root diseases are a common concern when soybeans are planted with no-till techniques. Management practices that might affect root health in this planting system have not been fully investigated. This study was conducted to evaluate the effect of tillage system, variety, Ridomil use, and management of either phosphate or potash fertilizers on the root health and subsequent yield of soybeans.

Experimental Procedure

This study was conducted in fields of cooperating farmers in Dakota, Olmsted, and Swift Counties. All sites selected were well drained and had been planted to soybeans in 1994 using no-till planting systems. The management practices studied were: 1) tillage system (no-till, either disk or field cultivation before planting, 2) variety (Pioneer 9071, Pioneer 9091), 3) Ridomil use (none, full rate), and phosphate or potash fertilizer management. The Pioneer 9071 variety is resistant to Phytophthora Root Rot. The Pioneer 9091 variety is susceptible to this pathogen. The Ridomil, when used, was placed in a band over the row at planting. Potash management (none, 40 lb. K_2O per acre in a band, 80 lb. K_2O per acre broadcast) was evaluated at the Dakota and Olmsted County sites. Phosphate management (none, 35 lb P_2O_5 per acre in a band, 70 lb. P_2O_5 per acre broadcast) was evaluated at the Swift County site. All fertilizer treatments were applied before tillage operations were completed in the spring.

Whole plant samples were dug from each plot at approximately 30 and again at 70 days after planting. Top growth was separated from the roots. The majority of the soil was removed from the root system and the root systems were transported to the laboratory. The root systems of six plants collected from each plot were scored for lesions, nodules, and tested with ELISA for Phytophthora Root Rot. Root sections were plated on water and Acid Potato Dextrose agar to determine fungal colonization of the root tissue.

Leaf samples from each plot were collected at early to mid-bloom. These samples were analyzed for potassium (Dakota and Olmsted County sites), or phosphorus (Swift County site). Yields were measured in October with a plot combine.

Summary of Results

Results were quite varied. At the Swift County site, tillage system, variety, and Ridomil use had no significant effect on yield. The broadcast application of phosphate improved yields in the conventional tillage planting system. Yields were in the range of 50 to 55 bushels per acre.

Soybean yield at the Dakota County site was not affected by the tillage system. Considering variety, the yield of Pioneer 9071 was higher than the yield of 9091. The use of Ridomil also increased yields at this site. Yields ranged from 45 to 50 bushels per acre.

No-till reduced the soybean yield at the Olmsted County site. Banded K_2O increased yield in the no-till planting system. The yield of Pioneer 9071 was slightly higher than the yield of 9091. Use of Ridomil had no effect on yield at this site. Yields ranged from 35 to 45 bushels per acre.

In general, incidence of Phytophthora Root Rot was lower when Pioneer 9071 was planted in the conventional planting system with the use of Ridomil. The effect of treatment on other disease development and nodulation was inconsistent.

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SOYBEAN YIELD IN SOUTHEASTERN MINNESOTA AS AFFECTED BY INOCULATION AND NITROGEN FERTILIZATION

Fritz Breitenbach and George Rehm[1]

Abstract

The soybean crop with adequate nodulation is capable of manufacturing needed nitrogen from the atmosphere. In the past, use of nitrogen fertilizers has reduced nodulation. For this study, three rates of nitrogen fertilizer (0, 50, 100 lb. per acre) were broadcast and incorporated before planting. Both inoculated and non-inoculated soybeans were planted with each nitrogen rate. Nitrogen fertilizer use reduced nodulation, but had no significant effect on the yield of soybeans.

Introduction

There is general agreement that soybeans which are adequately nodulated will not need a nitrogen fertilization program. Excessive nitrate-nitrogen in the root zone has been known to reduce the amount of nodules present on soybean root systems. Yet, there were reports that nitrogen fertilizers would increase the yield of inoculated soybeans. Therefore, this study was conducted to monitor the effect of inoculation and nitrogen fertilization on early growth, nodulation, and yield of soybeans grown in southeastern Minnesota.

Experimental Procedure

This study was conducted in the field of a cooperating farmer in Olmsted County. Two rates of nitrogen (50, 100 lb. per acre), supplied as urea, were broadcast and incorporated before planting. An appropriate non-fertilized control was also used. Inoculated as well as non-inoculated soybeans were planted at each rate of fertilizer nitrogen.

Soybean plants were dug in early August. Whole plants were dried and weighed. Soil was carefully removed from the root system in the field. After washing, nodules were removed from the roots and fresh weights were measured. Soybean yields were measured in October.

Summary of Results

Nitrogen fertilization increased plant growth of both inoculated and non-inoculated soybeans. This increased plant weight, however, was not reflected in increased yields. With yields of approximately 45 bu. per acre, neither inoculation nor nitrogen fertilization had a significant effect on yield. The use of nitrogen fertilizer decreased nodule weight on both inoculated and non-inoculated soybeans.

Current plans call for repeating this study in 1996.

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SEED-PLACED FLUID FERTILIZER FOR SOYBEAN PRODUCTION

George Rehm, Dave Huggins, Gyles Randall, Andy Scobbie, Thor Sellie, and Jeff Vetsch[1/]

Abstract

Fertilization is important for soybean production. Yet, correct placement of immobile nutrients is difficult when soybeans are planted with no-till techniques. In this study, three fertilizer materials were applied at two rates in contact with the soybean seed. Seed placement reduced emergence. When planted in 8-inch rows, the reduced emergence was not reflected in yields.

Introduction

Soybeans will respond to fertilization with phosphate and potash at low soil test levels. The immobile nutrients should be broadcast and incorporated before planting for best results. This is not possible with no-till planting procedures. Seed placement is one option for fertilizer use. This study was conducted to measure the effect of seed-placed fertilizer on emergence, early growth, and yield of soybeans.

Experimental Procedure

This study was conducted at the Waseca and Lamberton Experiment Stations. Using a Tye Drill, soybeans were planted in a tilled seedbed in late May. The row spacing was 8 inches. The soil test levels for P and K were high at both sites. Three materials (7-21-7, 4-10-10, 10-34-0) were applied in contact with the seed (pop-up) at two rates at each site. A non-fertilized control was used as a basis for comparison. Stand counts were taken. Early growth and nutrient uptake were measured. Yields were measured in October.

Summary of Results

All fluid materials applied in contact with the seed caused a substantial reduction in emergence. Stand reduction at each site increased as rate of fertilizer applied increased. The fertilizer applied did improve the early growth of soybeans and uptake of P and K increased with the application of the fluid fertilizer. This method of fertilization, however, did not produce a significant reduction in yield. Apparently, soybeans seeded in narrow rows can compensate for some reduction in stand. Nevertheless, seed-placed fertilizer caused a substantial reduction in emergence and should not be used as a method of placement for soybean production.

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SWINE MANURE APPLICATIONS FOR SOYBEAN

M.A. Schmitt, G.W. Randall, J.A. Lamb, J.H. Orf, and J.P. Schmidt[1/]

Abstract

Soybean may be a feasible alternative crop for manure applications. This study was designed to evaluate the agronomic and environmental effects of applying manure for soybean. A series of manure and commercial N application rates was applied for soybean at two sites. Preliminary, first-year results indicate that soybean respond in a visual manner to added N.

Introduction

Pork producers commonly use a crop rotation of corn-soybean. In this rotation, the majority of the manure is applied for corn. However, soybean may be a feasible crop for manure applications as well, even though the benefit of the N in manure may not be fully utilized. There may be several environmental benefits of applying manure for soybean, involving issues such as residue, immobilization, erosion, nutrient uptake potential, and risk. The objectives of this project are to study the production and environmental aspects of manure applied for soybean in a corn-soybean rotation. Emphasis will be placed on N cycling and transformations in the soil as well as varietal effects on N uptake and use efficiency.

Experimental Procedure

This study was initiated in 1995 at two locations--Morris and Waseca. Treatments consisted of several sweep-injected manure rates from 1,500 gal./acre to almost 10,000 gal./acre. A couple of these rates were also applied broadcast. A series of commercial fertilizer N rates were also applied to span the range of N from the manure rates. Soil N and plant uptake N were measured throughout the growing season and at harvest. Nodulating and non-nodulating soybean isolines were planted within each treatment and evaluated in terms of N uptake efficiency and recycling potential.

Summary of Results

Two trial sites were established in 1995 and all of the soil, plant, and seed data have not been completely analyzed and summarized. Preliminary observations indicate that added N, either from manure or commercial fertilizer, resulted in darker green plant color, taller plants, and quicker canopy closure. Although there appears to be some treatment effects on seed yield, additional data and analysis will be required to answer the research questions.

Status

This study was started in 1995 and is scheduled to continue through 1998.

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SULFUR AND FOLIAR FERTILIZATION OF HARD RED SPRING WHEAT

George Rehm, Albert Sims, and Russell Severson[1/]

Abstract

The effect of sulfur fertilization combined with foliar fertilization on the yield of hard red spring wheat was not known. This study was conducted on a sandy soil in East Polk County to measure the effects of these fertilization practices. Use of sulfur broadcast and incorporated before planting produced substantial increases in yield with the application of sulfate-sulfur producing the highest yield. Foliar fertilization had no consistent effect on yield.

Introduction

Sulfur is recognized as an important part of the total fertilizer program for both corn and alfalfa grown on sandy soils in Minnesota. Response of small grains (especially hard red spring wheat) to this nutrient is not known. There is also a possibility that foliar fertilizer use, when combined with sulfur applications, might be beneficial for production of hard red spring wheat grown on sandy soils.

Experimental Procedure

This study was conducted in a field of a cooperating farmer in East Polk County. The soil had a loamy sand texture with an organic matter content of 1.7%. Two sulfur sources (sulfate-sulfur, elemental sulfur/clay mixture) applied at rates to supply 25 lb. sulfur per acre were broadcast and incorporated before planting. A no sulfur control was also used. All treatments received the same rate of nitrogen, phosphate, and potash broadcast and incorporated before planting.

Two fertilizers (28-0-0, 20-0-0-3) were applied to plots receiving the various sulfur fertilizers at either tillering or just after flowering. These fluid materials were applied at rates to supply 30 lb. nitrogen per acre. Yields and protein concentration in the grain were measured.

Summary of Results

Use of sulfur broadcast and incorporated before planting produced a substantial increase in yield. Yields were relatively good for a sandy soil (37-47 bu./acre). The sulfate sulfur source produced the highest yield which averaged approximately 3 bushels per acre higher than the yields produced by the elemental sulfur/clay mixture. A response to sulfur would be expected when crops are grown on a loamy sand with a soil organic matter content of 1.7%.

Use of foliar fertilizers at both growth stages produced inconsistent effects on yield. There was no obvious damage or burn from the foliar application.

The concentration of protein in the grain was not affected by either sulfur use or foliar fertilization. In general, grain protein decreased as grain yields increased.

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AMMONIUM-NITRATE NUTRITION OF HARD RED SPRING WHEAT

George Rehm, Albert Sims, and Russell Severson[1/]

Abstract

Based on previous research with corn, there was some thought that yields of hard red spring wheat might be improved if nitrogen was supplied in the ammonium form. In this study, nitrogen was supplied as ammonium, nitrate, or a combination of both forms. Sulfur was supplied as either sulfate-sulfur or the elemental sulfur/clay mixture in combination with each nitrogen form. A control (no sulfur used) was also included in the study. The form of nitrogen used had no significant effect on grain yield and grain protein.

Introduction

Recently, various researchers have studied the effects of ammonium and nitrate nutrition on corn production. Results have generally shown that a mixture of ammonium and nitrate produces optimum yields. The effect of ammonium and nitrate nutrition on wheat yield has not been clearly defined. This is especially true for sandy soils.

Experimental Procedure

This study was conducted in the field of a cooperating farmer in East Polk County. The soil texture was a loamy sand and the soil organic matter content was 2.4%. Sources of sulfur (none, sulfate-sulfur, elemental sulfur/clay mixture) were combined with nitrogen forms (ammonium, nitrate, mixture of ammonium and nitrate). Adequate rates of phosphate and potash were applied. The sulfur sources were applied to supply 25 lb. sulfur per acre. The forms of nitrogen were applied to supply 125 lb. nitrogen per acre. All fertilizer materials were broadcast and incorporated just before planting in late April. Grain yields and protein concentrations were measured.

Summary of Results

Sulfur fertilization had no effect on yield at this site. Yields were quite good and ranged from 55 to 61 bushels per acre. The organic matter content of the soil (2.4%) and low sulfur demand by wheat can explain the lack of response. At this site, the form of nitrogen used had no significant effect on yield. Considering the rapid rate of nitrification in sandy soils, a significant effect of form of nitrogen applied on yield was not expected.

Neither sulfur fertilization nor form of nitrogen used had a significant effect on the grain protein percentage of hard red spring wheat.

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PHOSPHORUS MANAGEMENT FOR SPRING WHEAT UNDER INCREASED RESIDUE SYSTEMS

J.A. Lamb, G.W. Rehm, A. Sims, and B.J. Holder[1/]

Abstract

The second year of a three year study on hard red spring wheat was conducted at the Northwest Experiment Station in 1995. The objective of the study was to characterize the effects of increased residue production systems on soil phosphorus. Treatments included three residue levels, four phosphorus fertilizer rates, and three application methods. Wheat grain yield was greatest with row application, followed by broadcast applications, and the least with a knife application. In 1994, sodium bicarbonate extractable P was greatest with band applications and decrease with time in all application methods.

Introduction

With conservation compliance many spring grain producers have had to alter their tillage systems to increase the amount of residue present to reduce erosion. Little research has been done on the effect of residue on phosphorus fertilizer rate and application method on spring wheat grown in the Northern Great Plains. The advent of increased residue farming systems has caused changes in soil chemical, biological, and physical properties. These changes can affect the availability of nutrients to wheat plants. Can soil or fertilizer phosphorus availability be affected by crop residue management and does the placement of phosphorus fertilizer need to be different in situations where large amounts of residue are present as compared to lesser amounts of residue? Research on winter wheat has shown a $5 to $10 per acre increase in profitability from use of an efficient row placement of phosphorus over a broadcast placement. The objectives of this study were to characterize the effects of phosphorus fertilizer management under increase residue production systems on the soil phosphorus chemistry in Northwest Minnesota.

Materials and Methods

A field and laboratory study was conducted at the University of Minnesota's Northwest Experiment Station. In the fall after small grain harvest, three residue treatments of no tillage, chisel plow, and moldboard plow (approximately 0, 50, and 100 percent reduction of initial residue) were established. Four rates of phosphorus fertilizer (0, 40, 80, and 120 pounds phosphate per acre) were applied with three different placements (broadcast, knife, and row). Triple super phosphate (0-44-0) fertilizer material was used. The broadcast and knife treatments were applied in the fall similar to what producers do. A spring broadcast treatment of 40 pounds phosphate per acre was applied as a comparison between fall and spring applications and how that effects soil phosphorus dynamics. The row application occurred at planting and the comparison between knife and row treatments will provide the fall versus spring comparison for banded treatments.

The bands were marked and sampled four times following application to determine the effect of soil on the availability of the fertilizer material and the amount of labile phosphorus present at these times. The soil samples are being analyzed for the following fractions: water soluble phosphorus, iron and aluminum phosphates, calcium phosphates, organic phosphorus, and labile phosphorus, The labile phosphorus is being determined by two different procedures: resin extraction and iron and aluminum oxide extraction.

Results and Discussion

This is the second field season for this study. Three factors were studied; residue level (plow, chisel, and nobill), phosphorus placement method (fall knife, fall broadcast, spring broadcast, and row), and phosphorus fertilizer rate (0, 40, 80, and 120 pounds phosphate per acre). The average spring grain yield was 45 bushels per acre. Grain yield was significantly affected by P rate and method of application. The P fertilizer response of 3.3 bushels per acre occurred with the first 40 pounds per acre of phosphate applied. The row placement produced the best grain yield (47.2 bushels per acre) then broadcast (46.1 bushels per acre), and the poorest grain yields were from the knife treatments (44.9 bushels per acre). The residue level had an effect at the 0.12 significance level. No-till treatments yield 40.3 bushels per acre, chisel yielded 44.6 bushels per acre, and plow 50.3 bushels per acre. There were no interactions between the three factors.

The phosphorus bands from the knife and row treatments and the soil treated with broadcast applications were sampled to a depth of six inches at three different times during 1994. In general the Olsen-P soil test values increased with increasing P application rates. The banded applications (knife and row) had greater soil test values than broadcast and the effect of the P application on soil test values decreased later in the growing season. The analyses of the 1994 soil samples for organic P, calcium phosphate, iron and aluminum phosphates and all analyses for 1995 are still in process.

This is a report on the second year of a three-year project and is partially funded by the Minnesota Wheat Council.

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RESPONSE OF "GRANDIN" WHEAT TO POTASH, SULFUR, AND COPPER IN NORTHWESTERN MINNESOTA

George Rehm, Carlyle Holen, Bobby Holder, and Albert Sims[1/]

Abstract

In recent years, the "Grandin" variety of hard red spring wheat has appeared to be light green on large areas of several fields in northwestern Minnesota. Potash, sulfur, and copper were applied in various combinations to determine if a deficiency in one or more of these nutrients was responsible for the light green color. The yield data in combination with results of soil tests indicate that the light green color, early in the growing season, was caused by a shortage of potassium.

Introduction

In recent years, the "Grandin" variety of hard red spring wheat has appeared to be light green on large areas of several fields in northwestern Minnesota. Comparative soil tests in combination with plant analysis indicated that this problem, which was most prevalent early in the growing season, could be caused by a shortage of potassium, sulfur, or copper.

Experimental Procedure

This study was conducted in the field of a cooperating farmer in East Polk County. A site was selected where wheat yields in 1994 had been reduced by the light green color which affects early growth. Various combinations of potash, sulfur, and copper fertilizers were broadcast and incorporated before planting. The rates of potash, sulfur, and copper were 120, 25, and 10 lb. per acre, respectively. All treatments received a uniform application of nitrogen (100 lbs. per acre) and phosphate (80 lbs. per acre).

Summary of Results

Wheat yields ranged from 38 to 44 bu. per acre. Lowest yields were measured when potash was omitted from the fertilizer program. These results, when combined with the results of a soil test, indicate that the stunting of this variety (Grandin) early in the growing season could be caused by a shortage of potassium.

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EVALUATION OF VARIABLE RATE PHOSPHATE APPLICATION FOR SPRING WHEAT

George Rehm, and Harold Stanislawski[1/]

Abstract

Variable rate fertilizer application is one example of new technology being used in agriculture. For this study, variable rate phosphate application was compared with a uniform rate used for the production of hard red spring wheat. In 1995, both approaches to broadcast fertilization produced equal yields. The variable rate phosphate application was at an economical disadvantage because of the added cost of sampling and fertilizer application.

Introduction

The concept of variable rate fertilizer application is new to Minnesota farmers. The capability of apply various rates of fertilizer across the landscape offers opportunities for economic and environmental benefits. This management option, however, has not been evaluated in detail in farmers' fields.

Experimental Procedure

This study was conducted in the field of a cooperating farmer in West Ottertail County. A portion of a field to be planted to hard red spring wheat was marked off into grid cells in the fall of 1994. Following harvest of the soybeans, soil samples (0-6 inches) were collected from each grid cell. The cooperating farmer was asked to assign a yield goal to each grid cell. Phosphate application (broadcast) was based on the combination of the yield goal and soil test values for phosphorus. Using variable rate application equipment, phosphate was broadcast to one strip. The same amount of phosphate fertilizer used in this strip was applied at a uniform rate to a second strip.

Adequate nitrogen was applied at a uniform rate to both strips. Wheat was planted in late April and harvested in August. A weigh wagon was used for measuring yields. Grain samples were analyzed for protein.

Summary of Results

Grain yields were higher than expected. The yield from the strip, which received a variable rate of phosphate, was 63.7 bu. per acre. The wheat , which received a uniform rate of phosphate, produced a yield of 63.5 bu. per acre. Method of fertilization had no significant effect on the protein content of the grain. In this study, the variable rate treatment was at a disadvantage because of the added cost of soil sampling and variable rate fertilizer application.

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EFFECT OF SULFUR SOURCE AND FREQUENCY OF APPLICATION ON THE PRODUCTIVITY OF IRRIGATED ALFALFA

George Rehm, Thor Sellie, Andy Scobbie, and Mel Wiens[1/]

Abstract

The importance of sulfur for alfalfa production on sandy soils in Minnesota is well documented. This study was conducted to study the effect of split applications of this nutrient on production. Sulfur supplied as either SO_4 or an elemental S/clay mixture was supplied at two rates (25, 50 lb. sulfur per acre.) in either single or split applications. In the seeding year (1995), none of the treatments had a significant effect on yield. The use of fertilizer did increase the concentration of sulfur in alfalfa tissue.

Introduction

Sulfur in a fertilization program is essential for optimum production of alfalfa on the sandy soils of Minnesota. Most of the previous research with this nutrient has involved single applications. This study was conducted to evaluate the effect of split applications when compared to a single application in early spring.

Experimental Procedure

This study was conducted under irrigated conditions at the Irrigation Center at Staples. Two forms of sulfur (sulfate-sulfur, elemental sulfur/clay mixture) were broadcast at rates to supply either 25 or 50 lb. sulfur per acre in either single or split applications. When split, ½ of the sulfur was applied before planting and the remaining ½ was applied after the first cutting. Adequate phosphate, potash, and boron fertilizers were also broadcast and incorporated before seeding. Alfalfa was seeded on May 10 and two cuttings were harvested. Whole plant samples from each plot were collected at each cutting. These samples were analyzed for sulfur.

Summary of Results

In 1995, the seeding year, the application of sulfur had no significant effect on alfalfa yield. First cutting yields were reduced by weed competition. Total yield for the two cuttings was in the range of two tons of dry matter per acre.

The sulfur concentration in the alfalfa tissue was increased by sulfur fertilization. Sulfur contraction in alfalfa not fertilized with sulfur was higher than .200%. This is considered to be the "critical" value in separating sulfur deficient from sulfur sufficient alfalfa. The plant analysis and the yield information indicate that the sandy soil provided adequate sulfur for alfalfa production in 1995.

Current plans call for this study to be continued in 1996.

[1/] Professor, Junior Scientist, Assistant Scientist, Department of Soil, Water, and Climate; Research Plot Coordinator, Central Lakes Center, respectively.

EVALUATION OF POTASSIUM SULFATE FOR ALFALFA PRODUCTION IN MINNESOTA

George Rehm, Thor Sellie, Andy Scobbie, and Mel Wiens[1/]

Abstract

The importance of sulfur for alfalfa production on sandy soils is widely recognized. Less is known about the effect of sulfur and chloride on forage quality. This study was conducted to measure the effect of sulfate and chloride on the quality of alfalfa forage. Treatments were topdressed to an established stand at the Irrigation Center at Staples. In Goodhue County, the treatments were broadcast and incorporated before planting. Compared to the appropriate controls, use of sulfate and chloride had no significant effect on forage quality. Use of potash increased yield at the Goodhue County location. Use of sulfur increased yield at the Staples location.

Introduction

There's ample evidence to demonstrate that potassium and sulfur will increase alfalfa production when these two nutrients are needed in a fertilizer program. Potassium chloride (0-0-60) is the most widely used source of potash. The impact of either chloride or sulfate supplied with the potash on the quality of alfalfa produced is, however, not known. This study was designed to measure the effect of sulfate-sulfur and chloride on production and quality of alfalfa.

Experimental Procedure

There are two parts to this study. At the Irrigation Center at Staples, treatments were topdressed to an established stand of alfalfa seeded in the spring of 1994. In Goodhue County, the treatments were broadcast and incorporated before alfalfa was seeded in the spring of 1995.

Two sources of K_2O were used (0-0-60, potassium sulfate). Appropriate controls were used to evaluate the effect of sulfate-sulfur and chloride on yield and quality. In addition, the impact of various rates of potassium was evaluated by adding various rates of potassium sulfate to supply 60, 120, and 180 lb. K_2O per acre.

Three cuttings were harvested at the Staples site. One cutting was harvested in the seeding year from the Goodhue County site. Whole plant samples were collected from each plot at each cutting. These samples were analyzed for protein content and percentages of ADF and NDF.

Summary of Results

Alfalfa production at the Staples site was affected by sulfur use, but not by the application of potash and chloride. Considering total yields, use of sulfur increased yields by approximately .5 ton per acre.

Use of sulfur and chloride had no significant effect on alfalfa production at the Goodhue County site. Yields were improved by the application of potash at this site.

The measures of forage quality (protein, ADF, NDF) were not affected by the application of potash, sulfur, and chloride. This observation was true for both sites.

This project will be continued at the Staples site in 1996.

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LIME SOURCE AND RATE FOR ALFALFA PRODUCTION

George Rehm, Mel Wiens, Thor Sellie, and Andy Scobbie[1/]

Abstract

There are several liming materials that can be used for alfalfa production in Minnesota. This study was conducted to evaluate the impact of sources and rate of application on production of alfalfa grown under irrigated conditions. Lime use increased yield, but lime source had no effect on production. When applied to supply the same rate of ENP, all liming materials had the same effect on yield.

Introduction

The importance of lime, where needed, for alfalfa production has been recognized for some time. There are several materials that can be used to increase soil pH. There was a need to evaluate the effectiveness of these materials when applied at equivalent rates.

Experimental Procedure

This study was initiated in 1993 in an irrigated field of a cooperating farmer in Wadena County. The soil had a sandy loam texture and the initial pH was approximately 6.0.

Four liming materials (aglime, sugarbeet lime, Cutler Magner lime, Pel Lime) were broadcast at rates of supply 4,000, 8,000, and 12,000 lb. ENP per acre and incorporated in 1993. Two varieties of alfalfa were seeded in each lime treatment in the spring of 1994. The MN GRN 8020 variety is tolerant of nematode damage. The Wrangler 9369 variety is susceptible to nematode damage. Alfalfa was harvested three times in 1995.

Summary of Results

In 1995, total dry matter production was in the range of 4.0 tons per acre. Compared to the control (no lime applied), liming increased total production by approximately .3 ton per acre. A rate of 4,000 lb. ENP per acre was adequate for optimum production. All sources had an equal effect on yield and there was no significant rate by source interaction.

Considering varieties, higher yields were produced by MNGRN 8020. When averaged over all lime treatments, the yield advantage was approximately .4 ton of dry matter per acre.

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NITROGEN FERTILIZATION OF GRASS-LEGUME MIXTURES IN NORTH-CENTRAL MINNESOTA

George Rehm, Thor Sellie, Andy Scobbie, and Mel Wiens[1/]

Abstract

Grass-legume mixtures could play an important role in the diverse farm enterprises of North-Central Minnesota. For this study, four rates of fertilizer nitrogen (0, 40, 80, 120 lb. nitrogen per acre) were topdressed to established stands of four forages (kura clover, kura clover plus orchardgrass, kura clover plus reed canarygrass, kura clover plus birdsfoot trefoil plus orchardgrass) in early spring. Forage yields were measured twice during the growing season and botanical composition was measured after the second cutting. The rate of nitrogen applied increased the yield of kura clover as well as the forage mixtures. The use of 80 lb. nitrogen per acre produced optimum yield. The highest yields were produced by the mixture of kura clover plus reed canarygrass, and kura clover plus birdsfoot trefoil plus reed canarygrass.

Introduction

Forage crops are important to the diverse farm enterprises of North-Central Minnesota. Fertilization is one management practice that can be used to improve the various forages grown in the region. Grass-legume mixtures are popular. Yet, response of these mixtures to nitrogen fertilization is not well known. In addition, there was a need to evaluate the use of kura clover as a potential forage crop for the region.

Experimental Procedure

This study was conducted at the Irrigation Center at Staples. The forages (kura clover, kura clover plus orchardgrass, kura clover plus reed canarygrass, kura clover plus birdsfoot trefoil plus orchardgrass) were seeded in May of 1994. No yields were harvested in 1994.

In April of 1995, four rates of nitrogen (0, 40, 80, 120 lb. per acre) were topdressed to the established stand of kura clover and the mixtures. The forages were harvested twice. Whole plant samples were collected at the time that the second cutting was harvested. Grasses were separated from legumes and the percentage of each in the mixture was determined on a dry matter basis.

Summary of Results

Total forage production in 1995 was significantly affected by both nitrogen rate and the forage crop that was seeded. When averaged over all crops, the optimum rate of nitrogen was 80 lb. per acre. When averaged over all nitrogen rates, highest yields were produced by the mixture of kura clover and reed canarygrass and the mixture of kura clover plus birdsfoot trefoil plus orchardgrass. The pure stand of kura clover produced the lowest yield. Nitrogen fertilization increased the percentage of grass in all forage mixtures.

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RECYCLING DAIRY MANURE NUTRIENTS USING REED CANARYGRASS

M. Schmitt, G. Randall, C. Sheaffer, M. Russelle, D. Ivers, R. Beck, W. Wedin, L. Greub, and P. Clayton[1/]

Abstract

An alternative crop for in-season manure applications is reed canarygrass. This study was conducted to evaluate how manure management strategies can affect agronomic and environmental factors associated with growing this forage. Data collected in 1995, which in part, are affected by 1994 treatments, indicate that reed canarygrass is responsive to increasing N rates from manure or fertilizer sources. There have not been any significant differences between broadcast and surface band methods of manure application. Split applications that included one application in early spring appear to be superior to any other application timing scheme.

Introduction

Many producers are forced into summer-time manure applications onto alfalfa. Because topdress applications often result in higher-than-desired risks of crop injury, reed canarygrass was selected as an alternative. Reed canarygrass removes several hundred pounds of N on an annual basis, is tolerant to manure application burn, is a perennial, and can provide somewhat high-quality feed. This study is being conducted to evaluate several manure application strategies (including rate, timing, and application method) for reed canarygrass.

Experimental Procedure

Manure rates ranging from 0 to 40,000 gal./acre/year were applied onto established reed canarygrass plots in Waseca, MN, Fort Dodge, IA, and River Falls, WI. The basic set of application rates were broadcast applied after the second and third cuttings. In addition, selected rates were also surface banded. Some manure rates were also applied in a single application, or split between after the second cutting and after the third cutting or early spring. Commercial N fertilizer treatments were applied at rates of 100, 200, 300 and 400 lb. N/acre/year. Forage yields and quality parameters and N removal were measured with each cutting. Soil N concentrations, stand density, and soil water nitrate-N content were also measured during the year.

Results:

Some preliminary observations and data trends are apparent after one full application/harvest cycle at River Falls and Fort Dodge and two cycles at Waseca. Yields increased with each increasing rate of manure or N fertilizer. Thus, significant N loss to the atmosphere or immobilization/tie-up may be occurring at the very high manure application rates. There have been essentially no differences in forage yield between treatments when the broadcast and surface band application methods were compared. While there were no differences between single and split applications delivered after the 2nd and 3rd cuttings, the split application that included the April application date consistently provided higher yields.

Status

Project was started in 1993 and will continue through the 1996 growing season, after which a residual phase of this study is planned.

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USING WATER AND NITROGEN MANAGEMENT TO REDUCE LOSSES CAUSED BY WHITE MOLD

George Rehm, Jerry Wright, Richard Meronuck, Mel Wiens, Andy Scobbie, and Thor Sellie[1/]

Abstract

White mold is a serious disease affecting the production of dry edible beans in Minnesota. This study was designed to measure the effect of fungicide use, water management, and nitrogen management on the incidence and severity of white mold. In 1995, none of the three factors studied had a significant effect on incidence of white mold and subsequent yield of light red kidney beans. These three factors also had no significant effect on plant height and canopy closure.

Introduction

Failure to control white mold can have serious negative effects on the yield of dry edible beans. Fungicides provide some control. If canopy closure can be delayed, wind will penetrate the canopy, thereby reducing the severity of the white mold growth. Irrigation management and timing fertilizer application should affect the degree of canopy closure. Therefore, this study was conducted to measure the effect of nitrogen management, water management, and fungicide use on the incidence and severity of white mold growth and yield of edible dry beans.

Experimental Procedure

This study was conducted at the Irrigation Center at Staples. The site selected had a history of white mold infestation. The three factors of irrigation management, nitrogen management, and fungicide use were evaluated in all possible combinations.

For fungicide use, Benlate was applied at two times with 2 lb. per acre applied each time. Two soil moisture deficits were used. For the low deficit, .5 to .6 inches of water was applied when the soil moisture deficit reached .35 to .4 inches. For the high deficit, .8 to 1.0 inches of irrigation water were applied when the soil moisture deficit reached .7 to .8 inches.

Three management options for nitrogen fertilizer were used. The nitrogen rate was constant at 120 lb. per acre. One-half was applied two weeks after emergence. Then, 3 options were used. These were: 1) the remaining ½ applied four weeks after emergence, 2) the remaining ½ applied at bloom, and 3) the remaining ½ applied two weeks after bloom.

Plant heights and canopy width measurements were taken in late July and early August. Yields of edible beans were recorded in September.

Summary of Results

Yield of edible beans was not significantly affected by any of the factors studied. With the light red kidney beans, there was not enough vegetative growth to provide canopy closure. Therefore, white mold was not a serious problem in 1995. The factors included did not have a significant effect on plant height or canopy closure.

This study will be repeated In 1996.

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RATE AND PLACEMENT OF ZINC FERTILIZER FOR EDIBLE BEAN PRODUCTION

George Rehm, Thor Sellie, and Andy Scobbie[1/]

Abstract

The response of edible beans to zinc fertilization has been recognized for some time. There are, however, several sources of zinc that can be used. In addition, the effect of rate and placement of zinc had not been well defined. For this study, four zinc sources were either broadcast at a rate to supply 10 lb. zinc per acre or applied in a band at planting to supply both 1 and 5 lb. zinc per acre. When compared to the control, the use of zinc fertilizer did not increase the yield of navy beans at this experimental site.

Introduction

In Minnesota, zinc is usually applied in a fertilizer program for edible bean production if soil test levels for zinc are in the low or very low range. The evaluation of various fertilizers that supply zinc, their placement, and rate of application, however, was not extensive. Therefore, this study was conducted in West-Central Minnesota in 1995.

Experimental Procedure

This study was conducted in the field of a cooperating farmer in Lac Qui Parle County. The previous crop was wheat. The soil test for zinc, measured by the DTPA procedure, was .5 ppm. Four granular sources of zinc were applied to supply 10 lb. zinc per acre (broadcast) or both 5 and 1 lb. zinc per acre in a band at planting. An appropriate control (no zinc applied) was also used. All treatments were fertilized with 120 lb. nitrogen per acre (supplied as 46-0-0) and 100 lb. 18-46-0 applied in a starter band at planting.

The navy beans were planted in late May at a seeding rate of seven seeds per foot of row. Recently matured trifoliate leaves were sampled at mid-bloom, dried, ground, and analyzed for zinc. Yields were measured in September.

Summary of Results

In 1995, source, placement, and rate of zinc had no significant effect on yield. Even though the soil test for zinc was low (.5 ppm), the navy beans did not respond to the use of this nutrient. These results are not consistent with results measured in previous years.

The broadcast application of zinc fertilizers increased the concentration of zinc in plant tissue. When placed in a band, use of lower rates did not increase the concentration. The yields were in the range of 3300 lb. per acre. Yet, the soil was apparently capable of supplying the needed zinc.

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TILLAGE COMPARISON AT ROSEMOUNT, 1995[1]

L. M. Wallach, T. L. Hansmeyer, D.R. Linden, K.L. Walters, R.H. Dowdy, R.R. Allmaras, and C.E. Clapp[2]

ABSTRACT: A long term tillage system study was initiated at Rosemount in 1991. Four tillage systems including Conventional Tillage, Conservation Tillage, Ridge Tillage, and Minimum Tillage are used with continuous corn and corn/soybean rotations. Nitrogen inputs remained constant across all treatments planted to corn with no nitrogen applied to treatments in soybeans. The objective of the study is to determine the long term effects of various cropping systems on herbicide movement, earthworm activity, grain yield, nutrient availability, nutrient uptake, root distribution, and soil quality. Though only preliminary results are available for many of the objectives, enough information has been gathered to study grain yield, corn emergence, and surface residue.

SITE: An 18 acre site at the Rosemount Agricultural Experiment Station was chosen for study. The dominant soil type is a Waukegon Silt Loam (Typic Hapludoll) which has 20 to 32 inches of silt loam overlying calcareous sand and gravel with a slope of less than 2%. The site was grid sampled for elevation and depth to gravel prior to plot layout.

EXPERIMENTAL DESIGN: The site was separated into 36 plots of 0.4 acres each. A continuous corn (CC or C1), corn/soybean (CS or C2) [corn 1995], and soybean/corn (SC or C3) [soybean 1995] rotations were planted into four tillage systems in a randomized complete block design with three replications. The four tillage systems are described as follows:

Conventional (T1): Stalks are chopped in the fall. Plots are then moldboard plowed following corn and fall chisel plowed following soybeans. Disk to prepare seedbed. One or two cultivations after planting as needed.

Conservation (T2): Stalks are chopped in the fall. Plots are then chisel plowed following corn with no fall tillage following soybeans. Disk and/or field cultivate to prepare seedbed for soybeans. Corn is no-till seeded into soybean stubble. One or two cultivations after planting as needed.

Ridge-till (T3): No fall tillage following corn or soybeans (stalks chopped in the fall following corn harvest). Planting done in ridges formed by previous cultivation. Two cultivations following planting to control weeds and reestablish ridges.

Minimized Tillage (T4): Generally, no primary or secondary tillage is prescheduled. Tillage will be performed only when soil or weed conditions require attention. Cultivation performed only when determined necessary.

EXPERIMENTAL PROCEDURE: All of the T1 plots and all of the T2 plots that were in corn in 1994 were field cultivated prior to planting. Corn (Pioneer 3751) was planted in the CC and CS plots across all tillage systems on May 11. The seeds were planted at a population of 26,100 seeds/acre. Force insecticide was banded over the row on all continuous corn plots at a rate of 8 oz./acre. Corn emergence was counted from two 20' sections of row in each plot periodically for the first four weeks of growth. Round-up was broadcast on all no-till plots planted to soybeans at a rate of 6 pt. Round-up/acre on May 17. Soybeans were planted on May 18 at a rate of 60 lbs/acre to a depth of 2". The Hodgson variety was used which contains 2900 seeds/lb. All tilled corn and soybean plots were rotary hoed to a depth of 2" on May 18 to eliminate small emerging weeds. Lasso was broadcast on May 19 to all plots at a rate of 4 pt. Lasso/acre. Basagran was broadcast on June 2 to all plots at a rate of 4 pt. Basagran/acre. On June 3, all CC and CS plots received 205 lbs. N/acre and were cultivated with a Hinnicker Sweep. On June 12, all T3C3 plots were cultivated with a 6 row shovel cultivator. Accent was broadcast sprayed at the rate of 4 oz./acre on plots T4C1 and T2C1 on June 13. All T3C3 plots were hand-weeded on June 14. Fusilade was broadcast on T2C3 and T4C3 plots at the rate of 24 oz./acre on June 19. All T3C1 plots were cultivated with a 6 row shovel cultivator on June 19. Plots T3C1, T3C3, T4C2, and T2C3 were cultivated with a 6 row cultivator to a depth of 3" on June 28. All T3C1 and T3C3 plots, as well as T3C2 (#23), were ridged on July 11. All plots were harvested on October 30. Tillages were not performed in the fall as laid out in the experimental procedure due to the lack of time. Corn stands were observed and recorded during the season and the final plant population count was recorded on October 16.

RESULTS

YIELD: Grain yields and moisture percentages from all tillages and rotations are given in figures 1-3 and table 1. Within the continuous corn system, the grain yields from the conventional till plots out-yielded all other tillages, followed by the yields from the conservation, ridge, and minimized tillages, respectively (fig. 1). The continuous corn yields averaged over the past four years rank the tillage systems differently. The four year average places conventional in front followed by ridge, conservation, and minimized tillage.

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[1]This project was supported by the University of Minnesota Agricultural Experiment Station at Rosemount and the USDA-ARS Soil and Water Unit in St. Paul.

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The 1995 corn yields in the corn/soybean rotation created a different yield rank than the 1995 continuous corn yields and the 1994 soybean/corn rotation yields, when comparing the 4 tillage systems. Conventional tillage yielded the highest, followed by ridge, minimized, and conservation tillages (fig. 2). The four year average for the corn/soybean rotation ranked conventional first, followed by ridge, conservation, and minimized tillages.

The 1995 soybean yields in the soybean/corn rotation were greatest under the conventional tillage system, followed by ridge, conservation, and minimized tillage (fig 3). The 4 year average soybean yield ranked conventional first, followed by conservation, minimized, and ridge tillage. The complete difference in rank between the 1995 and four year average soybean yields points to unpredictability.

The mean yield (figure 5) for each tillage system (for the plots cropped in corn in 1995 only) shows that conventional tillage produced the highest yield followed by conservation, ridge, and minimized tillages, respectively. This ranking is the same as that in 1994. The mean yield across crop rotations (figure 5) shows that the corn/soybean rotation produced a higher yield compared to the continuous corn rotation. Statistically, this yield is highly significant at the 1% level when comparing the plots cropped to corn only and was the only statistically significant yield difference found between treatments during 1995.

RESIDUE: The residue cover comparison after planting is shown in table 2 and figure 6. The conservation and minimized tillage provide enough corn and soybean residues on the surface to meet the erosion control requirements, which stipulates that at least 30% of the surface must be covered at planting. It must be noted that in the conservation tillage plots, corn is no-tilled into the previous years soybean stubble leaving the soybean stubble on the surface. The ridge-till plots provided sufficient residue to meet conservation compliance under the continuous corn and the soybean/corn rotation. Ridge-tilling buried a majority of corn residue under the corn/soybean rotation leaving only 17.8% surface residue. The conventional tillage system did not provide enough surface residue to qualify for the residue requirements under either crop. It might be expected that the soybean plots in conventional tillage would contain at least 30% residue cover over the winter since they are chisel plowed in the fall, but the fall chisel plowed soybean plots (CS in 1995) only had 13.3% residue cover. This is consistent with the previous years residue data, where the fall chisel plowed soybeans only left 9% surface residue.

EMERGENCE: Corn seedling emergence was first recorded on May 23, 12 days after planting. Most plots had between 0-5% emergence at this time, except conventional tillage plots (CC and CS) which showed 12-20% emergence. Emergence had increased greatly by the 16th day after planting, but the percentages were highly variable between the cropping systems. This variability and slow start is presumably due to the spring soil moistures and temperatures. Figure 4 shows 3 different corn emergence trends. Conventional (CC and CS), ridge (CS), and minimized (CS) plots sprouted corn quickly with 76-84% emergence 16 days after planting. The second trend is within the conservation plots (both CC and CS) and the ridge (CC) plot where they had attained 49-60% corn emergence after 16 days. The last and slowest trend was seen in the minimized (CC) plot where only 14% emergence was seen after 16 days. The corn emergence trend in 1995 is fairly similar to the trend seen previously, except that in general the emergence numbers were somewhat lower in 1995 than in 1994. Corn seedling emergence exceeded 80% for all cropping systems 21 days after planting.

Table 1 Grain yields for the tillage study at Rosemount, 1995.

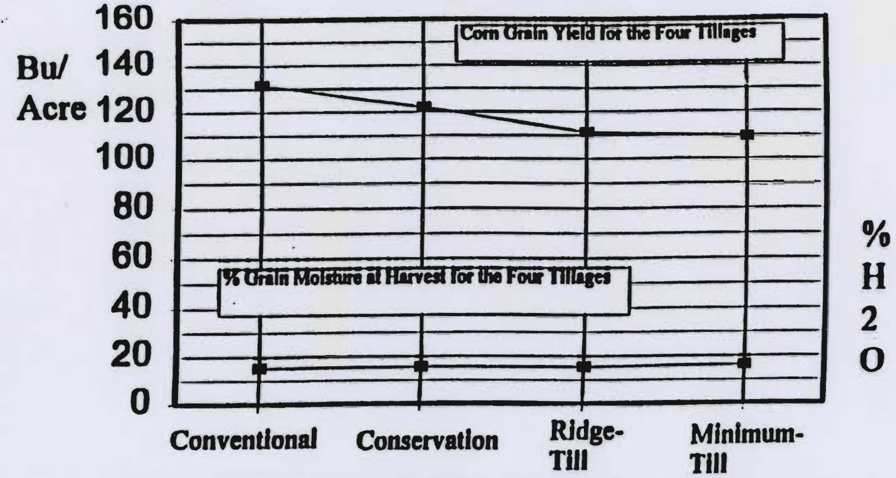
Treatment			Grain Yield			
Tillage	Rotation		1995		92-95 avg.	
			bu/ac	mt/ha	bu/ac	mt/ha
Conventional (T1)	Cont.Corn	c1	131.4	6.97	137.7	7.3
	Corn/Soy	c2	143.5	7.61	154.4	8.2
	Soy/Corn	c3	34.8	1.85	41.0	2.4
Conservation (T2)	Cont.Corn	c1	121.9	6.46	127.0	6.7
	Corn/Soy	c2	128.3	6.8	141.5	7.5
	Soy/Corn	c3	33.2	1.76	40.5	2.3
Ridge-Till (T3)	Cont.Corn	c1	111.3	5.9	130.4	6.9
	Corn/Soy	c2	132.6	7.03	149.7	7.9
	Soy/Corn	c3	34.3	1.82	39.7	2.3
Minimum-Till (T4)	Cont.Corn	c1	109.5	5.8	113.9	6.0
	Corn/Soy	c2	129.5	6.86	136.2	7.4
	Soy/Corn	c3	32.8	1.74	40.0	2.3

Table 2 % Residue Cover for the Tillage Study at Rosemount, 1995

Treatment			Residue Cover
Tillage	Rotation		% residue
Conventional (T1)	Cont.Corn (CC)	c1	5.9
	Corn 95 (CS)	c2	13.3
	Soybean 95 (SC)	c3	21.5
Conservation (T2)	Cont.Corn (CC)	c1	37.8
	Corn 95 (CS)	c2	43.0
	Soybean 95 (SC)	c3	48.1
Ridge-Till (T3)	Cont.Corn (CC)	c1	48.1
	Corn 95 (CS)	c2	17.8
	Soybean 95 (SC)	c3	32.6
Minimum-Till (T4)	Cont.Corn (CC)	c1	79.3
	Corn 95 (CS)	c2	56.3
	Soybean 95 (SC)	c3	69.6

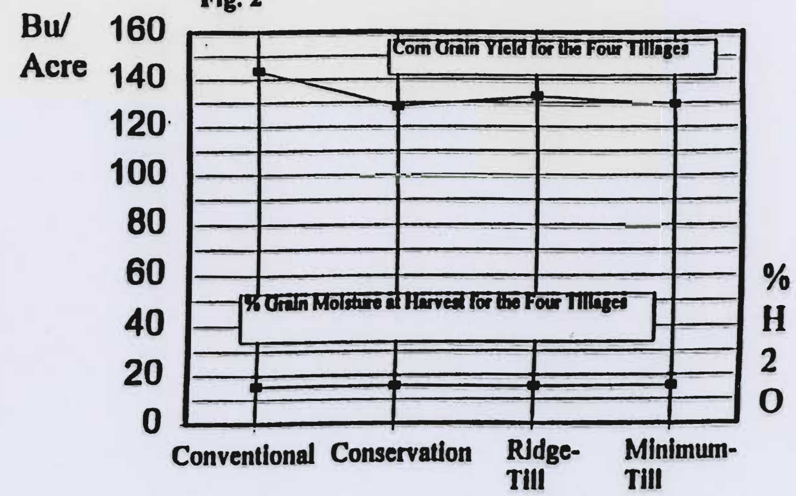
Grain Yield Summary
Continuous Corn

Fig. 1



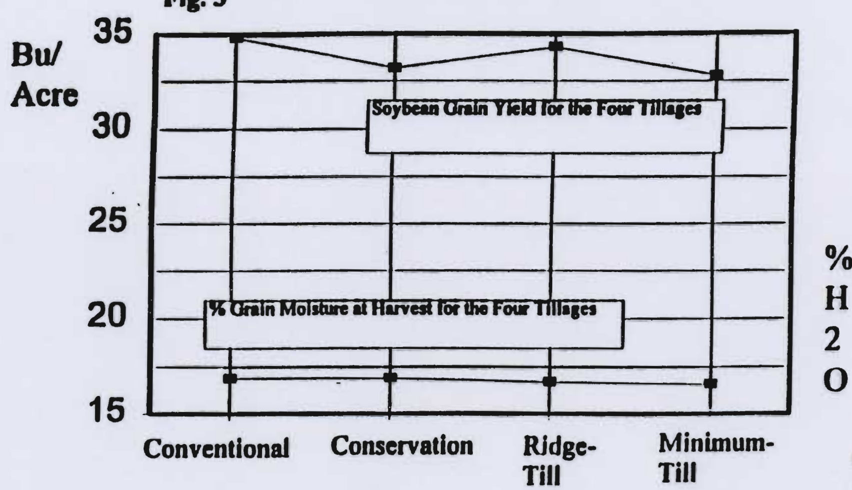
Grain Yield Summary
Corn in '95 after Soybean Rotation

Fig. 2



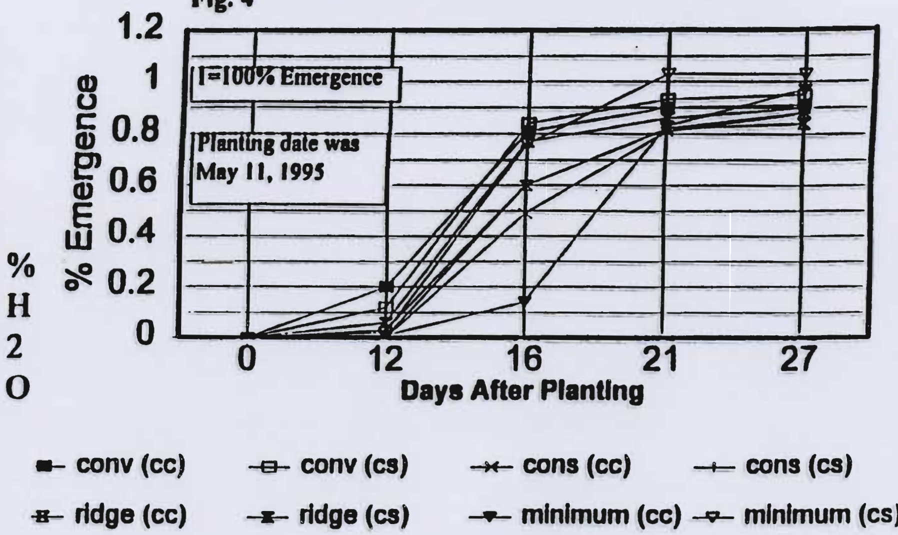
Grain Yield Summary
Soybean in '95 Following Corn

Fig. 3



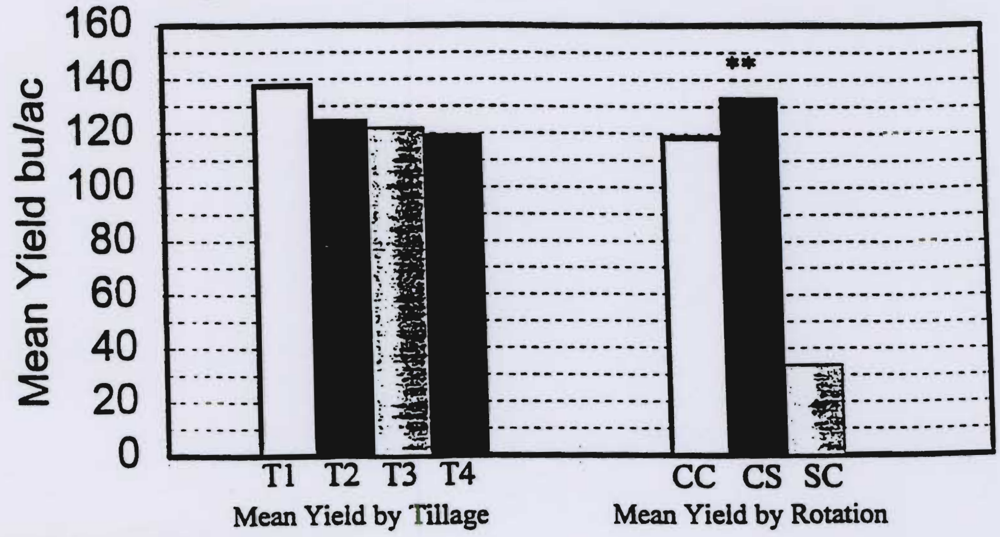
1995 Corn Emergence
Tillage and Rotation Comparison

Fig. 4



1995 Mean Yield Comparison
by Tillage and Rotation

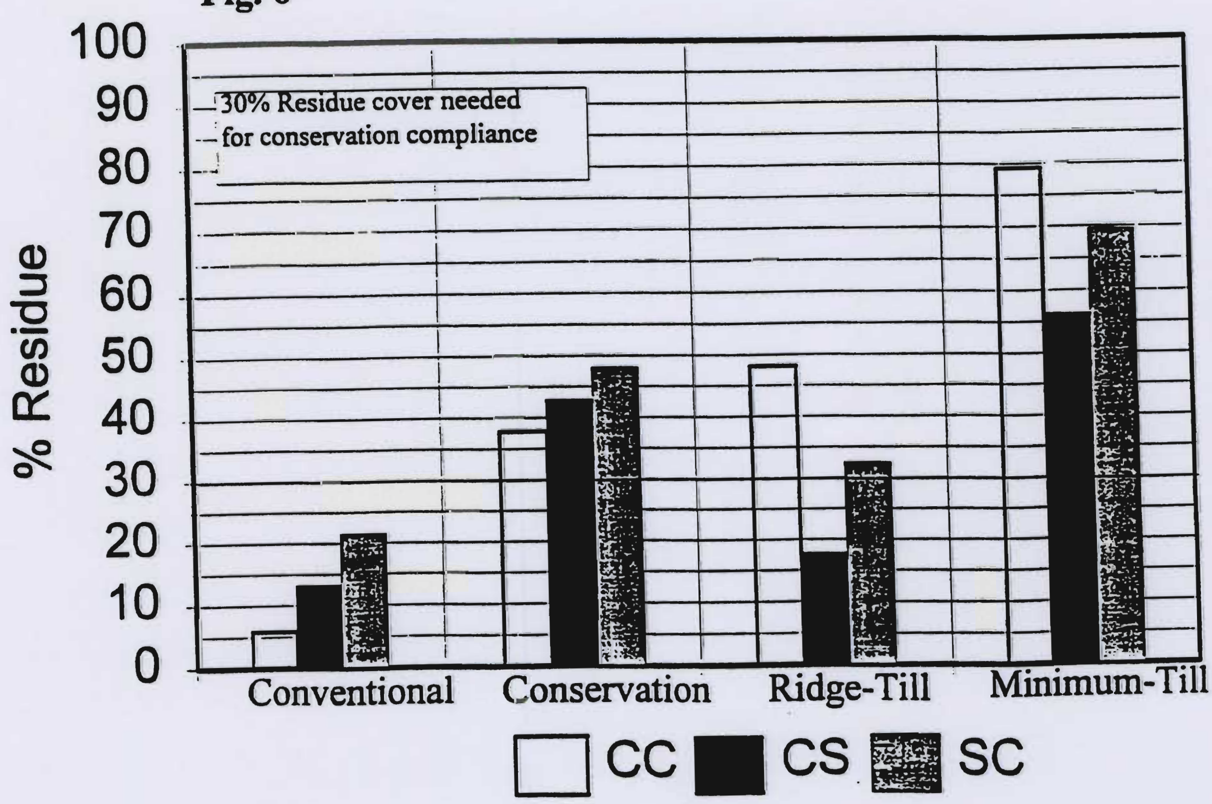
Fig. 5



*LSD at 5%=7.97;
**LSD at 1%=11.06;
Comparing plots in corn only

Residue Cover Comparison

Fig. 6



ASSESSMENT OF THE EFFECTS OF TILLAGE AND MANURE APPLICATION ON RUNOFF AND YIELD OF SOYBEAN AFTER CORN[1]

D. Ginting, J.F. Moncrief, S.C. Gupta, S.D. Evans, G.A. Nelson, A. Ranaivoson, and Andreas Naujoks[2]

ABSTRACT

Tillage and manure interactions on surface runoff are being evaluated at Morris, MN. This research is the continuation of erosion study for continuous corn during the 1992-1994 period which was then planted to soybean in 1995. Water equivalent of snowfall during 1994-1995 winter was 16.2 cm. Due to snow trapping by standing residue, the amount of snow water equivalent in the ridge till (RT) plots was 58 percent of the snow fall compared to 12 percent in the moldboard plow (MP) plots. This resulted in total snowmelt runoff 6.6 times greater in the RT (7.8 cm) compared to MP (1.2 cm) plots. Tillage, manure or manure by tillage interactions had no significant effects on rainfall runoff because rainfall was low intensity and occurred when the soil was covered by soybean residue after senescence. The annual runoff (November 1994-October 1995) was 6 times greater in the RT than MP plots. Soybean yield was 720 kg/ha higher in the MP (2.61 Mg/ha) than RT (1.89 Mg/ha) plots. The difference in yield was due to greater yield per plant or number of seed per plant in MP than RT plots. There was no significant effect of manure of manure by tillage interaction on soybean yield.

INTRODUCTION

The importance of runoff as a driving force of non-point source pollutants lies in the significant association between runoff, sediment, sediment associated and soluble chemicals. Runoff is the main driving factor to carry the sediments, sediment associated P and the soluble chemicals to the edge of the plots once the soil particle or aggregates are detached by rain drops. In Minnesota hog, dairy and poultry farming is extensive, therefore, manure application to land is a regular management practice for crop production. However to get the nutrient benefits from manure, it needs to be incorporated in the soil. The dilemma is: to what degree of soil cultivation is necessary to incorporate manure while maintaining enough residue to prevent excessive runoff and the associated erosive losses of sediment and phosphorus.

This research is the continuation of erosion study started in 1992. During the 1992-1994 period, the crop was continuous corn. In 1995, it was cropped to soybean. During the winter, standing corn residue influenced the amount of snow trapped. In the summer, the corn residue and soybean canopy affected the rainfall runoff. The specific objectives of this study are:

1. To evaluate the effects of moldboard vs. ridge tillage in combination with and without manure application on surface runoff both from snowmelt and rainfall.

2. To evaluate the effects of tillage and manure on soybean yield.

MATERIALS AND METHODS

Tillage and manure interactions on sediment and phosphorus transport in surface runoff are being evaluated at Morris, MN. Soil at the experimental site is Barnes loam (fine-loamy mixed udic Haploborolls, 12 % slope with south-eastern aspect). The initial soil test in 1992 for pH, Olson-P, Bray-P and ammonium acetate extractable K were 8, 17 ppm, 23 ppm and 155 ppm respectively.

The experimental design is a randomized complete block with split plots and three replications (tillage main plots and manure the subplots). Twelve erosion plots, 22 m by 3 m (to accommodate four rows of soybean) were marked and isolated using corrugated steel plates. At the end of each plot the runoff was routed with a polyvinyl chloride (PVC) sheet (3 m by .3 m) and then channeled through a PVC pipe to a collecting system. Until August 1995, the collecting system consisted of three barrels of 210 L each. The first barrel collects very coarse sediments. The overflow from the first barrel was channelled to the second barrel. At the second barrel, 9 adjacent holes of 3.8 cm diameter were drilled near the rim of the barrel. One of the holes was connected to a PVC pipe of 3.8 cm diameter which channelled the excess runoff to the third barrel. This setup allowed 1/9 of the overflow from the second barrel to be collected in the third barrel. The collector was designed for a runoff depth of 3.5 cm (10 year 24-hour rainfall of 9.7 cm considering the curve number of 71). Corrugated roofing was placed over the PVC sheet at the end of the plots to avoid direct precipitation getting into the collecting system.

In September 1995, the barrel-collecting system was replaced with a tipping bucket system linked to an automated data logger. This new system provided more detailed runoff data. Each tipping bucket was made of PVC sheets and calibrated for 2.45 L for each tip. The tipping bucket was stationed on a platform also made of PVC sheeting. On both sides of the platform (the tipping sides of bucket) a 2.5-cm hole was drilled. Both holes were connected to a 25 L pale with 2.5-cm diameter PVC pipes. Therefore from each tipping, 100 mL runoff sample was collected for sediment and P analysis (sediment and P data are pending). This procedure resulted in a flow-weighted composite runoff sample which was collected for each

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[1] Support for this project was provided by the Legislature Commission on Minnesota Resources. The support is greatly appreciated.

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runoff event.

Tillage treatments include ridge tillage and moldboard plowing systems. In the moldboard system, primary tillage in fall was achieved with moldboard plowing and followed in the spring by a field cultivation prior to planting. Ridge tillage represents an intermediate level of soil incorporations. Plant residues were concentrated between plant rows during winter and spring. Ridging was done on 12 July 1995. Detailed cultural practices are presented in Table 1. Manure treatments are with and without. Solid beef manure was applied at the rate of 56 Mg/ha. The manure contained approximately 161 kg P/ha.

Before September 1995, the runoff volume in each barrel was measured using a calibrated dip stick. Starting in September 1995, runoff was measured with tipping buckets linked to an automated data logger. Logarithmic (base 10) transformation of runoff data was done prior to the analysis of variance using SAS, 1986. The central tendency of runoff data is reported as geometric means.

Soybean was planted on the twelve erosion plots at the seeding rate of 460,000 seeds/ha. Seeding was done up and down the slope. Herbicides used for weed control are listed in Table 1. Grain and stover yield, and the weight of 100 seeds were measured. Number of plants were tallied from two 3-m rows at the flowering stage (18 July, 1995). Yield data and the associated variables are presented.

Corn residue cover was measured using the line transect procedure, diagonally across the row and interrow area. The "row area" was defined as a 10-cm wide strip centered over the row and the "interrow area" was the remainder. Measurement were made in quadruplicate for each plot at various tillage operations i.e. before secondary tillage and before planting, after secondary tillage and after planting, and at ridging. The surface residue cover is presented in percent.

RESULTS AND DISCUSSIONS

Runoff

Ridge Till (RT) vs. Moldboard Plow (MP)

Corn residue cover in the interrow area was greater in the RT than the MP plots. In RT plots, over-winter surface residue was 76 percent and increased to 82 percent after soybean planting. A slight increase of residue was due to the removal of residue from the inrow to the interrow area at planting. The Hiniker planter was equipped with clearing disks that removes residue from in row area. The in row corn residue after planting in the RT plots was 24.6 percent. After ridging, corn residue in the interrow area decreased to 34 percent. At ridging, soil and residue were removed from interrow to in row area by the 40-cm sweep which was equipped with a lister. In the MP plots, corn residue over winter and after planting was 3.0 and 3.4 percent, respectively. The corn residue in row area after planting in the MP plots was 3.4 percent.

During the 1994-1995 winter, snowfall (water equivalent) was 16.2 cm. Snow depth (water equivalent) measured two days before snowmelt runoff occurred in RT and MP was 9.4 and 1.9 cm respectively. Greater amount of snow in RT plots was due to snow trapping by standing residue. In MP plots, due to lack of residue cover, snow drifted from the plots. The amount of snow in the RT plots was 58 percent of the snow fall compared to 12 percent in the MP plots. Greater snow depth resulted in greater snowmelt runoff from the RT plots compared to the MP plots (Table 2). There where only two snowmelt runoff events (March 11 and 12) during the 1994-1995 winter. Total snowmelt runoff was 6.6 times greater in the RT compared to MP plots. As expected, the main effects of manure (three years after application) or the interaction of manure and tillage on snowmelt runoff was not significant (Table 2).

During the rainfall period (April-October 1995) the total rainfall was 67.9 cm. In this period, four rainfall runoff events were recorded(September 29 and 30 and on October 2 and 4). There was no significant difference in total rainfall runoff between the RT and MP plots (Table 2). The runoff events occurred when soybean leaf were shed. Therefore soybean leaves (in addition to corn residue) were covering the ground and resulted in similar runoff, especially when the rainfall intensity was low. The main effects of manure or the interaction of manure by tillage was not significant (Table 2). During the growing season in 1992, 1993 and 1994 it has been observed that manure reduced rainfall runoff mostly in rain events with high intensity. Therefore, the absence of manure effects on reducing runoff was due to the low intensity of rainfall.

The annual runoff (November 1994-October 1995) was significantly different between the RT and MP plots (Table 2). Annual runoff was 6 times greater in the RT than MP plots. For both the RT and MP plots, snowmelt runoff was the major portion of the annual runoff. In the RT plots, the snowmelt runoff was 61 times greater than rainfall runoff. In the MP plots, the snowmelt runoff was 8.3 times greater than the rainfall runoff. The manure main effects or the interaction of manure by tillage were not significant (Table 2).

Soybean Yield

Soybean yield was significantly higher in the MP than RT plots (Table 3). Soybean yield in MP plots (2.61 Mg/ha) was 720 kg/ha higher than the RT plots (1.89 Mg/ha).The difference in yield apparently was not due to plant number or seed weight, but due to the yield per soybean plant or the number of seed per plant. Plant number and the weight of 100 seeds were similar between the RT and the MP plots (Table 3). However, the yield and number of seeds per plant were significantly greater in the MP than RT plots (Table 3). This was also shown by greater stover yield in the MP than RT plots. This indicates that soybean growth was better in the MP than the RT plots. The main effects of manure and the interaction of manure by tillage were not significant on grain and stover yield, number of plants, weight of 100 seeds, yield per plant, and number of seeds per plant (Table 3).

Table 1. Cultural practices at the West Central Agricultural Experimental Station, Morris, MN.

Tillage		**Cropping History**
1994	Fall Moldboard (Oct. 27, 1993)	1994-Corn Pioneer-3751
	Spring field cultivation (Apr. 28, 1994)	1995-Lambert Soybean
	Ridge tillage (June 24, 1994)	
1995	Fall Moldboard (Oct. 27, 1994)	
	Spring field cultivation (May 16, 1995)	
	Ridge tillage (July 12, 1995)	

Planting and Harvest Dates

	Planting		
Crop	Date	Rate	Harvested
Soybean	May 16, 1995	406,000 seeds/ha	Oct. 16, 1995 Two rows of 15 feet long each

1992 Manure Analysis

Manure source	Rate	Date Applied	NH4	NO3	Mineral	Organic	Total N	Total P	Total K	DMRP	Solids Total	Solids Volatile	Solids fixed
			%										
Beef	56Mg/ha	May 6/92	.215	.005	.220	.64	.860	.289	.668	0.114	29.12	84	16

Rate of applied and available N, P_2O_5 and K_2O and DMRP

Manure source	Rate	Date Applied	NH4	NO3	Mineral	Organic	Total N	Total P2O5	Total K2O	DMRP
			kg/ha							
Beef	56 Mg/ha	May 6/92	120	2.8	123	358	481	370	374	146

Soil

Barnes loam (fine-loamy mixed Udic Haploborolls, 12 % slope with southern aspect. Soil is high in organic matter, and pH is 8.0. Initial soil test on Olson-P, Bray-P and K are 17, 23 and 155 mg/kg respectively.

Weed Control

Lasso, 3.3 kg ai/ha + Glyphosate (1.7 kg ai/ha) as pre-emergent herbicide (May 18, 1995).
Basagran (1.1 kg ai/ha) + Poast (0.31 kg ai/ha) were applied (June 23, 1995).

Table 2. The effects of tillage and manure application on the snowmelt runoff, rainfall runoff, and the annual runoff (November 1994-October 1995).

	RIDGE TILL			MOLDBOARD			Average		P>F Values		
	No Man	Man	Avg	No Man	Man	Avg	No Man	Man	Tillage (T)	Manure (M)	T by M
Snowmelt Runoff (mm)	88.7	69.2	**77.6**	11.2	12.3	**11.7**	30.9	29.5	.030	.828	.593
Rainfall Runoff (mm)	1.31	1.21	**1.25**	1.37	1.46	**1.41**	1.34	1.33	.264	.902	.405
Annual Runoff (mm)	89.1	69.2	**77.6**	11.5	12.9	**12.3**	38.0	30.3	.030	.836	.559

Table 3. The effects of tillage and manure application on the soybean and stover yield, number of plants, weight of 100 seeds, yield per plant, and number of seed per plant in 1995.

	RIDGE TILL			MOLDBOARD			Average		P>F Values		
	No Man	Man	**Avg**	No Man	Man	Avg	No Man	Man	Tillage (T)	Manure (M)	T by M
Yield (Mg/ha)	1.89	1.89	**1.89**	1.89	2.40	**2.82**	2.15	2.35	.009	.265	.250
Stover (Mg/ha)	1.41	1.46	**1.44**	2.25	2.30	**2.27**	1.83	1.88	.029	.718	.984
plants (1000/ha)	309	301	**305**	309	315	**312**	309	308	.768	.982	.668
100 seeds (g)	17.8	16.8	**17.3**	17.8	17.6	**17.7**	17.8	17.2	.248	.143	.268
Yield/plant (g)	6.22	6.32	**6.27**	7.84	9.01	**8.42**	7.04	7.66	.021	.508	.572
seeds/plant	35.0	37.7	**36.3**	44.1	50.9	**47.5**	39.5	44.3	.033	.036	.683

PHOSPHATE FERTILIZER MANAGEMENT FOR CORN AND SOYBEAN PRODUCTION IN TWO CONTRASTING TILLAGE SYSTEMS

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Abstract

Management of phosphate fertilizer for soybean production on calcareous soils that have very low or low soil test levels for P has not been fully researched. The possibility of applying phosphate fertilizer prior to the soybean crop instead of the corn crop may offer potential for added profit. This study was conducted to evaluate all possible combinations of 1) row spacing for soybeans, 2) tillage system, 3) frequency of phosphate application, 4) phosphate rate, and 5) phosphate placement on production of corn and soybeans grown in rotation. In 1995, all factors studied had a significant effect on soybean yield.

Introduction

Traditionally, major emphasis on fertilizer use is focused on corn in the corn/soybean rotation. The possibility of applying phosphate fertilizer prior to the soybean crop instead of the corn crop has not been fully researched and may offer potential for added profit. This is especially true where soybeans are grown on calcareous soils that have low to very low levels of soil test phosphorus. Placement options for phosphate fertilizer also needed further evaluation.

Experimental Procedure

This study was initiated in the fall of 1994 at the West-Central Experiment Station after corn harvest. The study involved all combinations of 1) row spacing (7, 30 inch), 2) tillage system (fall chisel, no-till), 3) frequency of phosphate application (annual, biennial), 4) phosphate rate (0, 23, 46, 69, 92 lb. P_2O_5 per acre), and 5) phosphate placement (band, broadcast). The phosphate was applied in the fall of 1994. The chisel tillage operation was completed after fertilizer application.

Soybeans were seeded in each tillage system in either 7 -inch or 30-inch rows. A John Deere drill was used for planting in narrow rows. A conventional planter was used for the 30-inch row spacing.

Recently, matured trifoliates were collected from each plot at mid-bloom. These samples were dried, ground, and analyzed for P to monitor P uptake. Grain yields were measured in October.

Summary of Results

In 1995, soybean yields were affected by all factors studied. When averaged over all other factors, yields were higher when the chisel plow system is compared to the no-till system (47.2 bu./acre vs. 44.2 bu./acre). Considering row spacing and averaging over all other factors, yields were higher when 7-inch rows are compared to 30-inch rows (53.4 bu./acre vs. 38.0 bu./acre).

Averaging over other factors, yields were higher when the P_2O_5 was broadcast rather than applied in a band (47.0 bu. per acre vs. 44.7 bu. per acre). Yields increased as the rate of applied phosphate increased. With the very low soil test for phosphorus, a response to phosphate fertilization would be expected.

This study will be continued in 1996.

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