UNIVERSITY OF MINNESOTA

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ACKNOWLEDGEMENTS

This 1995 edition of the soils "bluebook" compiles data collected and analyzed throughout Minnesota. Information is contributed by personnel of the University of Minnesota Department of Soil Science; by soil scientists at the Minnesota Agricultural Experiment Station branch stations at Crookston, Lamberton, Morris and Waseca, and at the Becker and Staples research farms; and by Soil and Crop area agents. Associated personnel from the Soil Conservation Service, and the Soil and Water Research group of the ARS-USDA, the Tennessee Valley Authority, and the Departments of Agriculture and Natural Resources also contribute.

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DISCLAIMERS

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Spring

Entering the late winter and early spring, a significant potential existed for spring flooding. An above average snow pack, waterlogged soils, and unusually high stream base flow provided the components for possible heavy flooding. Fortunately, the weather from mid February through early April was favorable for reducing the flood threat. Light precipitation and moderately warm temperatures led to a gradual snow melt. In the final result, light to moderate flooding occurred in some areas of the South and West.

Relatively warm temperatures and periods of dry weather during early to mid April allowed farmers to perform much needed field work, especially in the South. However, field work came to a halt during the last week of April when the state experienced heavy rains, severe weather, and a spring snow storm.

May was mild and relatively dry and brought more "summer-like" weather than nearly the entire summer of 1993. Temperatures above 80 were common, and many weekends were sunny and mild.

Summer

The Summer of 1994 brought a return to the type of weather typical for a state the size of Minnesota. Some areas of the State experienced benign, nearly ideal weather. Other areas suffered through unusual weather with detrimental impacts. This pattern differs from recent summers, where large scale anomalies in atmospheric circulation brought peculiar weather to most of the state. For the majority of Minnesota, near normal temperatures and timely rains benefited agriculture and other climate sensitive industries. Notable exceptions to this rule were the unusual wetness in the northwest and economically significant hail damage in West Central, South Central, and Southwest Minnesota.

June delivered the usual pattern of "spells" of wet and dry weather. However, in Northern and Southwestern Minnesota, frequent and often heavy thunderstorms pushed June precipitation totals well above normal.

In Northwest and portions of West Central Minnesota, the wet weather continued into July. The unusually recurrent and heavy rainfall drowned crops, enhanced plant disease potential and ceased haying operations across much of the area from the Red River valley eastward.

August featured a mix of pleasant weather along with episodes of cool, wet, and sometimes severe weather. The most significant rainfall event of the late summer occurred on August 9-10 as moderate but persistent storms dropped over four inches of rain over a large area of Southern Minnesota. However, unlike 1993, the rain did not fall upon already saturated soil and thus did not create wide-spread difficulties.. As is common during the summer months, severe storms in August brought tornado, wind, lightning and hail damage to portions of the state. One particularly intense hailstorm damaged over 9000 acres of corn, soybeans, and alfalfa in LeSueur county.

Fall and early Winter

September was characterized by mild temperatures and occasional wet weather. Northwest, South Central, Southeast, and East Central Minnesota received above normal precipitation. Overall it was a pleasant month with the mild weather enhancing evaporation, accelerating crop maturity, and eliminating the threat of frost damage.

The weather during most of October was similar to that found in September. Mild and pleasant weather alternated with occasional wet spells. The most notable weather feature of the month was an absence of a killing frost until late in the month. Many locations went two to four weeks beyond the long term average frost date without receiving freezing temperatures.

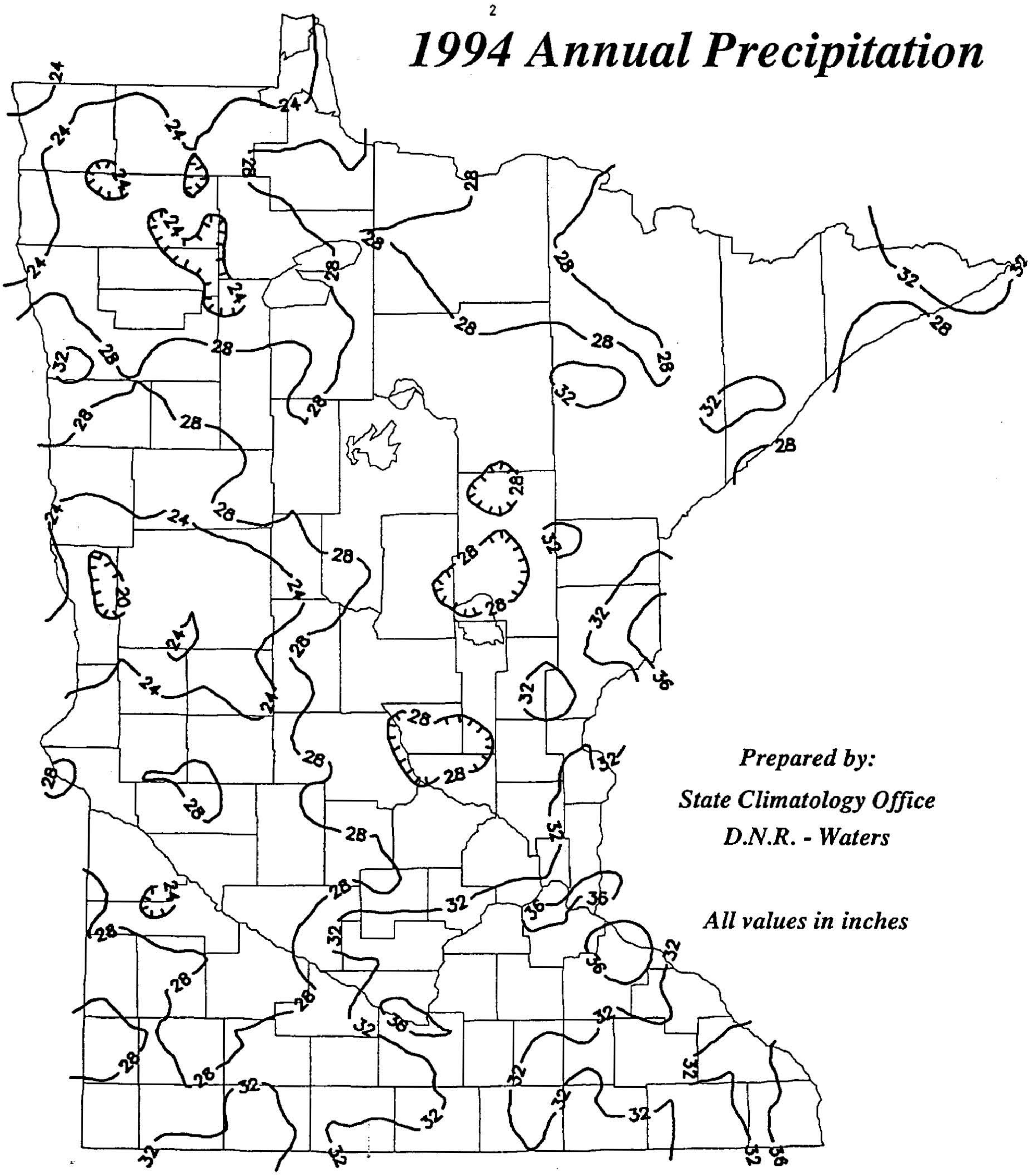
The first significant snowfall of the season came on November 18 in Northern Minnesota, and November 27 for the remainder of the state. These dates roughly match the average occurrence of the first measurable snowfall, and contrast with the late-October and early-November first-snows experienced earlier in the 1990's. The state experienced a mild late fall and early winter. Temperatures for November and December were well above historical averages. Many maximum temperature records were broken in Northern Minnesota in mid to late December

For the Year

Nineteen ninety four precipitation totals were rather ordinary. In contrast to recent years, 1994 precipitation was near the long-term average (normal) over much of Minnesota (see figures) Scattered areas of the state reported above normal precipitation, most notably in the Northwest. Despite this return to "normalcy," many hydrologic systems in Minnesota remain above average due to the unusually heavy precipitation that occurred during the early 1990's.

State Climatology Office, DNR - Division of Waters

1994 Annual Precipitation



Prepared by:

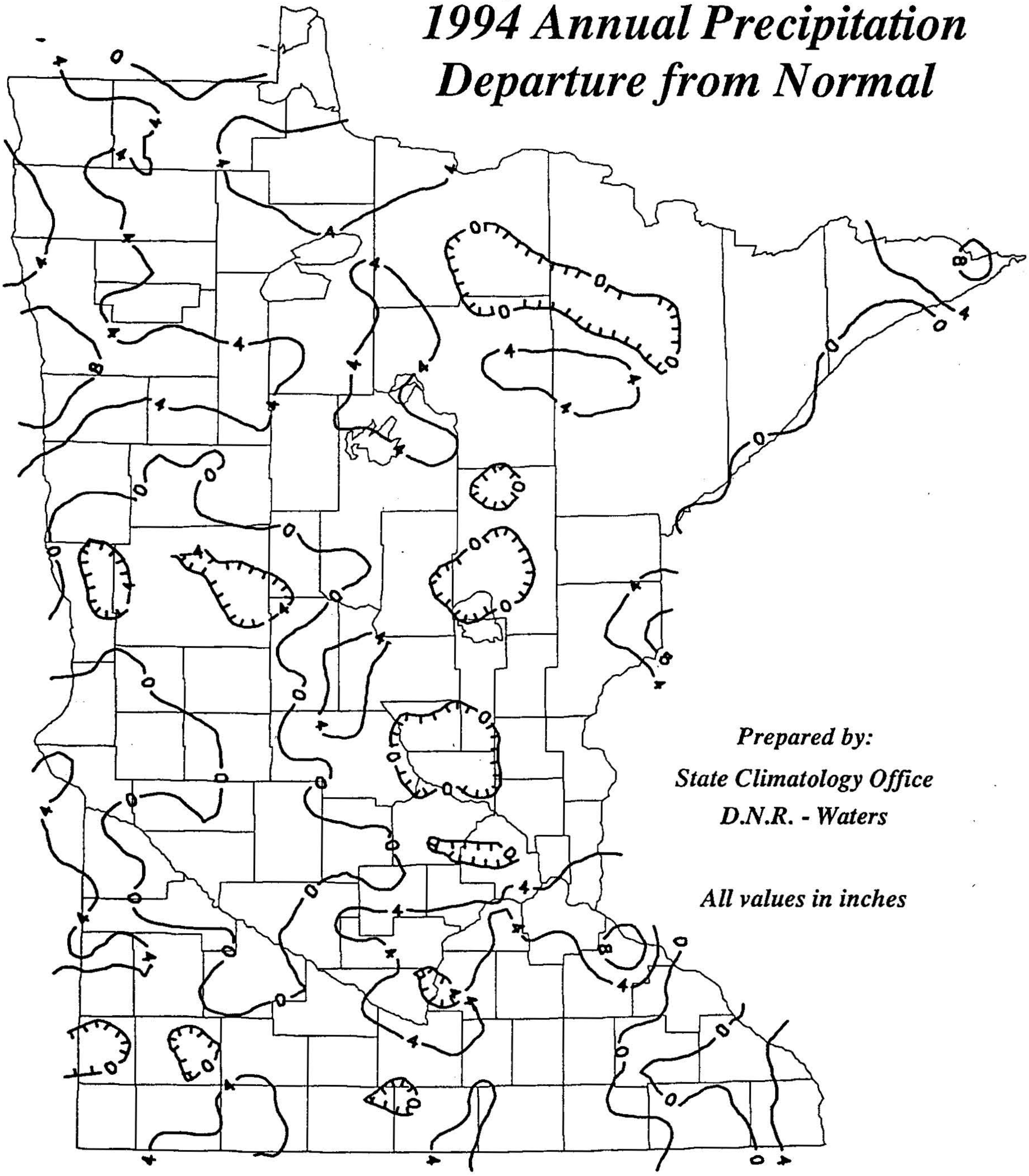
State Climatology Office

D.N.R. - Waters

All values in inches

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

1994 Annual Precipitation Departure from Normal



Prepared by:

State Climatology Office

D.N.R. - Waters

All values in inches

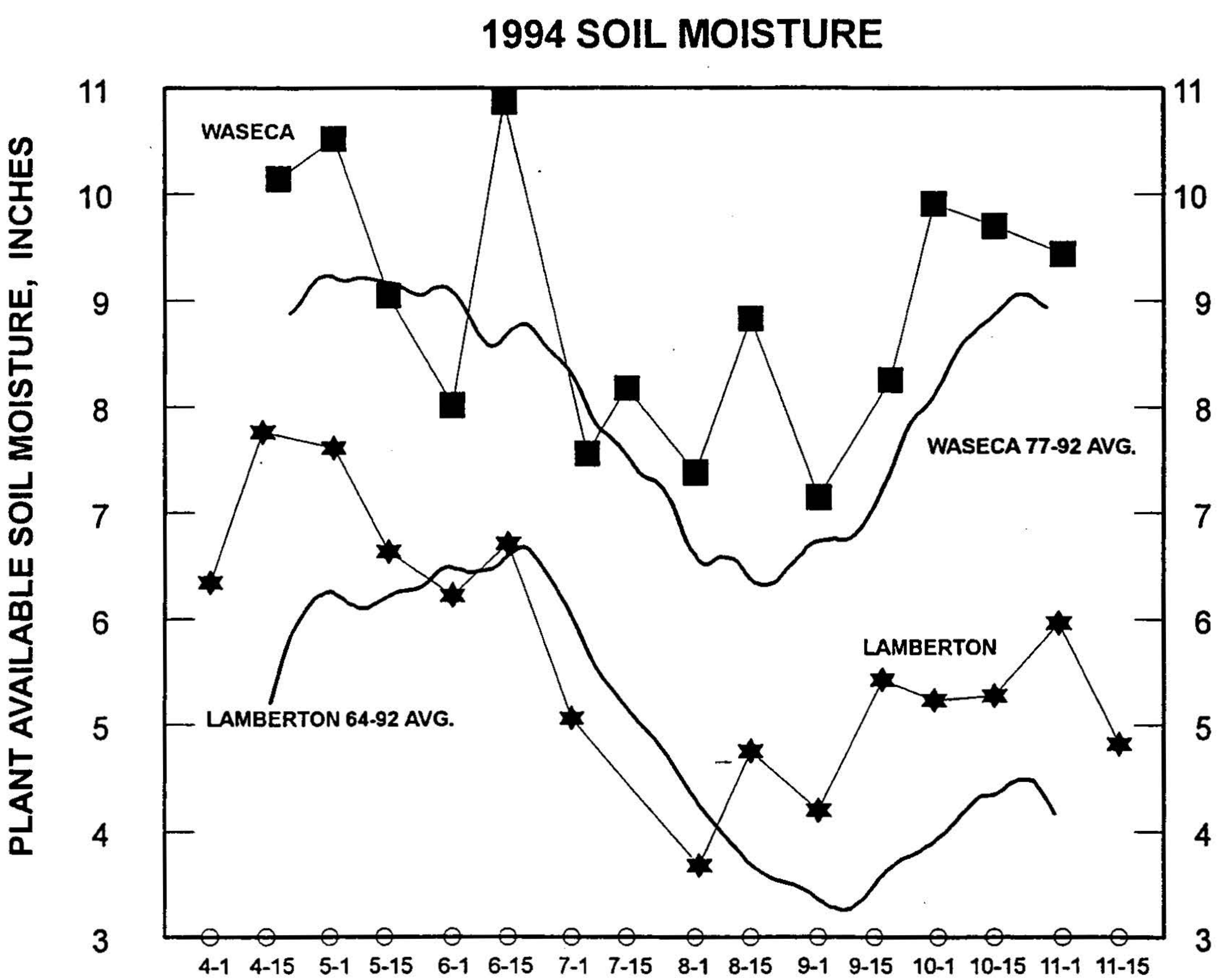
Data sources: National Weather Service, Soil & Water Conservation Districts, DNR - Forestry, Metro Mosquito Control District, DNR/NWS Backyard Rain Gauge Network, Minnesota Association of Watersheds, Future Farmers of America, Minnesota Power and Light, Deep Portage Conservation District, Metropolitan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

1994 Soil Moisture Content at Lamberton and Waseca

D. G. Baker, D. L. Ruschy, G. Randall, and D. Huggins

The 1994 soil moisture values under continuous corn at Lamberton (Redwood Co.) and Waseca (Waseca Co.) are shown in Fig. 1. At both stations the early season moisture amounts were above average, and they were also above average at the end of the season. Assuming there was no runoff from the two plots the water consumed by the corn crop (evapotranspiration) amounted to about 23.97 inches at Lamberton and about 27.72 inches at Waseca. These results in combination with the moderate growing season temperatures explain the generally excellent corn yields obtained in Minnesota last year.

The long-term average soil moisture content at the two stations represent what are most probably the longest continuous records in the United States. As such they are extremely valuable for research in the seasonal water consumption of corn. The approximate 3-inch difference in soil moisture content between the two stations equals the annual total precipitation between them.



NITROGEN MANAGEMENT FOR IRRIGATED POTATOES: EFFECTS OF NITROGEN TIMING AND SOURCE ON SOIL NITRATE MOVEMENT AND PETIOLE SAP NITRATE INTERPRETATION - 1994[1]

Carl Rosen, Mohamed Errebhi, John Moncrief, Satish Gupta, H. H. Cheng, and Dave Birong[2]

ABSTRACT: The fourth year of a four year study was conducted at the Sand Plain Research Farm in Becker, MN to evaluate the effects of various N management strategies on N use and nitrate movement under irrigated potatoes. A second objective was to continue with calibration of a quick petiole nitrate sap test for determining N status of the crop and predicting nitrogen needs. Overall, 1994 was a low leaching year. Insect pressure due to Colorado potato beetle and aphids caused early dieback and limited yields. Tuber yield increased with increasing N rate, with the greatest increase occurring between the 0 and 120 lb N/A rate. Relatively low response to N above this rate may have been due to lack of N leaching and poor late season growth due to insect pressure. At equivalent N rates, there were no significant differences in tuber yield or quality due to timing of N application. Hollow heart increased with increasing N rate, but was not affected by post-hilling N application. Higher concentrations of nitrate in soil water at the 4 ft depth were found in the row compared to between the row for most treatments. Leaching of N was related more to rate of N applied than timing of application. Final tuber yields with urea as the N source were similar to those with ammonium nitrate as the N source. Petiole nitrate increased with increasing N rate and with post-hilling N applications. The quick tests used reflected the changes in petiole nitrate with N treatment. Sap nitrate concentrations determined with the Cardy meter tended to be 50 to 100 ppm higher than readings from the Hach or Wescan instruments.

Potatoes grown on sandy soils under irrigation are usually provided with high rates of nitrogen (N) to promote growth and yield. Concern about ground water quality, however, has raised questions about the fate of N applied to potatoes on irrigated soils. In part, this concern is due to the fact that potatoes have a relatively shallow root system, yet require relatively high rates of N to maintain profitable production. Proper N management is critical to minimize losses of N from the root zone and maintain yields. The objectives of this study were to characterize the pattern of soil nitrate-N movement during irrigated potato production under defined nitrogen management regimes and to develop diagnostic tools for quick and accurate prediction of the need for N by potato during the growing season. The results presented below are the fourth year of a four year study.

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, 6.9; organic matter, 2.5%; phosphorus, 40 ppm; potassium, 123 ppm; sulfur, 2 ppm. Residual nitrate-N in the top 3 feet of soil was 14 lb/A. Prior to planting, 200 lbs/A 0-0-22 and 210 lbs/A 0-0-60 were broadcast and incorporated. Russet Burbank "B" size potatoes were planted April 14, 1994 at a spacing of 36" between rows and 10" within the row. Phosphate (0-46-0) and potash (0-0-60) fertilizer were applied in the band at planting at a rate of 80 lb P_2O_5/A and 200 lb K_2O/A to all plots. The fertilizer was banded 3" to each side and 2" below the tuber. Individual plot size consisted of six, 30 ft rows. The middle two rows (3 and 4) were harvest rows and rows 2 and 5 were sample rows. Ten treatments were tested to evaluate the effects of various N management practices on potato productivity, N use/uptake, soil nitrate movement, and petiole N status during the course of the season. The 10 specific treatments were as follows:

	N Application Rate (lb N/A)						
N Source	Planting	Emergence	Hilling	Post-Hilling	Post-Hilling	Post-Hilling	Post-Hilling
1) Control	0	0	0	0	0	0	0
2) Urea	40	100	100	0	0	0	0
3) Urea	20	70	70	20	20	20	20
4) Urea	20	70	70	0	0	0	0
5) Ammonium nitrate	40	100	100	0	0	0	0
6) Ammonium nitrate	20	70	70	20	20	20	20
7) Ammonium nitrate	20	70	70	0	0	0	0
8) Ammonium nitrate	40	40	40	0	0	0	0
9) Ammonium nitrate	40	40	40	0	20	20	20
10) Ammonium nitrate	40	40	40	20	20	20	20

[1]Funding for this project was provided by the Legislative Commission on Minnesota Resources. We thank Glenn Titrud for assistance in plot maintenance.

[2]Assoc. Prof., Grad. Res. Asst., Ext. Soil Sci., Prof., Prof., and Asst. Sci., respectively, Dept. of Soil, Water and Climate.

Nitrogen applied at planting was banded with the P and K fertilizer. Nitrogen applied at emergence (May 19) was banded 1" deep and 8" from each side of the plant. At hilling (June 7), the N fertilizer was sidedressed on the surface on either side of the plant and then incorporated during the hilling process. Post-hilling applications to treatments #3, 6, and 10 were applied on June 15, June 23, June 28 and July 6. Applications were made by broadcasting 50% ammonium nitrate and 50% urea over the plot by hand and then irrigating in. Post-hilling applications to treatment #9 were June 15, June 28, and July 12.

The experimental design was a randomized complete block with 4 replications. Rainfall was supplemented with overhead irrigation to supply water needs according to the checkbook method. Rainfall during the growing season totaled 22 inches and was supplemented with 9.5 inches of irrigation. The nitrate-N concentration in the irrigation water averaged 8 to 10 ppm. Given that 9.5 inches of irrigation were applied, approximately 20 lbs of additional N was provided with the irrigation water. Figure 1 shows the weekly precipitation (rainfall + irrigation) through the growing season.

Recently matured potato leaves (4th leaf from the growing terminal) were collected every 10-14 days starting one day before hilling for nitrate-N determinations. Thirty 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.

Two instruments designed for quick tests were compared: the Hach nitrate electrode and the Horiba/Cardy nitrate electrode. In addition to the quick test procedures, nitrate in sap and nitrate in dried petioles were determined conductimetrically using a Wescan nitrogen analyzer.

Specific methods for analyses were as follows:

Hach Test - The instrument was calibrated using two standard solutions. One ml of expressed sap was mixed with 25 ml of 0.075 molar aluminum sulfate solution. The electrode was immersed in the solution and a reading was recorded. The reading was related to concentration of nitrate-N in the sap by using a standard curve.

Horiba/Cardy Test - The instrument was calibrated using two standard solutions, 34 and 450 ppm nitrate-N. A few drops of nondiluted sap were placed on the electrode membrane and a direct reading of nitrate-N was recorded.

Wescan Sap Test - The instrument was calibrated using five standard solutions. One ml of expressed sap was mixed with water to a volume of 100 ml in a volumetric flask. Diluted solutions were run through the instrument and the reading recorded was related to the concentration of nitrate-N in the sap using a standard curve.

Wescan Petiole Nitrate Test - The instrumental set up was the same as for the sap test. Dried petioles were ground and 0.1 g of ground tissue was weighed and mixed with 20 ml of water. Samples were shaken for 30 minutes and then filtered. The reading recorded was related to concentration of nitrate-N in dried tissue using a standard curve.

Nitrate-N was determined in soil samples collected one week after harvest. Samples consisted of 3 cores from an individual plot taken to a depth of 3 feet at 1 foot increments. All samples were brought back to the lab and air dried. Nitrate and ammonium were extracted with 2 N KCl using a 5 g to 25 ml soil:extractant ratio. Results are expressed as pounds of nitrate-N using the convention ppm X 2 = lb/A for a 6" furrow slice. Bulk density of each sampling depth was not determined, so lb/A values should be considered approximate.

Suction tubes, consisting of a porous ceramic cup and 1.5" diameter PVC tubes, were installed one week after planting in one of the sample rows and between the rows at the 4 ft depth. Nitrate-N in soil water was determined in samples collected every 1-2 weeks from the suction tubes.

Three plants from the other sample row from each plot were harvested on June 20 to determine the effects of the N treatments on initial growth. Samples were dried, weighed, and ground. Total N was determined using the salicylic Kjeldahl method. At harvest, vines were cut and weighed 8 days prior to harvest. Potatoes were mechanically harvested on September 15. Subsamples of vines and tubers were collected to determine dry matter and N accumulation. Tubers were evaluated for hollow heart and specific gravity was determined.

RESULTS

Rainfall and Soil Nitrate Movement. Weekly precipitation over the course of the season is presented in Figure 1. Major leaching events (> 2" rainfall/day) did not occur during the 1994 growing season. Seasonal nitrate-N concentrations in soil water extracted with the suction tubes at the 4.5' depth in and between the row for each treatment are shown in Figures 2 to 11. Although nitrate-N in the soil water was measured, these numbers do not represent the concentration of nitrate in the ground water. Nor do they indicate the amount of nitrate lost to the ground water. The only way these data can be interpreted is in a more qualitative sense. That is, a higher peak for one treatment compared to another at a given time, indicates that losses of nitrate were relatively greater, but does not indicate how much greater. These data, therefore, can be used to determine which treatments minimized nitrate movement out of the root zone. The control treatment, where no fertilizer N was applied, had nitrate-N concentrations that increased to 20 ppm during the first 12 weeks of the growing season, decreased and then increased after harvest (Figure 2). The nitrate detected in this treatment originated from organic matter mineralization that occurred following tillage operations (planting, cultivation, and harvest).

As expected, nitrate concentrations below the root zone increased with increasing N rate with concentrations in the row generally greater than concentrations between the row (Figures 4, 7, 8 vs. 2, 3, 6, 7, 10). Nitrate concentrations at equivalent N rates when urea was used as the N source tended to be less than those when ammonium nitrate was used as the N source (Figs. 2, 3, 4 vs. 5, 6, 7). When urea was used as the N source there was little difference between nonpost-hilling and post-hilling applications at equivalent rates. However, with ammonium nitrate as the N source, nitrate concentrations in the row were lower with post-hilling N applications. Higher than expected nitrate concentrations were detected in posthilling treatments where lower rates of N were applied through hilling (treatments 9 and 10, Figures 10 and 11). Reasons for the higher levels in these treatments are unclear.

One week after harvest, extractable soil nitrate was higher in the N fertilized plots compared to the 0 N control, but there was little difference in residual soil nitrate concentrations among the N fertilized treatments (Table 1).

Treatment Effects on Early Plant Growth. Increasing nitrogen rate had no effect on tuber number, but did result in greater dry matter accumulation, and higher N concentrations in plants sampled one week after hilling (Table 2). Source of N (ammonium nitrate vs urea) had no effect on tuber number, dry matter accumulation, or tissue N concentrations. All N applied up to hilling resulted in greater dry matter accumulation and tuber number compared to posthilling N treatments. Reduced N at planting, emergence and hilling resulted in smaller plant growth early in the season.

Tuber Yield, Specific Gravity, Hollow Heart, and Vine Yield. The effects of the various N treatments on tuber yield, specific gravity, hollow heart, and vine yield are presented in Table 3. Total yield increased with N rate with most of the yield increase occurring between the control treatment and 120 lb N/A (treatment 8) with little increase in yield between 160 and 240 lb N/A. The 7-14 oz tuber size increased significantly with N rate. Reasons for the apparent lack of N response may have been due to the fact that 1) leaching losses were not that high, and 2) the crop died back early as a result of an uncontrollable outbreak of Colorado poatato beetle and aphids. The early dieback may have limited the use of N at late in the season. Vine yield tended to increase with increasing N rate. Specific gravity of tubers from the control treatment was generally higher than in those receiving N. Specific gravity decreased with increasing N rate. At similar N rates and timing of application, there was little difference between urea and ammonium nitrate on vine and tuber yields. Specific gravity was similar for the urea and ammonium nitrate treatments. The post-hilling N application, treatments 3 and 6, resulted in equal tuber yields compared to 240 lbs N/A applied through hilling (treatments 2 and 5). At equivalent N rates, vine yield was greater with posthilling N applications. Specific gravity was not affected by post-hilling N applications. Additional N after hilling resulted in larger tubers compared to the lower rates applied up to hilling. Hollow heart tended to increase with increasing N rate but was not consistently affected by timing of N application.

Dry Matter and Nitrogen Accumulation. Dry matter and N accumulation, as well as concentrations of N in vines and tubers at harvest, are presented in Table 4. As expected, dry weight, N concentrations in vines and tubers, and N accumulation increased with increasing N rate. At equivalent N rates, post-hilling N applications increased N concentrations in vines and vine N content compared to all N applied up to hilling, but did not significantly affect tuber N. Dry matter accumulation was not affected by post-hilling N applications. Total N uptake and dry matter production were not affected by N source (urea vs. ammonium nitrate); although, N concentrations in vines tended to be higher with ammonium nitrate as the N source.

Nitrate-N Concentrations in Petiole Samples. The N status of the plant (sampled every 10-14 days starting one day before hilling), as measured by conventional petiole analysis and sap analysis, is presented in Table 5. On all sampling dates, nitrate-N concentrations on a dry weight or sap basis increased with increasing N rate. On some sampling dates, petiole nitrate concentrations were lower with urea as the N source than with ammonium nitrate. Differences were generally small, but in some instances may affect the interpretation. Differences in petiole nitrate due to post-hilling applications were not apparent until July 11. Sap nitrate-N concentrations determined with the Cardy meter were 50 to 100 ppm higher than the those determined with the Hach or Wescan instruments. On some sampling dates Cardy meter readings were 200-300 ppm higher. Reasons for these differences are not not clear and are currently being investigated further.

SUMMARY

The 1994 season at Becker was a low year for nitrate leaching. Increasing N rate significantly increased nitrate concentrations below the root zone. Because 1994 was a low leaching year, post-hilling applications of N had minimal effects on nitrate losses compared to similar rates of N applied before hilling. Potato yield was primarily affected by N rate. The greatest yield increase was obtained between the 0 and 120 lb N/A increment. Insects control was a problem in 1994. The early dieback caused by insect damage may have limited the response to N fertilizer. Petiole sap nitrate tests using portable nitrate electrodes appear to have promise for determining N status of the crop. Fine-tuning of the quick test is still needed to accurately predict potato N needs.

Table 1. Effect of nitrogen treatments on soil nitrate-N in the top 3 ft. (pounds per acre ± one standard deviation) at the end of the growing season. Becker, MN.

Treatment		0 to 1 foot	1 to 2 foot	2 to 3 foot	Field total
N source	N timing				
		Pounds per acre			
1. Control	(0 N/A)	12.95 ± 3.58	3.69 ± 1.21	2.06 ± 0.48	18.69 ± 4.46
2. (46-0-0)	(40,100,100)[1]	30.06 ± 9.44	6.21 ± 2.86	2.00 ± 0.83	38.27 ± 10.69
3. (46-0-0)	(20,70,70)+80[2]	32.09 ± 14.25	4.71 ± 1.43	1.61 ± 0.46	38.41 ± 15.27
4. (46-0-0)	(20,70,70)	19.28 ± 6.24	12.92 ± 13.02	3.09 ± 1.23	35.29 ± 8.55
5. (34-0-0)	(40,100,100)	26.71 ± 6.31	6.72 ± 3.37	2.36 ± 1.88	35.79 ± 9.69
6. (34-0-0)	(20,70,70)+80[2]	37.35 ± 17.01	7.59 ± 1.80	2.61 ± 1.15	47.55 ± 19.77
7. (34-0-0)	(20,70,70)	18.55 ± 4.90	5.75 ± 2.74	2.01 ± 0.68	26.31 ± 8.10
8. (34-0-0)	(40,40,40)	20.31 ± 2.24	6.30 ± 2.55	2.52 ± 0.59	29.13 ± 3.03
9. (34-0-0)	(40,40,40)+60[3]	28.98 ± 8.47	6.60 ± 1.83	2.77 ± 1.84	38.36 ± 11.71
10. (34-0-0)	(40,40,40)+80[2]	28.45 ± 5.24	7.02 ± 1.11	2.74 ± 1.34	38.21 ± 5.36

[1] = Planting, emergence, and hilling respectively. [2] = Four post-hilling applications at 20 pounds N/A each, based on sap analysis. [3] = Three post-hilling applications at 20 pounds N/A each, based on sap analysis.

Table 2. Effect of nitrogen treatments on fresh weight of vines, tubers, and hollow heart. Becker, MN.

Treatment			Fresh weight							Specific	Hollow
			Vines	Knobs	<3 oz	3-7 oz	7-14 oz	>14 oz	Total	Gravity	Heart-%
	N source	N timing	Tons/A	cwt/A							incidence
1.	Control	(0 N/A)	0.51	13.2	84.1	183.7	45.6	3.7	330.3	1.0871	8.0
2.	(46-0-0)	(40,100,100)[1]	2.67	48.8	56.7	171.7	184.9	52.2	514.3	1.0829	19.0
3.	(46-0-0)	(20,70,70)+80[2]	6.54	37.4	63.7	158.6	177.6	55.0	492.3	1.0862	26.0
4.	(46-0-0)	(20,70,70)	1.85	20.1	74.0	197.1	167.1	44.1	502.4	1.0877	16.0
5.	(34-0-0)	(40,100,100)	2.53	30.4	72.6	173.5	164.7	44.5	485.7	1.0849	17.0
6.	(34-0-0)	(20,70,70)+80[2]	3.92	29.3	73.2	161.2	169.6	43.2	476.5	1.0851	12.0
7.	(34-0-0)	(20,70,70)	1.13	28.8	74.2	197.0	154.5	23.0	477.5	1.0875	21.0
8.	(34-0-0)	(40,40,40)	1.27	18.1	70.1	204.4	152.8	25.4	470.8	1.0861	20.0
9.	(34-0-0)	(40,40,40)+60[3]	1.34	22.5	74.4	183.1	157.5	39.5	477.0	1.0846	14.0
10.	(34-0-0)	(40,40,40)+80[2]	2.04	23.2	80.7	172.3	140.5	37.9	454.6	1.0823	15.0
Significance			*	*	*	**	**	**	**	*	*
BLSD (0.05)			3.25	19.6	16.5	25.6	38.2	20.2	57.3	0.004	11.5
Contrasts											
Lin Rate N (1, 5, 7, 8)			NS	*	++	NS	**	**	**	NS	*
Quad Rate N (1, 5, 7, 8)			NS	NS	NS	NS	**	**	**	NS	NS
Post-hilling (2, 5) vs (3, 6)			*	NS	NS	NS	NS	NS	NS	NS	NS
(2, 3, 4) vs (5, 6, 7)			NS	NS	*	NS	NS	*	NS	NS	NS
Treatment 3 vs 4			**	*	NS	**	NS	NS	NS	NS	*
Treatment 6 vs 7			++	NS	NS	**	NS	*	NS	NS	*
Treatment 9 vs 10			NS	NS	NS	NS	NS	NS	NS	NS	NS

[1] = Planting, emergence and hilling respectively. [2] = Four post-hilling applications at 20 pounds N/A each, based on sap analysis. [3] = Three post-hilling applications at 20 pounds N/A each, based on sap analysis. NS = Nonsignificant; ++, *, ** = significant at 10%, 5% and 1%, respectively.

Table 3. Effect of nitrogen treatments on root and vine dry matter, tuber number and dry matter; sampled June 20, 1994 - Becker, MN.

Treatment	N source	N timing	Tubers	Tuber (dry matter)	Vine (dry matter)	Root (dry matter)	Total (dry matter)	Tuber (N concentration)	Vine (N concentration)	Root (N concentration)
			-#/plant-	g/plant				% N		
1.	Control	(0 N/A)	11.9	22.3	21.2	4.2	47.7	1.10	2.76	1.40
2.	(46-0-0)	(40,100,100)[1]	16.5	35.8	67.5	5.2	108.5	1.56	4.24	2.32
3.	(46-0-0)	(20,70,70)+80[2]	9.5	17.8	44.7	3.5	66.0	1.61	4.36	2.39
4.	(46-0-0)	(20,70,70)	9.5	20.3	46.3	3.5	70.1	1.73	4.49	2.47
5.	(34-0-0)	(40,100,100)	14.3	29.8	57.5	4.8	92.1	1.66	4.57	2.41
6.	(34-0-0)	(20,70,70)+80[2]	14.6	26.8	52.7	4.2	83.7	1.59	4.46	2.40
7.	(34-0-0)	(20,70,70)	13.4	28.5	64.0	4.3	96.8	1.64	4.45	2.28
8.	(34-0-0)	(40,40,40)	11.8	21.3	58.3	4.0	83.6	1.63	4.19	2.49
9.	(34-0-0)	(40,40,40)+60[3]	16.5	31.0	57.0	4.8	92.8	1.49	4.00	2.13
10.	(34-0-0)	(40,40,40)+80[2]	12.6	28.4	50.4	4.8	83.6	1.46	3.85	2.06
Significance			++	NS	**	++	**	**	**	**
BLSD (0.05)			6.9	--	14.4	1.5	29.6	0.27	0.30	0.26
Contrasts										
Lin Rate N (1, 5, 7, 8)			NS	NS	**	NS	**	**	**	**
Quad Rate N (1, 5, 7, 8)			NS	NS	*	NS	NS	*	**	**
Post-hilling (2, 5) vs (3, 6)			++	++	*	**	*	NS	NS	NS
(2, 3, 4) vs (5, 6, 7)			NS	NS	NS	NS	NS	NS	NS	NS
Treatment 3 vs 4			NS	NS	NS	NS	NS	NS	NS	NS
Treatment 6 vs 7			NS	NS	NS	NS	NS	NS	NS	NS
Treatment 9 vs 10			NS	NS	NS	NS	NS	NS	NS	NS

[1] = Planting, emergence and hilling respectively. [2] = Four post-hilling applications at 20 pounds N/A each, based on sap analysis. [3] = Three post-hilling applications at 20 pounds N/A each, based on sap analysis. NS = Nonsignificant, ++, *, ** = significant at 10%, 5%, and 1%, respectively.

Table 4. Effect of nitrogen on N content, concentration, and dry matter production. Becker, MN

Treatment	N source	N timing	Vines (N content)	Tubers (N content)	Total (N content)	Vine (N concentration)	Tubers (N concentration)	Vines (Dry matter)	Tubers (Dry matter)	Total (Dry matter)
			lbs/A			% N		Tons/A		
1.	Control	(0 N/A)	3.6	66.0	69.6	0.75	0.88	0.24	3.78	4.02
2.	(46-0-0)	(40,100,100)[1]	15.1	143.9	159.1	1.05	1.30	0.73	5.64	6.37
3.	(46-0-0)	(20,70,70)+80[2]	30.6	154.1	184.7	1.43	1.40	1.07	5.54	6.61
4.	(46-0-0)	(20,70,70)	13.8	145.6	159.4	0.92	1.31	0.74	5.58	6.32
5.	(34-0-0)	(40,100,100)	21.3	147.9	169.1	1.38	1.42	0.78	5.21	5.99
6.	(34-0-0)	(20,70,70)+80[2]	27.1	146.1	173.2	1.67	1.38	0.80	5.31	6.11
7.	(34-0-0)	(20,70,70)	11.5	133.3	144.8	0.85	1.27	0.68	5.25	5.93
8.	(34-0-0)	(40,40,40)	11.1	119.5	130.6	0.72	1.12	0.76	5.34	6.10
9.	(34-0-0)	(40,40,40)+60[3]	13.4	141.0	154.4	1.11	1.37	0.62	5.15	5.76
10.	(34-0-0)	(40,40,40)+80[2]	15.5	132.9	148.4	1.26	1.35	0.61	4.99	5.60
Significance			**	**	**	**	**	*	**	**
BLSD (0.05)			12.2	24.1	31.1	0.19	0.18	0.48	0.93	1.10
Contrasts										
Lin Rate N (1, 5, 7, 8)			**	**	**	**	**	**	**	**
Quad Rate N (1, 5, 7, 8)			++	**	**	**	*	++	*	*
Post-hilling (2, 5) vs (3, 6)			*	NS	NS	**	NS	NS	NS	NS
(2, 3, 4) vs (5, 6, 7)			NS	NS	NS	**	NS	NS	NS	NS
Treatment 3 vs 4			**	NS	NS	**	NS	++	NS	NS
Treatment 6 vs 7			**	NS	++	**	NS	NS	NS	NS
Treatment 9 vs 10			NS	NS	NS	NS	NS	NS	NS	NS

[1] = Planting, emergence and hilling respectively. [2] = Four post-hilling applications at 20 pounds N/A each, based on sap analysis. [3] = Three post-hilling applications at 20 pounds N/A each, based on sap analysis. NS = Nonsignificant, ++, *, ** = significant at 10%, 5%, and 1%, respectively.

Table 5. Effect of nitrogen treatments on 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 4				June 14			
	N source	N timing	dry weight Petiole-N	sap Horiba	sap Hach	sap Wescan	dry weight Petiole-N	sap Horiba	sap Hach	sap Wescan
			ppm NO_3-N							
1.	Control	(0 N/A)	6290	545	481	446	309	109	61	46
2.	(46-0-0)	(40,100,100)[1]	17969	1250	1259	1141	16522	1475	1225	1219
3.	(46-0-0)	(20,70,70)+80[2]	17052	1170	1165	1065	15435	1550	1219	1230
4.	(46-0-0)	(20,70,70)	16606	1125	1130	1019	13793	1313	1121	1082
5.	(34-0-0)	(40,100,100)	18170	1275	1233	1114	19061	1775	1465	1415
6.	(34-0-0)	(20,70,70)+80[2]	18103	1225	1224	1142	17445	1638	1358	1220
7.	(34-0-0)	(20,70,70)	17318	1200	1195	1136	16450	1525	1244	1216
8.	(34-0-0)	(40,40,40)	16945	1225	1198	1098	13572	1350	1051	1041
9.	(34-0-0)	(40,40,40)+60[3]	17480	1175	1156	1079	12990	1200	943	1033
10.	(34-0-0)	(40,40,40)+80[2]	16858	1215	1167	1105	11295	1158	979	948
Significance			**	**	**	**	**	**	**	**
BLSD (0.05)			1919	166	151	118	2024	147	137	117
Contrasts										
Lin Rate N (1, 5, 7, 8)			**	**	**	**	**	**	**	**
Quad Rate N (1, 5, 7, 8)			**	**	**	**	**	**	**	**
Post-hilling (2, 5) vs (3, 6)			NS	NS	NS	NS	++	NS	NS	++
(2, 3, 4) vs (5, 6, 7)			NS	NS	NS	NS	**	**	**	**
Treatment 3 vs 4			NS	NS	NS	NS	NS	**	NS	*
Treatment 6 vs 7			NS	NS	NS	NS	NS	NS	NS	NS
Treatment 9 vs 10			NS	NS	NS	NS	NS	NS	NS	NS

[1] = Planting, emergence and hilling respectively. [2] = Four post-hilling applications at 20 pounds N/A each, based on sap analysis. [3] = Three post-hilling applications at 20 pounds N/A each, based on sap analysis. NS = Nonsignificant, ++, *, ** = significant at 10%, 5%, and 1%, respectively.

Table 5 cont. Effect of nitrogen treatments on 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 28				July 11			
	N source	N timing	dry weight Petiole-N	sap Horiba	sap Hach	sap Wescan	dry weight Petiole-N	sap Horiba	sap Hach	sap Wescan
			ppm NO_3-N							
1.	Control	(0 N/A)	546	96	56	43	47	122	44	20
2.	(46-0-0)	(40,100,100)[1]	20573	1275	1354	1384	13882	1150	1093	1031
3.	(46-0-0)	(20,70,70)+80[2]	22098	1525	1471	1536	21851	1613	1612	1500
4.	(46-0-0)	(20,70,70)	18047	1175	1225	1268	9112	733	657	628
5.	(34-0-0)	(40,100,100)	21173	1475	1388	1401	15931	1375	1286	1221
6.	(34-0-0)	(20,70,70)+80[2]	23342	1400	1386	1503	21891	1625	1590	1488
7.	(34-0-0)	(20,70,70)	17573	1363	1362	1363	10789	980	872	809
8.	(34-0-0)	(40,40,40)	9934	795	788	812	2483	355	280	248
9.	(34-0-0)	(40,40,40)+60[3]	17305	1035	1005	1105	10418	1010	903	846
10.	(34-0-0)	(40,40,40)+80[2]	19376	1275	1264	1266	19137	1325	1311	1234
Significance			**	**	**	**	**	**	**	**
BLSD (0.05)			2712	158	147	124	2843	152	164	145
Contrasts										
Lin Rate N (1, 5, 7, 8)			**	**	**	**	**	**	**	**
Quad Rate N (1, 5, 7, 8)			**	**	**	**	*	**	**	**
Post-hilling (2, 5) vs (3, 6)			++	NS	NS	*	**	**	**	**
(2, 3, 4) vs (5, 6, 7)			NS	++	NS	NS	NS	**	*	*
Treatment 3 vs 4			*	**	**	**	**	**	**	**
Treatment 6 vs 7			**	NS	NS	*	**	**	**	**
Treatment 9 vs 10			**	**	**	*	**	**	**	**

[1] = Planting, emergence and hilling respectively. [2] = Four post-hilling applications at 20 pounds N/A each, based on sap analysis. [3] = Three post-hilling applications at 20 pounds N/A each, based on sap analysis. NS = Nonsignificant, ++, *, ** = significant at 10%, 5%, and 1%, respectively.

Table 5 cont. Effect of nitrogen treatments on 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	sap	sap	sap	dry weight	sap	sap	sap
N source	N timing	Petiole-N	Horiba	Hach	Wescan	Petiole-N	Horiba	Hach	Wescan
		ppm NO_3-N							
1. Control	(0 N/A)	32	61	26	4	39	270	33	10
2. (46-0-0)	(40,100,100)[1]	3534	360	298	266	1340	418	190	159
3. (46-0-0)	(20,70,70)+80[2]	9928	1028	907	826	2998	629	395	357
4. (46-0-0)	(20,70,70)	1759	198	167	143	846	281	96	71
5. (34-0-0)	(40,100,100)	6225	653	537	502	2101	486	258	227
6. (34-0-0)	(20,70,70)+80[2]	11743	1060	893	839	4508	643	441	397
7. (34-0-0)	(20,70,70)	2619	248	196	174	563	295	84	63
8. (34-0-0)	(40,40,40)	402	62	35	17	52	253	46	26
9. (34-0-0)	(40,40,40)+60[3]	6119	665	591	547	1753	425	238	201
10. (34-0-0)	(40,40,40)+80[2]	7771	635	539	498	1884	441	280	244
Significance		**	**	**	**	**	**	**	**
BLSD (0.05)		2411	164	149	137	2029	101	93	86
Contrasts									
Lin Rate N (1, 5, 7, 8)		**	**	**	**	*	**	**	**
Quad Rate N (1, 5, 7, 8)		NS	*	*	*	NS	++	*	*
Post-hilling (2, 5) vs (3, 6)		**	**	**	**	**	**	**	**
(2, 3, 4) vs (5, 6, 7)		*	*	++	*	NS	NS	NS	NS
Treatment 3 vs 4		**	**	**	**	*	**	**	**
Treatment 6 vs 7		**	**	**	**	**	**	**	**
Treatment 9 vs 10		NS	NS	NS	NS	NS	NS	NS	NS

[1] = Planting, emergence and hilling respectively. [2] = Four post-hilling applications at 20 pounds N/A each, based on sap analysis. [3] = Three post-hilling applications at 20 pounds N/A each, based on sap analysis. NS = Nonsignificant, ++, *, ** = significant at 10%, 5%, and 1%, respectively.

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

Treatment		Date			
		August 22			
		dry weight	sap	sap	sap
N source	N timing	Petiole-N	Horiba	Hach	Wescan
		ppm NO_3-N			
1. Control	(0 N/A)	168	148	60	21
2. (46-0-0)	(40,100,100)[1]	1638	218	160	105
3. (46-0-0)	(20,70,70)+80[2]	2685	353	310	249
4. (46-0-0)	(20,70,70)	1023	170	106	63
5. (34-0-0)	(40,100,100)	1486	266	241	171
6. (34-0-0)	(20,70,70)+80[2]	2886	310	359	270
7. (34-0-0)	(20,70,70)	562	191	115	67
8. (34-0-0)	(40,40,40)	265	135	69	26
9. (34-0-0)	(40,40,40)+60[3]	963	210	176	119
10. (34-0-0)	(40,40,40)+80[2]	2543	278	277	194
Significance		*	**	**	**
BLSD (0.05)		2191	123	168	134
Contrasts					
Lin Rate N (1, 5, 7, 8)		NS	*	*	*
Quad Rate N (1, 5, 7, 8)		NS	NS	NS	NS
Post-hilling (2, 5) vs (3, 6)		++	*	*	**
(2, 3, 4) vs (5, 6, 7)		NS	NS	NS	NS
Treatment 3 vs 4		++	**	*	**
Treatment 6 vs 7		*	*	**	**
Treatment 9 vs 10		++	NS	NS	NS

[1] = Planting, emergence and hilling respectively. [2] = Four post-hilling applications at 20 pounds N/A each, based on sap analysis. [3] = Three post-hilling applications at 20 pounds N/A each, based on sap analysis. NS = Nonsignificant, ++, *, ** = significant at 10%, 5%, and 1%, respectively.

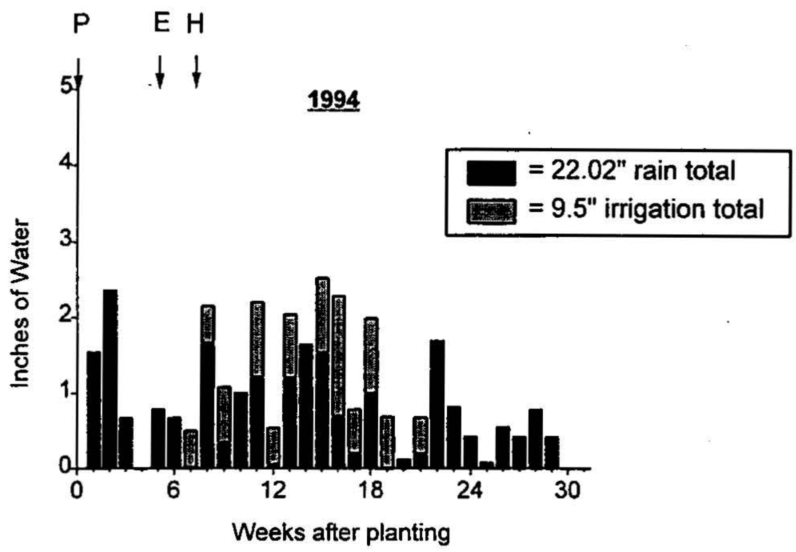


Figure 1. Rainfall and irrigation at Becker, MN during the 1994 growing season. P, H and E = planting, emergence and hilling, respectively.

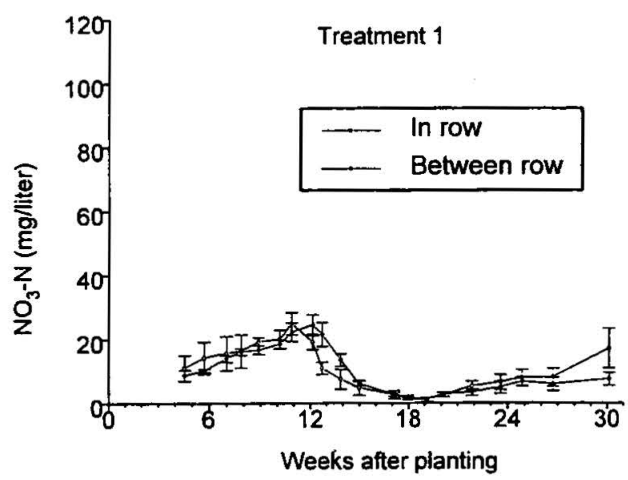


Figure 2. Nitrate - N concentration in soil water sampled in the row and between the row at the 4 ft. depth, over the 1994 growing season. Nitrogen application rate: no nitrogen. Error bars represent SE of the mean.

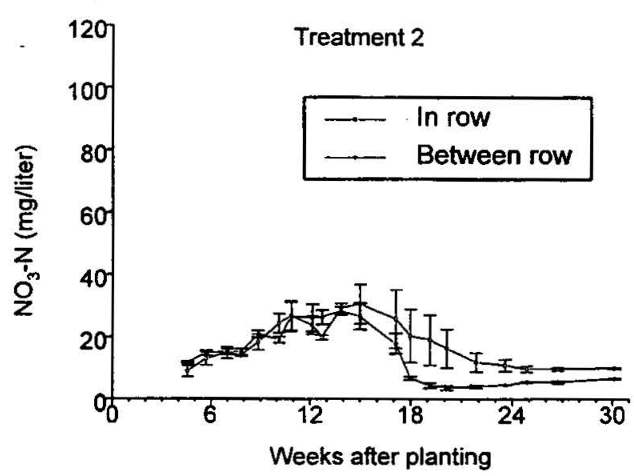


Figure 3. Nitrate - N concentration in soil water sampled in the row and between the row at the 4 ft. depth, over the 1994 growing season. Nitrogen application rate: 40 lb N/A at planting, 100 lb at emergence and hilling (46-0-0). Error bars represent SE of the mean.

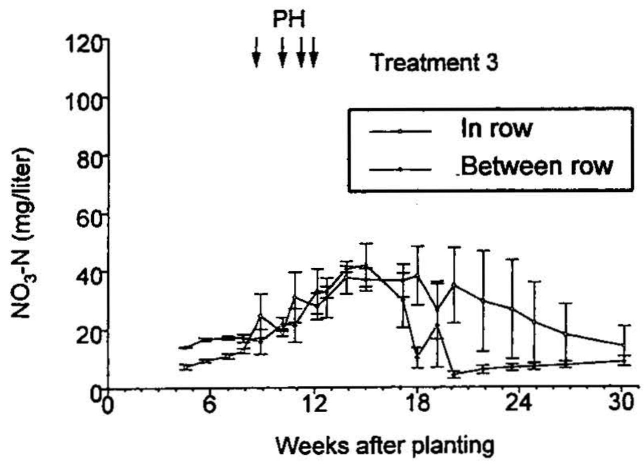


Figure 4. Nitrate - N concentration in soil water sampled in the row and between the row at the 4 ft. depth, over the 1994 growing season. Nitrogen application rate: 20 lb N/A at planting, 70 lb at emergence and hilling, plus 4 post-hilling applications at 20 lb N/A each (46-0-0). Error bars represent SE of the mean.
PH = post-hilling applications.

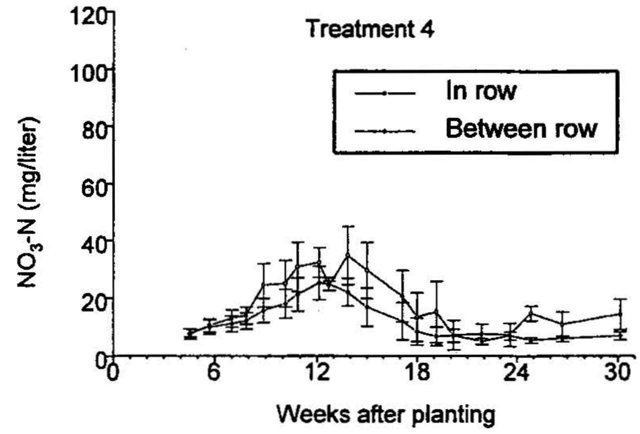


Figure 5. Nitrate - N concentration in soil water sampled in the row and between the row at the 4 ft. depth, over the 1994 growing season. Nitrogen application rate: 20 lb N/A at planting and 70 lb at emergence and hilling (46-0-0). Error bars represent SE of the mean.

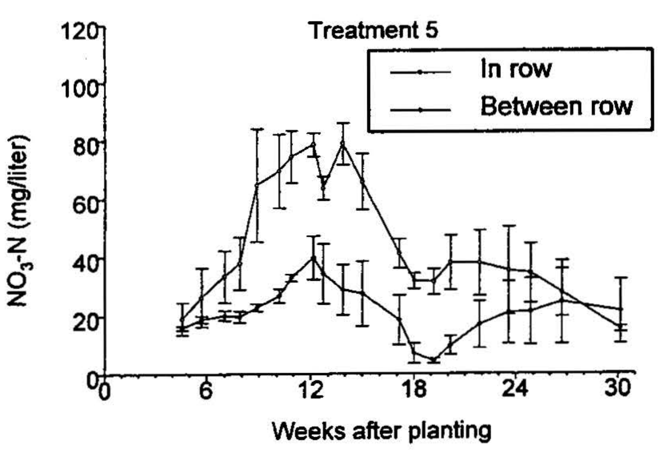


Figure 6. Nitrate - N concentration in soil water sampled in the row and between the row at the 4 ft. depth, over the 1994 growing season. Nitrogen application rate: 40 lb N/A at planting, 100 lb at emergence and hilling (34-0-0). Error bars represent SE of the mean.

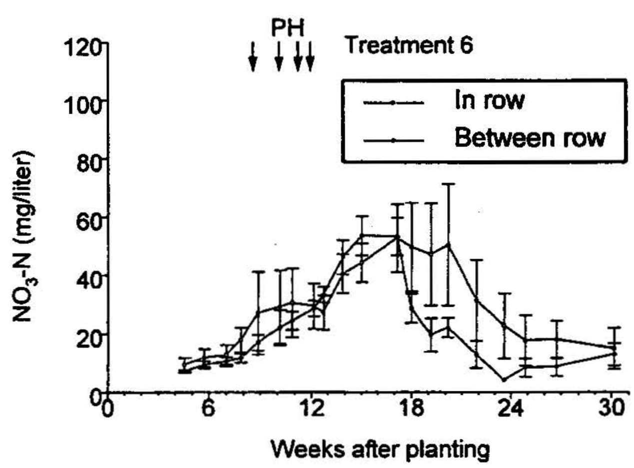


Figure 7. Nitrate - N concentration in soil water sampled in the row and between the row at the 4 ft. depth, over the 1994 growing season. Nitrogen application rate: 20 lb N/A at planting, 70 lb at emergence and hilling, plus 4 post-hilling applications at 20 lb N/A each (34-0-0). Error bars represent SE of the mean.
PH = post-hilling applications.

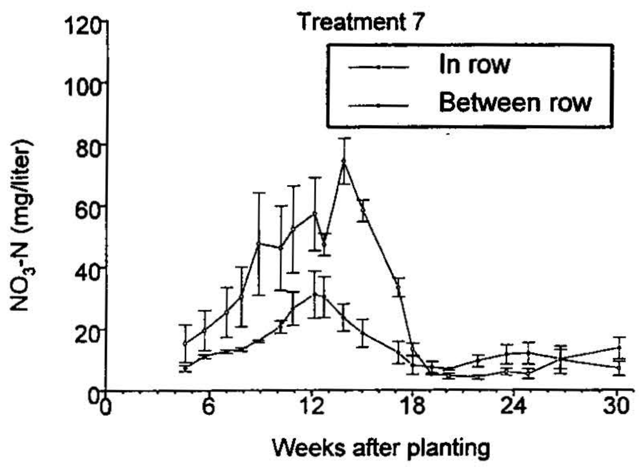


Figure 8. Nitrate - N concentration in soil water sampled in the row and between the row at the 4 ft. depth, over the 1994 growing season. Nitrogen application rate: 20 lb N/A at planting and 70 lb at emergence and hilling (34-0-0). Error bars represent SE of the mean.

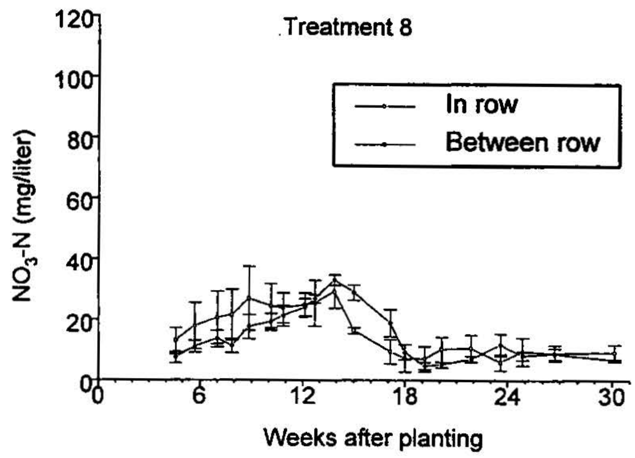


Figure 9. Nitrate - N concentration in soil water sampled in the row and between the row at the 4 ft. depth, over the 1994 growing season. Nitrogen application rate: 40 lb N/A at planting, emergence and hilling (34-0-0).
Error bars represent SE of the mean.

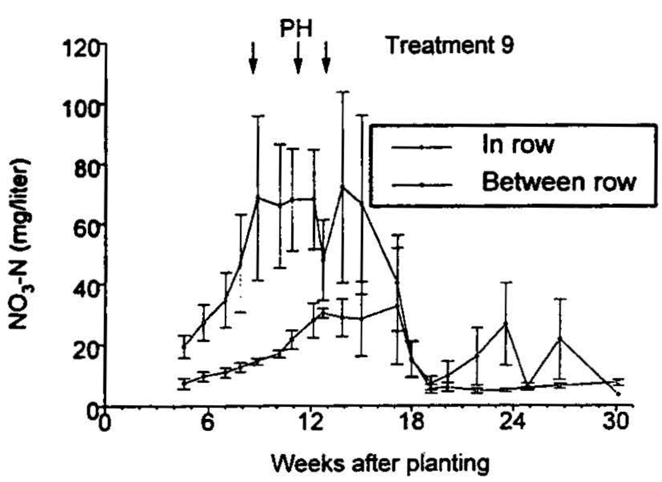


Figure 10. Nitrate - N concentration in soil water sampled in the row and between the row at the 4 ft. depth, over the 1994 growing season. Nitrogen application rate: 40 lb N/A at planting, emergence and hilling, plus 3 post-hilling applications at 20 lb N/A each (34-0-0).
Error bars represent SE of the mean.
PH = post-hilling applications.

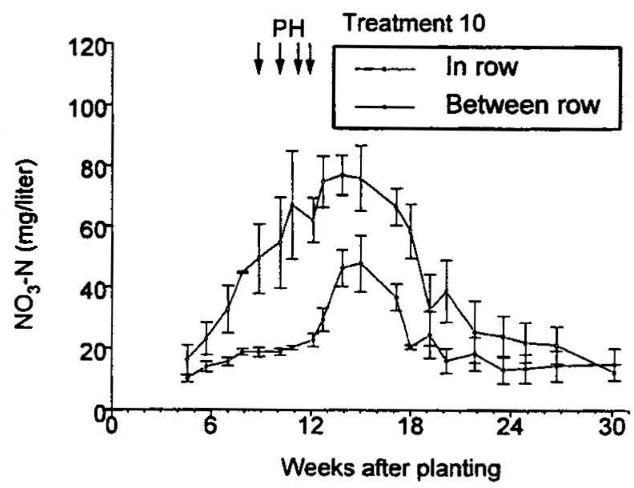


Figure 11. Nitrate - N concentration in soil water sampled in the row and between the row at the 4 ft. depth, over the 1994 growing season. Nitrogen application rate: 40 lb N/A at planting, emergence and hilling, plus 4 post-hilling applications at 20 lb N/A each (34-0-0).
Error bars represent SE of the mean.
PH = post-hilling applications.

POTASSIUM MANAGEMENT FOR IRRIGATED POTATOES: EFFECTS OF POTASSIUM RATE, TIMING, SOURCE AND INTERPRETATION OF A PETIOLE SAP TEST FOR POTASSIUM - 1994[1]

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

ABSTRACT: A potassium fertilizer experiment was conducted at the Sand Plain Research Farm in Becker, MN with a primary objective of evaluating the effects of various K management strategies on potato productivity and quality. A secondary objective was to calibrate a quick petiole K sap test for determining K status of the crop. Tuber yield tended to increase with increasing K fertilizer up to 160 to 240 lb K_2O/A although insect damage resulted in some inconsistent effects. Use of K applications during the growing season did not increase yields, but did increase K concentrations in plant tissue and in the soil. At equivalent K rates, broadcast plus banding potash resulted in yields similar to or better than those obtained with banding alone. Overall highest yields were obtained with 160 lb K20 broadcast one week before planting plus 80 lb K_2O banded at planting. The soil at this site could supply substantial amounts of K to the crop without K fertilizer addition, however the high K removal in the tuber (up to 0.45 lb K/cwt) suggests that the soil K level would drop over the years without K fertilizer additions. Potassium concentrations in nondiluted sap determined with the Horiba electrode were about 900-1500 ppm lower than those determined with the atomic absorption (AA). Sap diluted with $Al_2(SO_4)_3$ 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. Petiole K on a dry weight basis decreased over the season, while petiole sap K concentrations through the season did not follow a consistent pattern.

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, 6.9; P (Bray P), 45 ppm; K and Mg (NH_4OAc), 113 and 155 ppm, respectively; SO_4-S (Ca-phosphate), 1.5 ppm; Zn (DTPA), 0.4 ppm; and B (hot water), 0.2 ppm. Residual nitrate-N in the top 6 inches of soil was 1.6 lb/A. The cultivar "Russet Burbank" was planted on April 14, 1994. 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	80	40	40	280

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

[1]We thank Glenn Titrud for assistance in plot maintenance.

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

Broadcast potash applications were applied by hand one week before planting. Russet Burbank cut potatoes were planted on April 14 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 25), 110 lbs N/A as urea at hilling (June 11). For treatments 8 and 9, nitrogen rates were adjusted so that a total of 240 lb N/A were applied to all plots. In other words, the N from 13-0-44 was taken into account. The nine treatments were replicated 4 times in a randomized complete block design. Each plot consisted of 4 rows, 25 feet in length. The middle two rows (2 and 3) 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 K^+ 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.

Diluted Horiba - The Horiba hand held 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^+ was recorded.

AA Sap - The sap was diluted 100 times with water. An Atomic Absorption Spectrophotometer 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.

On June 20, 3 plants were harvested to determine the effects of the K treatments on initial growth. Samples were taken and separated into roots, tubers, and vines. The number of tubers were counted and the plant parts were dried and then weighed.

Exchangeable K and nonexchangeable K were determined in soil samples collected on June 20 (mid-season) and September 8. Samples consisted of 3 cores from an individual plot taken to the depth of 0-6" and 6"-12". All samples were air dried prior to analysis. Exchangeable K was extracted with 1M neutral NH_4OAc (2 g soil to 20 ml extractant). Exchangeable plus nonexchangeable K was determined on 1.0 N HNO_3 extracts (2.5 g soil to 25 ml extractant). Nonexchangeable K was determined by subtracting the K concentration in the 1 M NH_4OAc extract from the K concentration in the 1 M HNO_3 extract. 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 8. 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 internal tuber disorders. Potassium content of tuber and vines was determined using similar procedures described above for dry weight petiole analysis.

RESULTS

Treatment Effects on Early Plant Growth. The K treatments tested in this study did not significantly affect early plant growth (Table 1). These results suggest that at this early stage, the soil used in this study could supply enough K to support plant growth even though the extractable level was considered to be in the medium K range.

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 2. Potato yields increased with banded applications of 0-0-60 up to 160 lb K_2O/A. Rates higher than 160 lb K_2O/A had inconsistent effects on yield. The 240 lb K_2O/A rate decreased yield while the 320 lb/A rate was similar to the 160 lb/A rate. The reason for lower yield at the 240 lb K_2O/A rate is unclear. Some of the plots died back early due to insect and disease pressure, which may have caused the erratic response. The highest yield recorded in this study was with the 160 lb K_2O/A rate applied as a broadcast before planting plus 80 lb K_2O/A banded at planting (240 lb K_2O/A). This treatment also resulted in more 6-12 oz tubers and a low incidence of hollow heart. Overall, hollow heart was not consistently affected by K treatment. Specific gravity of tubers from the control treatment was generally higher than in those receiving K. Specific gravity decreased with increasing K rate. The treatments with potassium nitrate (13-0-44) had yields comparable to those provided with potassium chloride (0-0-60). Specific gravity was similar for the KCl and KNO_3 treatments when applied at equal rates. Supplying K after planting does not appear to significantly affect potato yield or quality. Vine yield increased slightly with increasing K rate except treatment 4 (240 lb/A all banded) and 8 (240 lb/A split applied during the season). Low vine yields on these plots may have been due to insect damage and early dieback.

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 3. Potassium treatments did not significantly affect dry matter accumulation in vines and tubers. Increasing K application tended to increased K concentrations of vines and tubers except for the treatments that were damaged by insects (treatments 4 and 8). Potassium accumulation in tubers ranged from 190 to 236 lb K/A and in vines ranged from 14 to 33 lb K/A. The effects of K fertilizer treatment on K accumulation were inconsistent although increasing K rate and use of potassium nitrate tended to increase K accumulation.

Potassium Petiole Analysis. Potassium concentrations in potato petioles expressed on a sap and dry weight basis are presented in Table 4. On all sampling dates, K concentrations on a dry weight or sap basis generally increased with increasing K rate, especially in later in the growing season. At equivalent K fertilizer rates, petiole K concentrations tended to be higher when K was applied during the season with potassium nitrate compared to planting applications of potassium chloride. 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 $Al_2(SO_4)_3$ 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 relationship between petiole sap K and petiole dry weight K was not consistent through the season. In general, dry weight petiole K decreased over the season, whereas K concentrations on a sap basis bounced up and down. One reason for this difference may be due to the fact that petiole dry weight also increases during the season. Sap K concentrations would therefore tend to increase (sap becomes more concentrated) as petiole dry weight increases. In contrast, petiole K expressed on a dry weight basis would tend to decrease as dry weight increases. This problem with sap lack of agreement between sap K and dry weight K poses problems in K test interpretation and needs to be resolved before the K sap test can be used for diagnostic purposes.

Exchangeable and Nonexchangeable Soil Potassium. Potassium fertilizer effects on soil K levels are presented in Tables 5 and 6. Potash fertilizer application at planting had little effect on exchangeable and nonexchangeable soil K in the early tuber bulking stage (June 28). Potassium nitrate applied at hilling and emergence significantly increased exchangeable K levels. After harvest, exchangeable soil K concentrations increased in the top soil. Reasons for an increase at the end of the season, but not during the season may be due to sampling procedures. During the season, the soil probe may not have included the fertilizer band, while after harvest this band would have been mixed during the harvesting process. The reason for apparent increase in exchangeable at the end of the growing season compared to samples taken during the growing season may be due to K leakage from dead vine material.

SUMMARY

Results from this study indicate that potato yields increased with increasing K fertilizer up to 160 to 240 lb K_2O/A. Response to K fertilizer was somewhat inconsistent due to insect damage and early dieback. At equivalent K rates, broadcast and banding potash resulted in yields similar to or better than those obtained with banding alone. There was no yield advantage to applying potassium nitrate during the growing season. The K supplying power of this soil was high considering the high accumulation of K in the control plots. However, high levels of K in the tuber suggest that soil K could be depleted over the years if K fertilizer was not applied. Petiole sap K tests using portable K electrodes appear to have promise for determining K status of the crop if diluted sap is tested; however, lack of agreement between petiole sap K and dry weight K needs to be resolved before diagnostic criteria can be established. Use of petiole K status to predict K needs will also require additional calibration research on lower K soils.

Table 1. Effect of potash treatments on root and vine dry matter, tuber number and dry matter; sampled June 20, 1994 - Becker, MN.

Treatment: K_2O source	Treatment: K_2O timing	Tubers	dry matter: Tuber	dry matter: Vine	dry matter: Root	dry matter: Total
		-#/plant-	g/plant	g/plant	g/plant	g/plant
1. Control	(0 K_2O/A)	19.00	47.5	73.5	5.3	126.3
2. KCl	(80,0,0)[1]	12.25	25.3	56.8	4.8	86.9
3. KCl	(160,0,0)	18.50	40.3	70.5	5.3	116.1
4. KCl	(240,0,0)	14.88	42.5	64.0	5.5	112.0
5. KCl	(320,0,0)	11.75	30.8	59.3	3.5	93.6
6. KCl	(80[2]+80,0,0)	18.25	40.0	83.5	6.3	129.8
7. KCl	(160[2]+80,0,0)	17.75	40.3	70.5	5.5	116.3
8. KCl/KNO_3	(80[3],80,80)	19.38	39.5	71.8	5.5	116.8
9. KCl/KNO_3	(80[3],40,80,40,40)[4]	15.38	37.3	68.3	5.5	111.1
Significance		NS	NS	NS	NS	NS
BLSD (0.05)		--	--	--	--	--
Contrasts						
Linear Rate K_2O (1,2,3,4,5)		NS	NS	NS	NS	NS
Quadratic Rate K_2O (1,2,3,4,5)		NS	NS	NS	NS	NS
Cubic Rate K_2O (1,2,3,4,5)		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 10% and 5%, respectively.

Table 2. Effect of potash treatments on fresh weight of vines, tubers, and hollow heart. Becker, MN.

Treatment: K_2O source	Treatment: K_2O timing	Fresh weight: Vines	Fresh weight: Knobs	Fresh weight: <3 oz	Fresh weight: 3-6 oz	Fresh weight: 6-12 oz	Fresh weight: >12 oz	Fresh weight: Total	Specific Gravity	Hollow Heart-%
		Tons/A	cwt/A	cwt/A	cwt/A	cwt/A	cwt/A	cwt/A		incidence
1. Control	(0 K_2O/A)	1.76	11.9	92.0	172.9	152.0	41.5	470.3	1.0929	6.0
2. KCl	(80,0,0)[1]	2.01	18.0	86.1	173.9	163.1	54.5	495.6	1.0912	7.0
3. KCl	(160,0,0)	2.35	11.8	94.5	175.8	177.4	52.0	511.5	1.0908	11.0
4. KCl	(240,0,0)	1.47	7.2	105.8	157.1	132.3	28.1	430.5	1.0878	3.0
5. KCl	(320,0,0)	2.12	12.9	96.6	179.5	173.2	38.9	501.1	1.0923	7.0
6. KCl	(80[2]+80,0,0)	2.49	20.5	94.4	174.7	147.5	45.9	483.0	1.0897	7.0
7. KCl	(160[2]+80,0,0)	2.12	17.0	83.9	166.8	199.9	54.6	522.2	1.0906	2.0
8. KCl/KNO_3	(80[3],80,80)	1.52	8.7	96.2	169.3	168.2	49.8	492.2	1.0882	1.0
9. KCl/KNO_3	(80[3],40,80,40,40)[4]	1.92	9.5	93.1	171.0	171.8	39.1	484.5	1.0894	4.0
Significance		*	NS	NS	NS	++	NS	NS	++	*
BLSD (0.05)		0.71	--	--	--	48.1	--	--	0.0045	6.5
Contrasts										
Linear Rate K_2O (1,2,3,4,5)		NS	NS	NS	NS	NS	NS	NS	NS	NS
Quadratic Rate K_2O (1,2,3,4,5)		NS	NS	NS	NS	NS	NS	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	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% and 5%, respectively.

Table 3. Effect of potash on potassium content, concentration, and dry matter production. Becker, MN

Treatment: K_2O source	K_2O timing	K content: Vines	K content: Tubers	K content: Total	K concentration: Vines	K concentration: Tubers	Dry matter: Vines	Dry matter: Tubers	Dry matter: Total
		lbs/A			% K		Tons/A		
1. Control	(0 K_2O/A)	16.2	190.4	206.6	1.18	1.80	0.65	5.33	5.98
2. KCl	(80,0,0)[1]	15.0	200.6	215.6	1.40	1.81	0.74	5.55	6.29
3. KCl	(160,0,0)	32.6	223.3	255.9	2.24	1.89	0.77	5.91	6.68
4. KCl	(240,0,0)	13.8	174.9	188.7	1.45	1.81	0.54	4.81	5.35
5. KCl	(320,0,0)	31.3	213.4	244.7	2.52	1.95	0.66	5.48	6.14
6. KCl	(80[2]+80,0,0)	29.1	212.8	241.9	2.40	1.86	0.66	5.73	6.39
7. KCl	(160[2]+80,0,0)	27.9	236.5	264.4	2.22	1.99	0.66	5.92	6.58
8. KCl/KNO_3	(80[3],80,80)	18.1	216.4	234.5	1.46	2.06	0.60	5.27	5.87
9. KCl/KNO_3	(80[3],40,80,40,40)[4]	30.5	224.7	255.2	2.63	2.22	0.68	5.39	6.07
Significance		*	**	**	*	**	NS	NS	NS
BLSD (0.05)		16.2	30.1	37.1	1.25	0.22	--	--	--
Contrasts									
Linear Rate K_2O (1,2,3,4,5)		++	NS	NS	*	NS	NS	NS	NS
Quadratic Rate K_2O (1,2,3,4,5)		NS	NS	NS	NS	NS	NS	NS	NS
Cubic Rate K_2O (1,2,3,4,5)		NS	*	*	NS	NS	++	++	*
Band vs Broadcast (3,4 vs 6,7)		NS	*	*	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 10%, 5% and 1%, respectively.

Table 4. 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: K_2O source	K_2O timing	June 6: dry weight Petiole-K	June 6: sap Horiba	June 6: diluted Horiba	June 6: sap AA	June 17: dry weight Petiole-K	June 17: sap Horiba	June 17: Diluted Horiba	June 17: sap AA
		% K	ppm K			% K	ppm K		
1. Control	(0 K_2O/A)	10.34	3850	5175	4806	10.33	3825	5075	5106
2. KCl	(80,0,0)[1]	10.52	4075	5600	5136	10.54	3875	5275	5278
3. KCl	(160,0,0)	11.23	4200	5675	5328	10.76	4075	5550	5479
4. KCl	(240,0,0)	10.98	4175	5600	5158	11.02	4025	5450	5412
5. KCl	(320,0,0)	11.10	4150	5450	5086	11.17	4125	5700	5506
6. KCl	(80[2]+80,0,0)	10.93	4225	5550	5385	10.84	4075	5425	5487
7. KCl	(160[2]+80,0,0)	11.27	4150	5625	5187	11.27	3975	5325	5418
8. KCL/KNO_3	(80[3],80,80)	10.60	4175	5775	5289	11.39	3950	5575	5393
9. KCl/KNO_3	(80[3],40,80,40,40)[4]	10.74	4100	5375	4984	10.77	3900	5325	5308
Significance		**	*	**	++	++	**	*	NS
BLSD (0.05)		0.42	248	269	309	0.84	158	329	--
Contrasts									
Linear Rate K_2O (1,2,3,4,5)		**	**	++	++	**	**	**	**
Quadratic Rate K_2O (1,2,3,4,5)		++	*	**	**	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
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 4 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		June 28				July 11			
K_2O source	K_2O timing	dry weight Petiole-K	sap Horiba	diluted Horiba	sap AA	dry weight Petiole-K	sap Horiba	diluted Horiba	sap AA
		--% K --	ppm K			--% K --	ppm K		
1. Control	(0 K_2O/A)	9.14	3925	5000	5103	8.28	3650	4575	4596
2. KCl	(80,0,0)[1]	9.56	4075	5450	5385	9.11	3825	5025	4750
3. KCl	(160,0,0)	10.24	4175	5450	5516	9.98	3850	5200	5031
4. KCl	(240,0,0)	10.06	4250	5850	5764	9.56	3875	5250	5173
5. KCl	(320,0,0)	10.28	4200	5625	5563	9.50	4000	5425	5134
6. KCl	(80[2]+80,0,0)	10.11	4200	5675	5617	9.14	4000	5575	5366
7. KCl	(160[2]+80,0,0)	10.29	4075	5700	5612	9.68	3900	5300	4945
8. KCL/KNO_3	(80[3],80,80)	10.51	4300	6050	5967	10.34	4100	5825	5560
9. KCl/KNO_3	(80[3],40,80,40,40)[4]	10.55	4250	5850	5760	10.44	4225	6000	5561
Significance		**	**	**	**	**	**	**	**
BLSD (0.05)		0.53	191	197	358	0.77	133	428	309
Contrasts									
Linear Rate K_2O	(1,2,3,4,5)	**	**	**	**	**	**	**	**
Quadratic 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	NS
Band vs broadcast	(3,4 vs 6,7)	NS	NS	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 4 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 25				August 8			
K_2O source	K_2O timing	dry weight Petiole-K	sap Horiba	diluted Horiba	sap AA	dry weight Petiole-K	sap Horiba	diluted Horiba	sap AA
		--% K --	ppm K			--% K --	ppm K		
1. Control	(0 K_2O/A)	7.93	3650	5150	5096	6.46	3400	4525	4506
2. KCl	(80,0,0)[1]	9.45	3900	5700	5361	7.92	3800	5250	5343
3. KCl	(160,0,0)	9.36	4075	5900	5704	8.29	3975	5650	5486
4. KCl	(240,0,0)	9.74	3900	6000	5838	8.76	3800	5275	5329
5. KCl	(320,0,0)	9.96	4200	5925	5731	8.63	3775	5375	5322
6. KCl	(80[2]+80,0,0)	9.66	3950	5825	5563	7.99	3800	5450	5328
7. KCl	(160[2]+80,0,0)	10.12	4200	6200	5938	8.60	4025	5675	5618
8. KCL/KNO_3	(80[3],80,80)	10.32	4400	6600	6428	8.82	3800	5850	5712
9. KCl/KNO_3	(80[3],40,80,40,40)[4]	9.95	4000	6150	6086	9.29	3950	5850	5699
Significance		**	**	**	**	**	**	**	**
BLSD (0.05)		1.17	333	507	566	0.82	232	471	419
Contrasts									
Linear Rate K_2O	(1,2,3,4,5)	**	**	**	**	**	**	**	**
Quadratic 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	*	++

[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 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 22			
K_2O source	K_2O timing	dry weight Petiole-K	sap Horiba	diluted Horiba	sap AA
		--% K --	--------ppm K	---------	
1. Control	(0 K_2O/A)	5.93	3150	4550	4620
2. KCl	(80,0,0)[1]	7.60	3300	5325	5311
3. KCl	(160,0,0)	8.55	3525	5675	5149
4. KCl	(240,0,0)	9.06	3500	5825	5872
5. KCl	(320,0,0)	9.15	3650	4500	6037
6. KCl	(80[2]+80,0,0)	8.66	3750	5700	5801
7. KCl	(160[2]+80,0,0)	8.56	3875	6000	6031
8. KCL/KNO_3	(80[3],80,80)	8.66	3625	5775	5920
9. KCl/KNO_3	(80[3],40,80,40,40)[4]	9.43	3450	5900	6013
Significance		**	NS	NS	**
BLSD (0.05)		1.00	--	--	755
Contrasts					
Linear Rate K_2O	(1,2,3,4,5)	**	*	NS	**
Quadratic 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
Planting vs P,E,H[1]	(4 vs 8)	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 5. Effect of potash treatments on soil potassium in the top 1 foot, June 28, 1994. Becker, MN.

Treatment		Exchangeable K			Nonexchangeable K		
K_2O source	K_2O timing	0 to 6"	6 to 12"	0 to 12"	0 to 6"	6 to 12"	0 to 12"
		ppm					
1. Control	(0 K_2O/A)	72.85	97.85	85.35	200.05	175.75	187.90
2. KCl	(80,0,0)[1]	73.18	84.08	78.63	197.63	165.93	181.78
3. KCl	(160,0,0)	78.90	87.93	83.41	199.80	166.93	183.36
4. KCl	(240,0,0)	83.75	95.88	89.81	216.95	168.33	192.64
5. KCl	(320,0,0)	77.55	89.15	83.35	202.45	151.65	177.05
6. KCl	(80[2]+80,0,0)	85.93	107.43	96.68	182.88	163.28	173.08
7. KCl	(160[2]+80,0,0)	102.30	104.10	103.20	190.38	144.80	167.59
8. KCl/KNO_3	(80[3],80,80)	148.50	101.40	124.95	199.70	167.00	183.35
9. KCl/KNO_3	(80[3],40,80,40,40)[4]	132.48	99.55	116.01	210.83	168.05	198.44
Significance		**	NS	**	NS	NS	++
BLSD (0.05)		27.48	--	15.30	--	--	19.75
Contrasts							
Linear Rate K_2O	(1,2,3,4,5)	NS	NS	NS	NS	++	NS
Quadratic Rate K_2O	(1,2,3,4,5)	NS	NS	NS	NS	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

[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 6. Effect of potash treatments on soil potassium in the top 1 foot, Sept 8, 1994. Becker, MN.

Treatment		Exchangeable K			Nonexchangeable K		
K_2O source	K_2O timing	0 to 6"	6 to 12"	0 to 12"	0 to 6"	6 to 12"	0 to 12"
		ppm					
1. Control	(0 K_2O/A)	127.65	102.65	115.15	215.75	174.35	195.05
2. KCl	(80,0,0)[1]	138.80	96.90	117.85	212.00	176.80	194.40
3. KCl	(160,0,0)	178.50	119.55	149.03	212.80	188.35	200.58
4. KCl	(240,0,0)	162.00	110.40	136.20	216.10	184.20	200.15
5. KCl	(320,0,0)	183.05	110.70	146.88	221.05	164.80	192.93
6. KCl	(80[2]+80,0,0)	161.00	109.90	135.45	205.50	187.00	196.25
7. KCl	(160[2]+80,0,0)	142.55	114.60	128.58	220.85	168.20	194.53
8. KCl/KNO_3	(80[3],80,80)	187.20	111.50	149.35	223.00	186.60	204.80
9. KCl/KNO_3	(80[3],40,80,40,40)[4]	225.73	131.65	178.69	213.88	187.65	200.76
Significance		*	NS	**	NS	NS	NS
BLSD (0.05)		55.61	--	27.45	--	--	--
Contrasts							
Linear Rate K_2O (1,2,3,4,5)		*	NS	**	NS	NS	NS
Quadratic 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
Band vs Broadcast (3,4 vs 6,7)		NS	NS	NS	NS	NS	NS
Planting vs P,E,H[1] (4 vs 8)		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 5% and 1%, respectively.

EVALUATION OF BIO-TILL AS A SOIL AMENDMENT FOR POTATO AND SWEET CORN PRODUCTION - 1994[1]

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

ABSTRACT: Field experiments were conducted at the Sand Plain Research Farm at Becker to determine the effects of Bio-Till soil amendment on potato (Russet Burbank) and sweet corn ('Jubilee') production as well as selected soil properties. Rates of Bio-Till application were 0.1 and 0.2 gal/A. Bio-Till had no effect on soil pH, organic matter content, microbial activity, or extractable P or K. Bio-Till tended to increase extractable Ca and Mg at the low application rate. Sweet corn yield was not affected by Bio-Till application; however, effects on potato yield were inconsistent, with a yield depression at the lower Bio-Till rate and no effect on yield at the high application rate. In two on-farm demonstrations with Russet Burbank potato, Bio-Till depressed yield in one demonstration and had no effect on yield in the other.

Bio-Till is a commercially available product that contains humic substances along with a small amount of soluble fertilizer. Results from various demonstrations have shown beneficial responses to Bio-Till when applied to the soil at the rate of 0.1 gal/A. Although demonstrations and testimonials can be suggestive, there is a lack of research that examines Bio-Till effects on crop growth and quality. The objective of this study, therefore, was to determine the effects of Bio-Till application on potato and sweet corn yield and quality.

PROCEDURES: Two sites at the Sand Plain Research Farm in Becker, Minn. were selected for this study. The soils at both sites are Hubbard loamy sands. Characteristics of each site were as follows:

	Sweet corn site	Potato site
Previous crop	Rye	Rye
Soil pH (1:1 - soil:water)	6.7	6.8
Bray P1	30 ppm	63 ppm
K - NH_4OAc	111 ppm	99 ppm
Ca - NH_4OAc	859 ppm	798 ppm
Mg - NH_4OAc	158 ppm	184 ppm
NH_4 - N (2N KCl)	1.3 ppm	1.4 ppm
NO_3 - N (2N KCl)	1.6 ppm	0.9 ppm
SO_4 - (Calcium phosphate)	1.0 ppm	1.5 ppm
Zn - DTPA	0.9 ppm	0.6 ppm
B - (Hot water)	0.4 ppm	0.3 ppm

Prior to planting, 200 lb sul-po-mag and 210 lb K_2O (as 0-0-60) were broadcast and incorporated at both sites. Russet Burbank "A" size seed potatoes were cut to about a 3 oz. size and planted on April 18, 1994 at a spacing of 36" between rows and 10" within the row. Each plot consisted of six, 34' rows. At planting, all plots received 40 lb N/A, 50 P_2O_5/A, and 150 lb K_2O/A. Nitrogen, phosphate, and potash was applied as a band 3" to each side and 2" below the row. Treatments were as follows: 0, 0.1, and 0.2 gallons Bio-Till/A. Bio-Till was mixed with water so that the final delivery of water was 36 gallon/A. Application of the Bio-Till solution was made with a CO_2 backpack sprayer. Treatments were sprayed on the soil surface just prior to planting. Post-planting N included 88 lb N/A emergence (May 23) and 88 lb N/A at hilling (June 6) as ammonium nitrate.

Sweet corn ('Jubilee') was planted on May 12, 1994 at a spacing of 30" between rows and a plant population of 27,600 kernels/A. At planting, 165 lbs/A of 8-10-30 was banded 2" to the side and 2" below the seed. Bio-Till was applied at the same rate and using the same procedure as for the potatoes. The experimental design was a randomized complete block with four replications. All sweet corn plots received 78 lbs N/A as ammonium nitrate as a sidedress application on May 26 and an additional 93 lb N/A as ammonium nitrate on June 13.

Each site was irrigated according to the checkbook method for potatoes and sweet corn, respectively. Soil samples were collected on July 8 from the 0-6" depth. Samples were analyzed for pH, cation exchange capacity organic matter, extractable P (Bray 1), ammonium acetate Ca, Mg, and K, and microbial activity (dehydrogenase activity).

For the potato study, whole plant samples (three plants per plot) were collected on June 20 and separated into roots, vines, and tubers. Tubers were counted and plant parts were dried at 60C for two weeks and then

[1]Funding for this research was provided by a grant from Pro-Ag Inc.
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weighed. In the sweet corn study, whole plant samples were collected on June 22 at the 10 to 12 leaf stage. Samples were dried for 2 days at 60C and then weighed. Ear leaf samples were collected at early silking and then dried. All dried potato and sweet corn samples were ground through a 30 mesh screen for subsequent analyses.

For the sweet corn study, the two middle rows of each plot were harvested on August 4 and ears were weighed, husked, and then reweighed. Ear length was measured and a subsample of the kernels was collected for moisture and nitrogen determination. For the potato study, the two middle rows of each plot were harvested on September 15 and tubers were graded according to weight classes: <3 oz, 3-7 oz, 7-14 oz, and >14 oz. A subsample of tubers was saved for specific gravity determination and hollow heart incidence.

RESULTS

Soil Properties: Analyses of soil samples collected on July 8 from both the potato and sweet corn studies are presented in Tables 1 and 2. In general, Bio-Till application had no effect on soil organic matter, CEC, pH, P, K, or microbial activity. There was a slight increase in Ca and Mg at the low application rate of Bio-Till. Reasons for this increase at only the low rate of application are not known.

SWEET CORN

Early plant growth: Dry weight, nitrogen content and stand count of sweet corn plants at the 10 to 12 leaf stage is presented in Table 3. Bio-Till had no effect early plant dry weight accumulation or nitrogen content. Stand count was also not affected by Bio-Till.

Final yield and quality: Bio-Till had no effect on sweet corn unhusked or husked yield (Table 3). Ear length tended to be depressed with Bio-Till application. Nitrogen concentration in the kernels (an indirect measure of protein) was not affected by Bio-Till. Kernel moisture percentage, a measure of maturity was not changed significantly with Bio-Till application (Table 3).

Tissue elemental concentrations: Elemental concentrations in the ear leaf of sweet corn sampled at silking are presented in Table 4. In general, Bio-Till did not consistently affect elemental concentrations in the ear leaf. Leaf nitrogen tended to be depressed at the lower Bio-Till application rate and leaf phosphorus tended to decrease with Bio-Till application.

POTATOES

Early plant growth: Dry weight of Russet Burbank vines, roots, and tubers sampled in June are presented in Table 5. Bio-Till fertilizer did not significantly affect dry weight of any of the tissues samples. Tuber initiation was not affected by Bio-Till nor was tissue nitrogen concentration (Table 5).

Tuber yield and quality: Tuber yield, size distribution, specific gravity, and hollow heart are presented in Table 6. Bio-Till tended to decrease yield at the low rate of application, but were equal to the control at the higher application rate. All the potatoes suffered from a severe insect infestation (aphids and Colorado potato beetle), as well as early dying. Some plots seemed to be more affected than others and may have contributed to the erratic yield results. Bio-Till had no effect on specific gravity, but tended to increase the incidence of hollow heart.

Tissue elemental concentrations: Elemental concentrations in the potato shoots sampled June 20 are presented in Table 7. Bio-Till did not significantly affect elemental concentrations in potato shoots.

On-farm potato yield checks: Russet Burbank potato yield and quality were measured at two commercial potato farms: one in Morrison county (Anderson Farm - Table 8) and the other in Sherburne county (Hammer Farm - Table 9). Potato yield was not significantly affected by Bio-Till application at the Anderson farm; however, Bio-Till significantly depressed yield at the Hammer farm.

GENERAL DISCUSSION

While, one year of field data is not enough to draw definitive conclusions on the effectiveness of Bio-Till, none of the studies conducted in 1994 on sandy soils showed a marked yield improvement due to Bio-Till application over the control. Perhaps different rates of application are needed on sandy soils compared to finer textured soils. Another year of research is needed to explore possible reasons for the lack of a positive Bio-Till response.

Table 1. Effect of Bio-Till fertilizer on soil parameters of Jubilee sweet corn experimental plot, sampled July 8, 1994.

Bio-Till Treatment Gallons/Acre	organic matter	microbial activity	cation exchange capacity	pH	P	K	Mg	Ca
						Element		
	%	µg/g soil/day	meq/100g		ppm			
0	1.9	44.7	6.5	6.1	29	72	155	815
0.1	2.0	41.3	7.0	6.2	29	74	174	898
0.2	2.0	37.4	6.3	6.2	27	74	157	807
Pr>F	0.79	0.57	0.13	0.40	0.73	0.95	0.07	0.05
Lin Bio-Till	NS	NS	NS	NS	NS	NS	NS	NS
Quad Bio-Till	NS	NS	++	NS	NS	NS	*	*

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

Table 2. Effect of Bio-Till fertilizer on soil parameters of Russet Burbank potato experimental plot, sampled July 8, 1994.

Bio-Till Treatment Gallons/Acre	organic matter	microbial activity	cation exchange capacity	pH	P	K	Mg	Ca
						Element		
	%	µg/g soil/day	meq/100g		ppm			
0	2.1	38.6	7.2	6.3	74	131	199	863
0.1	2.3	37.9	7.7	6.2	72	135	217	921
0.2	2.0	38.7	6.6	6.1	73	108	176	786
Pr>F	0.26	0.99	0.22	0.59	0.98	0.17	0.03	0.17
Lin Bio-Till	NS	NS	NS	NS	NS	NS	++	NS
Quad Bio-Till	NS	NS	NS	NS	NS	NS	*	NS

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

Table 3. Effect of Bio-Till fertilizer on dry matter of 'Jubilee' sweet corn whole plant samples (8-12 leave stage), final yield parameters, and plant population.

Bio-Till Treatment Gallons/Acre	whole plant	whole plant	kernel	ear green	ear husked	kernel moisture	useable ears	ear length	plant population
	Plant Part								
	g/plant	% N		T/A		%		--cm--	plants/A
0	12.94	3.60	1.93	8.88	6.03	78.3	92.5	19.9	26245
0.1	12.75	3.57	1.94	8.52	5.81	78.6	88.8	19.4	27334
0.2	13.19	3.60	1.93	8.91	6.10	77.7	96.3	19.3	27443
Pr>F	0.95	0.92	0.99	0.42	0.62	0.51	0.11	0.03	0.26
Lin Bio-Till	NS	NS	NS	NS	NS	NS	NS	*	NS
Quad Bio-Till	NS	NS	NS	NS	NS	NS	++	NS	NS

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

Table 4. Effect of Bio-Till fertilizer on elemental composition of 'Jubilee' sweet corn ear leaf, sampled July 20, 1994.

Bio-Till Treatment Gallons/Acre	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	%					ppm				
0	2.73	0.30	2.98	0.66	0.35	85	102	19	4.9	5
0.1	2.55	0.29	3.08	0.63	0.37	83	87	17	4.4	5
0.2	2.72	0.29	3.04	0.62	0.35	82	97	18	4.9	4
Pr>F	0.07	0.17	0.37	0.21	0.73	0.50	0.28	0.37	0.33	0.79
Lin Bio-Till	NS	++	NS	NS	NS	NS	NS	NS	NS	NS
Quad Bio-Till	*	NS	NS	NS	NS	NS	NS	NS	NS	NS

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

Table 5. Effect of Bio-Till fertilizer on dry matter of Russet Burbank potato vines, roots, tubers, and number of tubers - sampled June 20, 1994.

Bio-Till Treatment Gallons/Acre	Plant Part: vines	roots	tubers	total	vines	roots	tubers	number of tubers
	grams/plant				% N			per plant
0	69.67	5.33	28.17	103.17	3.68	2.47	1.72	16.25
0.1	63.00	5.50	24.50	93.00	3.81	2.56	1.75	16.83
0.2	70.50	5.50	30.67	106.67	3.82	2.50	1.61	19.00
Pr>F	0.77	0.98	0.78	0.77	0.20	0.87	0.72	0.62
Lin Bio-Till	NS	NS	NS	NS	NS	NS	NS	NS
Quad Bio-Till	NS	NS	NS	NS	NS	NS	NS	NS

NS = nonsignificant.

Table 6. Effect of Bio-Till fertilizer on yield and specific gravity of Russet Burbank potatoes.

Bio-Till Treatment Gallons/Acre	Tuber Yield: Knobs	Tuber Size: <3 oz	3-7 oz	7-14 oz	>14 oz	Total	Specific Gravity	Hollow Heart
	cwt/A							% incidence
0	8.6	120.1	226.6	96.7	11.5	463.5	1.0869	12.0
0.1	8.7	123.2	206.2	80.7	9.4	428.3	1.0850	15.0
0.2	6.6	119.5	233.7	107.1	10.4	477.2	1.0890	23.0
Pr>F	0.79	0.95	0.15	0.26	0.82	0.03	0.31	0.21
Lin Bio-Till	NS	NS	NS	NS	NS	NS	NS	++
Quad Bio-Till	NS	NS	++	NS	NS	*	NS	NS

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

Table 7. Effect of Bio-Till fertilizer on elemental composition of Russet Burbank potato shoots, sampled June 20, 1994.

Bio-Till Treatment Gallons/Acre	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	%					ppm				
0	3.68	0.29	6.99	1.29	0.87	569	137	25	3.5	25
0.1	3.81	0.30	6.91	1.31	0.88	491	133	24	3.3	25
0.2	3.82	0.28	6.61	1.29	0.86	487	136	21	3.5	24
Pr>F	0.20	0.67	0.28	0.95	0.95	0.69	0.96	0.17	0.68	0.33
Lin Bio-Till	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Quad Bio-Till	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS = nonsignificant.

Table 8. Effect of Bio-Till fertilizer on yield and specific gravity of Russet Burbank potatoes (Anderson).

Bio-Till Treatment (with or without)	Tuber Yield: Knobs	Tuber Size: <3 oz	3-6 oz	6-13 oz	>13 oz	Total	Specific Gravity	Hollow Heart
	cwt/A							% incidence
-	4.7	60.6	195.1	137.0	7.6	405.1	1.0837	8.0
+	5.6	77.1	196.4	144.8	1.6	425.6	1.0868	7.0
Pr>F	0.89	0.14	0.94	0.85	0.31	0.74	0.12	0.39

Table 9. Effect of Bio-Till fertilizer on yield and specific gravity of Russet Burbank potatoes (Hammer).

Bio-Till Treatment (with or without)	Tuber Yield: Knobs	Tuber Size: <3 oz	3-6 oz	6-13 oz	>13 oz	Total	Specific Gravity	Hollow Heart
	cwt/A							% incidence
-	9.8	25.4	132.2	252.5	44.4	464.4	1.0880	3.0
+	2.8	59.5	193.7	154.9	0.0	410.9	1.0886	3.0
Pr>F	0.23	0.01	0.01	0.02	0.02	0.10	0.29	1.00

POTATO RESPONSE TO PHOSPHORUS ON HIGH PHOSPHORUS TESTING SANDY SOILS: ON-FARM TRIALS 1994[1]

Carl Rosen and Dave Birong[2]

ABSTRACT: Response of Russet Burbank and Norland potatoes to phosphate fertilizer was evaluated in on farm trials. Phosphate fertilizer did not consistently affect early dry matter accumulation or tuber number in either cultivar. Effects on final yield were not consistent. For Russet Burbank, P fertilizer had no effect on yields. For Norland, total tuber yield increased up to 200 lb P_2O_5/A. Phosphate fertilizer increased phosphorus concentrations in petiole tissue of both cultivars.

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 potato on growers' fields 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, one in Clear Lake and the other in 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	seed corn
Soil pH (1:1 - soil:water)	5.3	6.0
Bray P1	165 ppm	105 ppm
K - (ammonium acetate)	209 ppm	201 ppm

Specific procedures at each site are as follows:

Clear Lake - Five treatments were evaluated: 0, 50, 100, 150, and 200 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: 31 lb N/A, 200 lb K_2O/A, and 21 lb S/A. Norland "B" size potatoes were planted with a pick planter on April 13, 1994 at a spacing of 9" within the row and 36" between rows. Plots were six rows wide and 300 ft in length. Each treatment was replicated four times. Additional nitrogen was applied at emergence (May 20) and hilling (June 10) at the rate of 70 lb N/A at each date. 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, 68 lb N/A at emergence and 34 lb N/A at hilling. Whole plant samples from 5 ft of row and petiole samples from the most recently matured leaf were collected on June 21. Whole plant samples were separated into roots, tubers, and vines. Samples were dried and then weighed. Nutrient concentrations were determined in dried ground petiole samples. Vines were killed on July 15. Two, 20 ft rows from the middle of each plot were harvested on July 27. Tubers were graded according to the following size categories: less than 2.25", 2.25-2.75", greater than 2.75", and culls.

Becker - Five treatments were evaluated: 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. Potatoes were planted at the time of starter fertilizer application but were not hilled. Immediately after planting, the phosphate fertilizer (0-46-0) treatments were applied as a band with a belt type applicator 3" to each side of the tuber. Hills were then formed. Russet Burbank "A" size

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[1]We thank the Area II potato growers for providing funds to support this project. We thank Howard, Paul and Gary Gray and K&O farms for providing plot space on their fields to conduct the experiments. We also thank the Howe Company for providing and blending the fertilizer used in this research.
[2]Ext. Soil Scientist and Asst. Scientist, respectively, Dept. of Soil, Water and Climate.

cut potatoes were planted with a cup planter on April 12, 1994 at a spacing of 11" within the row and 36" between rows. Plots were 12 rows wide and 50 ft in length. Each treatment was replicated four times. Additional nitrogen was applied at emergence (May 21) at the rate of 60 lb N/A and hilling (June 10) at the rate of 120 lb N/A. A 40 lb N/A fertigation was applied on July 13. A grower treatment bordering the experiment was also compared to the phosphate treatments. The phosphate rate for the grower treatment was 135 lb P_2O_5/A. All other nutrient rates were the same as in the experiment. Whole plant samples from 5 ft of row and petiole samples from the most recently matured leaf were collected on June 23. Whole plant samples were separated into roots, tubers, and vines. Samples were dried and then weighed. Nutrient concentrations were determined in dried ground petiole samples. Vines were killed on September 1. Two, 20 ft rows from the middle of each plot were harvested on September 6. Measurements at harvest included: total tuber yield, graded tuber yield, specific gravity, and incidence of internal tuber disorders.

RESULTS

Early plant growth: Dry weight of Norland and Russet Burbank vines, roots, and tubers sampled in June are presented in Tables 1 and 2, respectively. Phosphate fertilizer did not consistently affect dry matter production in either cultivar. Tuber set was relatively high (greater than 20 tubers per plant) for both cultivars regardless of fertilizer treatment.

Final harvest evaluation: Yield of Norland potatoes as affected by phosphate fertilizer is presented in Table 3. Total yield tended to increase with increasing phosphate fertilizer. Most of this increase was due to an increase in yield of the larger size tubers. The grower treatment resulted in lower total yield than that obtained in the P fertilizer experiment. However, the size of the tubers tended to be larger in the grower treatment. These results suggest that the grower treatment had less tuber initiation than those in the experimental area. Reasons for this size distribution difference may be due more to nitrogen management than phosphorus fertilizer management. Higher rates of N were applied early in the grower treatment than in the P fertilizer treatments. More research with Norland potatoes needs to be conducted to determine the effects of early season N applications on yield. Phosphate fertilizer had no effect on hollow heart or brown center in Norland potatoes.

Yield of Russet Burbank potatoes as affected by phosphate fertilizer is presented in Table 4. Phosphate fertilizer did not significantly affect Russet Burbank tuber yield in this experiment. Specific gravity tended to increase with increasing P fertilizer rate. Phosphate fertilizer had no effect on hollow heart incidence. The crop died early due to insect and disease pressure. Phosphorus did not appear to be a limiting factor to yield at this location.

Petiole nutrient concentrations: Nutrient concentrations in petioles sampled in the third week of June are presented in Tables 5 and 6. Concentrations of phosphorus in petioles of both cultivars increased with increasing phosphate fertilizer rate. The concentrations of P in Norland petioles were well above the critical range where a deficiency of P would be expected. The fact that Norland yield increased even though P levels in the petioles were in the high range, suggests that tuber initiation or set is affected by levels of P that are well above those required for adequate growth of the crop. Petiole Ca tended to increase with increasing phosphate fertilizer in Russet Burbank, probably due to the fact that 0-46-0 contains significant Ca. In Norland, petiole Ca was not affected by P treatment. Phosphate fertilizer did not consistently affect the concentrations of other elements in petiole tissue of either cultivar.

Table 1. Effect of phosphate fertilizer on dry matter of Norland potato vines, roots, tubers, and number of tubers - sampled June 21, 1994.

Phosphate Treatment	Plant Part				
lb P_2O_5	vines	roots	tubers	total	number of tubers
	grams/plant				per plant
0	135.65	6.25	39.00	180.90	22.50
50	129.74	5.50	28.00	163.24	21.29
100	144.81	6.42	27.92	179.14	21.00
150	141.52	5.75	30.08	177.35	22.63
200	134.59	5.67	23.67	163.92	22.83
Pr>F	0.85	0.50	0.34	0.70	0.96
Lin P_2O_5	NS	NS	++	NS	NS
Quad P_2O_5	NS	NS	NS	NS	NS
Cubic P_2O_5	NS	NS	NS	NS	NS

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

Table 2. Effect of phosphate fertilizer on dry matter of Russet Burbank vines, roots, tubers, and number of tubers - sampled June 23, 1994.

Phosphate Treatment lb P_2O_5	Plant Part: vines	roots	tubers	total	number of tubers
	grams/plant				per plant
0	191.21	6.67	49.25	247.13	20.08
50	169.35	6.17	47.25	222.76	19.38
100	169.13	6.50	53.83	229.47	21.17
150	165.78	6.33	50.58	222.70	20.54
200	160.90	6.00	51.58	218.48	19.83
Pr>F	0.66	0.93	0.65	0.77	0.97
Lin P_2O_5	NS	NS	NS	NS	NS
Quad P_2O_5	NS	NS	NS	NS	NS
Cubic P_2O_5	NS	NS	NS	NS	NS

NS = nonsignificant.

Table 3. Effect of phosphate fertilizer on yield and hollow heart of Norland potatoes.

Phosphate Treatment lb P_2O_5	Tuber Yield: culls	Tuber Size: <2¼"	2¼ to 2¾"	>2¾"	Total	Hollow Heart/ Brown Center
	cwt/A					% incidence
0	10.3	160.6	119.6	22.5	313.0	1.0
50	13.0	143.6	126.7	29.9	313.2	0.0
100	10.8	144.1	133.6	35.9	324.4	0.0
150	13.6	152.9	127.6	42.4	336.5	0.0
200	16.3	160.9	136.5	36.4	350.1	0.0
Grower	9.6	107.4	131.6	62.5	311.1	1.6
Pr>F	0.06	0.01	0.77	0.01	0.28	0.13
Contrasts						
Grower vs Rest	++	**	NS	**	NS	*
Lin P_2O_5	*	NS	NS	++	*	NS
Quad P_2O_5	NS	NS	NS	NS	NS	NS
Cubic P_2O_5	NS	NS	NS	NS	NS	NS

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

Table 4. Effect of phosphate fertilizer on yield and specific gravity of Russet Burbank potatoes.

Phosphate Treatment lb P_2O_5	Tuber Yield: Knobs	Tuber Size: <3 oz	3-7 oz	7-14 oz	>14 oz	Total	Specific Gravity	Hollow Heart/ Brown Center
	cwt/A							% incidence
0	14.0	89.0	223.8	152.6	22.4	501.8	1.0840	3.0
50	19.8	90.8	204.6	138.6	14.9	468.7	1.0836	1.0
100	19.7	85.0	195.6	148.9	34.9	484.1	1.0859	1.0
150	9.0	89.9	217.0	137.2	28.4	481.5	1.0846	1.0
200	18.4	91.3	204.7	157.1	18.2	489.7	1.0861	1.0
Grower	11.2	85.7	209.6	147.5	26.7	480.7	1.0861	2.0
Pr>F	0.32	0.97	0.58	0.88	0.14	0.95	0.07	0.80
Contrasts								
Grower vs Rest	NS	NS	NS	NS	NS	NS	NS	NS
Lin P_2O_5	NS	NS	NS	NS	NS	NS	*	NS
Quad P_2O_5	NS	NS	NS	NS	NS	NS	NS	NS
Cubic P_2O_5	++	NS	NS	NS	NS	NS	NS	NS

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

Table 5. Effect of phosphate fertilizer on elemental composition of Norland petioles sampled June 21, 1994.

Phosphate Treatment lb P_2O_5	dry wt. petiole NO_3-N	P	K	Ca	Mg	Element Fe	Mn	Zn	Cu	B
	ppm	%				ppm				
0	18287	0.57	13.7	1.01	0.33	130	179	55	4.9	44
50	16150	0.55	12.2	0.83	0.24	112	173	44	2.2	30
100	16727	0.59	12.7	1.08	0.30	154	233	55	6.4	37
150	18421	0.67	13.6	0.95	0.27	118	161	52	4.3	36
200	20127	0.66	13.3	0.99	0.26	161	174	58	6.2	34
Pr>F	0.04	0.12	0.06	0.50	0.40	0.42	0.36	0.06	0.19	0.41
Lin P_2O_5	*	*	NS	NS	NS	NS	NS	NS	NS	NS
Quad P_2O_5	*	NS	++	NS	NS	NS	NS	++	NS	NS
Cubic P_2O_5	NS	NS	*	NS	NS	NS	NS	NS	NS	NS

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

Table 6. Effect of phosphate fertilizer on elemental composition of Russet Burbank petioles sampled June 23, 1994.

Phosphate Treatment lb P_2O_5	dry wt. petiole NO_3-N	P	K	Ca	Mg	Element Fe	Mn	Zn	Cu	B
	-ppm-	%				ppm				
0	15571	0.28	10.9	0.59	0.38	64	110	28	1.5	26
50	13241	0.30	11.3	0.74	0.40	69	95	26	0.8	25
100	15730	0.32	11.6	0.70	0.41	67	114	29	1.7	27
150	15256	0.35	11.8	0.70	0.40	73	111	32	1.6	28
200	16384	0.36	11.5	0.73	0.42	66	89	25	0.8	24
Pr>F	0.37	0.01	0.28	0.03	0.07	0.41	0.31	0.25	0.67	0.09
Lin P_2O_5	NS	**	++	*	*	NS	NS	NS	NS	NS
Quad P_2O_5	NS	NS	NS	++	NS	NS	NS	NS	NS	++
Cubic P_2O_5	NS	NS	NS	*	NS	NS	NS	*	NS	*

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

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

L.D. Klossner, D.R. Huggins, G.W. Randall, M.P. Russelle, D.J. Fuchs[1]

ABSTRACT

In 1988, four crop systems: continuous corn, corn-soybean, alfalfa and Conservation Reserve Program (CRP) were established at the Southwest Experiment Station in Lamberton to determine the 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 would significantly affect water quality. Corn yields were greatest following CRP, but not significantly different than following alfalfa or soybeans. Continuous corn had significantly lower yields than the other rotations. Tile line discharge occured from April to early July and ranged in total from 4.03 acre-inches in alfalfa-corn to 5.52 acre-inches in corn-soybeans. Flow weighted NO_3-N concentrations were generally highest in April, with continuous corn, corn-soybean, and soybean-corn concentrations three to four times greater than NO_3-N concentrations with alfalfa-corn and crp-corn. Nitrate-N loss (lb/A) was similar in the continuous corn, corn-soybean and soybean-corn treatments. These values were significantly greater than the alfalfa-corn, and crp-corn treatments.

INTRODUCTION

Nitrate losses to tile drainage water have agricultural as well as environmental implications. The nitrogen-pesticide movement study was initiated in 1988 to determine the effect of four cropping systems on above ground biomass yield and NO_3-N loss in tile drainage water. The study is located on fifteen drainage plots, on Normania loam, measuring 45'x50' surrounded by plastic sheeting to a depth of 6'. These plots were 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.

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 four cropping systems included: continuous corn, corn-soybean, alfalfa, and CRP (Conservation Reserve Program). In 1994, 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 (Table 1). Soil samples taken in April were used to determine the rates of urea applied to the plots according to a 140 bu/A yield goal. Soil samples, and above ground biomass were collected during the season but are not reported. Complete plot management details are listed in Table 1.

RESULTS

In 1994, the crp-corn was significantly greater than the continuous corn, but not significantly different than soybean-corn or alfalfa-corn rotations (Table 2).

Tile line discharge occured from April through June in all five of the crop rotations systems. Continuous corn and corn-soybean rotations had continued drainage into early July. Drainage totals ranged from 4.03 acre-inches in the alfalfa-corn to 5.52 acre-inches in corn-soybean. All five of the crop rotations had significantly different tile line discharge (Table 2), but were similar in magnitude.

Flow weighted NO_3-N concentrations were generally highest in April, with the exceptions of continuous corn and corn-soybean which had the greatest flow weighted concentrations in July. There was no significant difference in flow weighted NO_3-N concentrations between continous corn, corn-soybean, and soybean-corn. Alfalfa-corn and crp-corn had significantly less (3 to 4 times) flow weighted concentrations than continuous corn, corn-soybean and soybean-corn (Table 2).

Nitrate-N loss (lb/A) were similar to the flow weighted NO_3-N concentrations in that the continuous corn, corn-soybean and soybean-corn values were significantly greater than the alfalfa-corn and crp-corn NO_3-N loss values (Table 2).

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Table 1. Nitrate-Pesticide Movement Plot Management for 1994

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

Item	Type	Rate	Date
Seed	Pioneer 3563	29,000/A	5/4/94
Fertilizer	Starter	15-30-20 lb/A ($N-P_2O_5-K_2O$)	5/4/94
	Urea	132 lb N/A - Cont. Corn	6/6/94
		143 lb N/A - crp-Corn	6/6/94
		None - alf-Corn	
Herbicide	Lasso	4 lb/A (ai)	4/21/94
	Bladex	3 lb/A (ai)	
Insecticide	Lorsban	0.75 lb/A	5/4/94
Primary Tillage	Moldboard Plow	1 pass	Fall 93
Secondary Tillage	Spring Cultivation*	2 pass	4/21/94
	Cultivator		5/4/94
	Row Cultivation	1 pass	5/4/94

Cropping System - CORN-soybean

Item	Type	Rate	Date
Seed	Pioneer 3563	29,000/A	5/4/94
Fertilizer	Starter	15-30-20 lb/A ($N-P_2O_5-K_2O$)	5/4/94
	Urea	85 lb N/A	6/6/94
Herbicide	Lasso	4 lb/A (ai)	4/21/94
	Bladex	3 lb/A (ai)	
Primary Tillage	None		
Secondary Tillage	Spring Cultivation	2 pass	4/21/94
	Cultivator		5/4/94
	Row Cultivation	1 pass	6/13/94

Cropping System - SOYBEAN-corn

Item	Type	Rate	Date
Seed	Parker	158,000/A	5/4/94
Row Width	30"		
Herbicide	Lasso	4 lb/A (ai)	4/21/94
	Pursuit	4 oz/A (ai)	
Primary Tillage	Moldboard Plow	1 pass	Fall 93
Secondary Tillage	Row Cultivation	1 pass	6/13/94

* crp-Corn was also disced on 4/22/94

Table 2. Tile Discharge, flow weighted NO_3-N concentration and NO_3-N loss via the tile lines as influenced by cropping system

Month	Cont-C	Corn-Sb	Sb-C	Alfalfa	CRP	$LSD_{0.05}$
Tile Flow (Acre-in)						
April	1.97	2.24	2.19	1.51	1.96	0.65
May	1.43	1.56	1.37	1.24	1.16	0.49
June	1.58	1.71	1.69	1.28	1.43	0.60
July	0.02	0.01	0.00	0.00	0.00	0.01
Total	5.00	5.52	5.25	4.03	4.55	0.21
Flow weighted NO_3-N Conc. (ppm)						
April	12.56	9.47	10.71	3.69	1.19	3.68
May	10.83	8.44	9.33	2.74	0.93	2.54
June	10.97	8.63	9.33	2.88	0.87	2.59
July	17.75	16.30	0.00	0.00	0.00	12.42
Average	11.45	8.85	9.79	3.10	1.00	2.89
NO_3-N loss (lb/A)						
April	5.72	5.20	5.20	1.25	0.56	2.12
May	3.58	2.91	2.97	0.77	0.24	1.48
June	4.04	3.52	3.36	0.86	0.28	1.74
July	0.08	0.03	0.00	0.00	0.00	0.04
Total	13.34	11.63	11.53	2.88	1.08	0.68
Yield (bu/A)						
	164.32	44.78	172.19	170.40	177.10	7.99 *

* Yield LSD does not include soybean yield

NITROGEN FERTILITY MANAGEMENT OF CORN

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

ABSTRACT

The N-Fertility study at the Southwest Experiment Station in Lamberton has N treatments of application rate, timing and form. This 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. Maximum corn yields were obtained with 160 lb N/A of either spring applied anhydrous ammonia or urea, or sidedressed anhydrous ammonia. The 160 lb N/A spring applied urea was significantly greater than both the fall and sidedressed 160 lb N/A urea applications. There was no significant change in sidedress corn yields with an increase from 120 lb N/A to 160 lb N/A of urea. The 1994 data shows that corn yields generally respond to an increased N-rate, with spring and sidedress applications generating higher yields than the fall applied N in the 40 lb N/A, and 80 lb N/A anhydrous ammonia applications and the 80 lb/A and 160 lb N/A urea applications.

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/corn-soybean). In 1994, soybeans were grown for the first time, consequently, 1994 data includes only continuous corn data. 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). Additional management data is shown in Table 2.

RESULTS

Maximum corn yields were obtained with 160 lb N/A spring applied anhydrous ammonia or urea, or sidedressed anhydrous ammonia (Table 3). Spring applied urea (160 lb N/A) was significantly greater than both the fall and sidedressed urea applications (160 lb N/A). There was no yield increase with urea sidedress applications as N-rate increased from 120 lb N/A to 160 lb N/A. Anhydrous ammonia (160 lb N/A) showed no significant difference between spring and sidedress applications (Table 3). Fall N applications consistently yielded less than spring or sidedressed N. Greater rates of fall applied N did not result in yields equal to spring applied N. Lower yields with fall N applications were likely due to above normal soil moisture conditions (Table 1) during the fall of 1993 which would have enhanced losses of fall applied N.

Table 1. Available Soil Moisture, Southwest Experiment Station, Lamberton (0-5')

Sample Date	1993 Total Available Soil Moisture	28 Year Average (1966-1993)
	inches	
9/1/93	7.00	3.85
9/15/93	6.82	4.23
10/1/93	6.33	4.18
10/15/93	6.15	4.39

1 L.D. Klossner, D.R. Huggins, and D.J. Fuchs are Assistant Scientist, Assistant Professor, and former Scientist at the Southwest Experiment Station, Lamberton, MN 56152.

Table 2. N-Fertility Plot Management for 1994

Corn

Item	Type	Rate	Date
Primary Tillage	Moldboard Plow	1 pass	Fall 93
Secondary Tillage	Field Cultivator	1 pass	5/4/94
			5/6/94
	Row Cultivation	1 pass	6/11/94
Seed	Pioneer 3563	29,000/A	5/7/94
Fertilizer	Starter	0-30-30 lb/A	5/7/94
		(N-P_2O_5-K_2O)	
N Treatment	Fall	40, 80, 120, 160 lb/A	Fall 93
	Spring	40, 80, 120, 160 lb/A	5/6/94
	Sidedress	40, 80, 120, 160 lb/A	6/13/94
Herbicides	Dual Broadstrike	2.5 pts/A (ai)	5/7/94
	Accent	0.031 lb/A (ai)	6/16/94
Insecticides	Force	1.5 lb/A	5/7/94

Table 3. Corn Yields in 1994

	Anhydrous Ammonia				Urea			
N-Rate (lb/A)	Fall	Spring	Sidedress	$LSD_{0.05}$	Fall	Spring	Sidedress	$LSD_{0.05}$
	bu/A							
40	102.1	125.0	128.1	15.7	97.9	101.1	97.7	11.1
80	114.0	136.7	141.6	20.6	117.7	134.4	135.4	15.6
120	nd*	159.7	165.4	13.3	143.5	163.3	159.2	16.1
160	nd	178.7	178.3	13.6	165.1	180.2	160.1	15.1
$LSD_{0.05}$	25.36	15.9	12.6		16.5	11.8	12.9	
Check	67.3							

nd*=no data

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

L.D. Klossner, D.R. Huggins, D.J. Fuchs[1]

ABSTRACT

Developing tillage practices that improve environmental quality while remaining economically beneficial is a major objective of agricultural research. Five tillage systems: no-tillage, ridge- tillage, conventional tillage, reduced tillage, and spring tillage were established in corn and soybean crop rotations in 1986. In 1994, tillage systems were further divided into five separate row management systems. Tillage systems varied as to how they responded to row management systems. Corn yields were greater in tillage systems that received starter fertilizer, regardless of whether the treatment was with or without row cleaners. No-tillage practices produced the lowest yields with corn row management treatments 1,2,3, and 4. Conventional tillage practices produced the highest soybean yields regardless of row management treatment. Corn and soybean yields for 1994 were greater than the longterm (1986-1993) average for all the tillage systems and virtually all the row management 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. In 1994, row treatments were integrated to fine-tune tillage management.

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 Tables 1 and 2).

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

Subplots within corn - 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 (15-26-31)
4. Without row cleaners and with starter fertilizer (15-26-31)
5. Anhydrous pre-plant indexed on the row (115 lb N/A), with row cleaners and starter fertilizer (15-26-31)

Subplots within soybeans - 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

Tillage systems varied as to how they responded to row management treatments (Tables 4 and 5). In all five of the corn tillage systems, the systems that received starter fertilizer had the greatest yields. Row management 4 (without row cleaners, with starter fertilizer) produced the greatest yields in the no-tillage and the ridge-tillage systems. In the conventional, reduced and spring tillage row management 3 (with row cleaners, with starter fertilizer) produced the greatest yields. When row management systems are compared with the tillage systems, no-tillage was the lowest yielding tillage system in row managements 1, 2, 3, and 4. In row management 5 (A.A., with row cleaners and starter fertilizer) all tillage treatments were depressed.

The 1994 soybean yields are shown in Table 5. Yields of no-tillage soybeans planted in 30" rows (row managements 1 and 2) were significantly lower than yields in 7.5" rows (row managements 4 and 5). No-tillage soybeans planted in 30" rows responded to N fertilizer (row management 3) whereas soybeans in 7.5" rows did not respond to N (row management 4 and 5). Row management 1 (30" rows, with row cleaners) was also the lowest yielding soybean system with ridge-tillage. Conventional, reduced and spring tillage systems showed no significant difference in soybean yield among the five row management systems. When the soybean row management treatments are compared with each tillage system, conventional tillage is the greatest yielding tillage system in every case. Yields of soybeans with conventional tillage remained constant regardless of the row management system.

Table 6 shows the longterm corn yield data (1986-1993). Conventional tillage, on average, produced significantly greater yield, (125.2 bu/A) than the other tillage treatments. Every one of the 1994 corn tillage systems, and their sub-treatment row management produced greater yields than the 8 year longterm average.

Table 7 shows the longterm soybean yield data (1986-1993). Conventional tillage was the greatest yielding tillage system. All of the 1994 soybean yields were greater than the longterm data. No-tillage row management 1 (30" rows, with row cleaners) yields were equal to the longterm yields, and spring tillage RM 4 was less than the longterm soybean average.

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[1] L.D. Klossner, D.R. Huggins, and D.J. Fuchs are Assistant Scientist, Assistant Professor, and former Scientist at the Southwest Experiment Station, Lamberton, MN 56152.

Table 1. 1994 Corn Plot Management

Corn Sub-Treatments Within Tillage Systems

Tillage System	Sub Trt*	Planter	Row Cult	Starter Fertilizer**	Seed	Spring Tillage	Weed Control
No-Tillage	1	JD 4-row	None	Trts 1 and 2 None Trts 3, 4 and 5	All subtreatments Pioneer 3563	None	Bladex 2 lb/A (ai) 5/12/94
no fall tillage	2	JD 4-row	None	15-26-31 lb/A $(N-P_2O_5-K_2O)$	29,000/A 5/11/94		Roundup 0.75 lb/A (ai) 5/12/94
	3	JD 4-row	None	5/11/94			2-4-D ½ lb/A (ai) 6/1/94 and 7/1/94
	4	JD 4-row	None				
	5	JD 4-row	None				
Ridge-Tillage	1	JD 4-row	6/13/94	Trts 1 and 2 None Trts 3, 4 and 5	All subtreatments Pioneer 3563	None	Bladex 2 lb/A (ai) 5/12/94
no fall tillage	2	JD 4-row	6/13/94	15-26-31 lb/A $(N-P_2O_5-K_2O)$	29,000/A 5/11/94		2-4-D ½ lb/A (ai) 7/1/94
	3	JD 4-row	6/13/94	5/11/94			
	4	JD 4-row	6/13/94				
	5	JD 4-row	6/13/94				
Conventional	1	JD 4-row	6/13/94	Trts 1 and 2 None Trts 3, 4 and 5	All subtreatments Pioneer 3563	Disc	Bladex 2 lb/A (ai) 5/12/94
chisel plow	2	JD 4-row	6/13/94	15-26-31 lb/A $(N-P_2O_5-K_2O)$	29,000/A 5/11/94	5/10/94	
Fall 1993	3	JD 4-row	6/13/94	5/11/94			
	4	JD 4-row	6/13/94				
	5	JD 4-row	6/13/94				
Reduced	1	JD 4-row	6/13/94	Trts 1 and 2 None Trts 3, 4 and 5	All subtreatments Pioneer 3563	Disc	Bladex 2 lb/A (ai) 5/12/94
no fall tillage	2	JD 4-row	6/13/94	15-26-31 lb/A $(N-P_2O_5-K_2O)$	29,000/A 5/11/94	5/10/94	
	3	JD 4-row	6/13/94	5/11/94			
	4	JD 4-row	6/13/94				
	5	JD 4-row	6/13/94				
Spring Tillage (94)	1	JD 4-row	6/13/94	Trts 1 and 2 None Trts 3, 4 and 5	All subtreatments Pioneer 3563	Disc	Bladex 2 lb/A (ai) 5/12/94
Flex Tillage (95)	2	JD 4-row	6/13/94	15-26-31 lb/A $(N-P_2O_5-K_2O)$	29,000/A 5/11/94	5/10/94	
no fall tillage	3	JD 4-row	6/13/94	5/11/94			
	4	JD 4-row	6/13/94				
	5	JD 4-row	6/13/94				

*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

**Dry starter fertilizer (Urea + MAP +KCl) applied at planting in 2x2 configuration. All subtreatments received 115 lb N/A Anhydrous Ammonia 5/10/94.

Table 2. 1994 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	6/14/94		Trt 1, 2, and 3 Parker 158,000/A	None	Sencor 0.25 lb/A Dual II 2.44 lb/A
no fall tillage	2	JD 4-row	6/14/94				Roundup 0.75 lb/A 5/20/94
	3	JD 4-row	6/14/94	Trts 3 and 4 60 lb N/A	Trt 4 and 5 Parker 200,000/A		Pinnacle 0.25 oz/A Select 6 oz/A
	4	JD 752	None	(NH_4NO_3) broadcast 5/13/94	planted 5/16/94		Pursuit 3 oz/A 6/30/94
	5	JD 752	None				
Ridge-Tillage	1	JD 4-row	6/14/94		Trt 1, 2, and 3 Parker 158,000/A	None	Sencor 0.25 lb/A Dual II 2.44 lb//A
no fall tillage	2	JD 4-row	6/14/94				Roundup 0.75 lb/A 5/20/94
	3	JD 4-row	6/14/94	Trts 3 and 4 60 lb N/A	Trt 4 and 5 Parker 200,000/A		
	4	JD 752	None	(NH_4NO_3) broadcast 5/13/94	planted 5/16/94		
	5	JD 752	None				
Conventional	1	JD 4-row	6/14/94		Trt 1, 2, and 3 Parker 158,000/A	Disc	Sencor 0.25 lb/A Dual II 2.44 lb/A
Primary Tillage	2	JD 4-row	6/14/94			5/13/94	5/20/94
Moldboard plow	3	JD 4-row	6/14/94	Trts 3 and 4 60 lb N/A	Trt 4 and 5 Parker 200,000/A		
Fall 93	4	JD 752	None	(NH_4NO_3) broadcast 5/13/94	planted 5/16/94		
	5	JD 752	None				
Reduced	1	JD 4-row	6/14/94		Trt 1, 2, and 3 Parker 158,000/A	Disc	Sencor 0.25 lb/A Dual II 2.44 lb/A
Primary Tillage	2	JD 4-row	6/14/94			5/13/94	5/20/94
Chisel plow	3	JD 4-row	6/14/94	Trts 3 and 4 60 lb N/A	Trt 4 and 5 Parker 200,000/A		
Fall 93	4	JD 752	None	(NH_4NO_3) broadcast 5/13/94	planted 5/16/94		
	5	JD 752	None				
Spring Tillage (94)	1	JD 4-row	6/14/94		Trt 1, 2, and 3 Parker 158,000/A	Disc	Sencor 0.25 lb/A Dual II 2.44 lb/A
Flex Tillage (95)	2	JD 4-row	6/14/94			5/13/94	5/20/94
no fall tillage	3	JD 4-row	6/14/94	Trts 3 and 4 60 lb N/A	Trt 4 and 5 Parker 200,000/A		
	4	JD 752	None	(NH_4NO_3) broadcast 5/13/94	planted 5/16/94		
	5	JD 752	None				

*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	Source	DF	SS	MS	F	P
	Rep	3	6128.74	2042.91	21.69	0.0001
	Till	4	9846.27	2461.57	26.13	0.0001
	Rep*Till	12	4871.26	405.94	4.31	0.0001
	RowMgt	4	4728.87	1182.22	12.55	0.0001
	Till*RowMgt	16	2876.99	179.81	1.91	0.0230
	Tests of Hypothesis Using Type III MS for Rep*Till as error term					
	Till	4	9846.27	2461.57	6.06	0.0066
Soybeans	Rep	3	13.10	4.37	0.38	0.7648
	Till	4	831.76	207.94	18.27	0.0001
	Rep*Till	12	411.78	34.32	3.02	0.0008
	RowMgt	4	98.96	24.74	2.17	0.0743
	Till*RowMgt	16	792.60	49.54	4.35	0.0001
	Tests of Hypothesis Using Type III MS for Rep*Till as error term					
	Till	4	831.76	207.94	6.06	0.0066

Table 4. Corn Yields in 1994

	Row Management					
Tillage System	1	2	3	4	5	$LSD_{0.05}$
	(bu/A)					
No-Tillage	142.9	139.6	145.3	154.9	150.8	9.2
Ridge-Tillage	165.7	157.5	166.5	171.2	150.2	8.7
Conventional	165.6	156.5	173.6	171.8	163.8	12.3
Reduced	152.1	158.4	169.2	167.4	166.3	9.8
Spring	160.6	158.3	170.9	169.8	162.8	9.0
$LSD_{0.05}$	9.9	13.7	20.9	15.2	17.7	

Table 5. Soybean Yields in 1994

Tillage System	Row Management 1	2	3	4	5	$LSD_{0.05}$
	(bu/A)					
No-Tillage	37.8	38.6	43.6	43.9	44.5	3.0
Ridge-Tillage	37.5	41.2	43.2	45.7	45.3	4.4
Conventional	47.4	47.8	47.1	47.3	46.0	4.1
Reduced	44.4	44.4	42.5	41.9	42.5	5.4
Spring	42.9	42.7	43.1	38.0	41.1	6.9
$LSD_{0.05}$	3.6	2.7	2.7	4.4	3.4	

Table 6. 1986-1993 Corn Yields

Tillage	1986	1987	1988	1989	1990	1991	1992	1993	Average
	bu/A								
Notill	142.0	132.4	73.7	122.2	114.5	133.4	134.2	71.9	116.1
Ridge	145.4	125.4	82.2	132.6	118.4	128.9	145.3	72.0	119.6
Conv.	141.5	136.4	76.7	139.0	137.2	132.2	153.6	76.6	125.2
Reduced	139.8	124.8	70.1	128.1	120.5	133.6	130.7	75.1	115.9
Spr. till	132.4	119.8	65.4	131.8	122.8	132.6	136.6	73.4	114.1
$LSD_{0.05}$	11.7	6.7	6.7	6.9	6.0	6.2	10.2	4.3	5.4

Table 7. 1986-1993 Soybean Yields

Tillage	1986	1987	1988	1989	1990	1991	1992	1993	Average
	bu/A								
Notill	47.4	39.3	26.9	40.9	44.7	40.3	35.9	19.8	37.8
Ridge	47.2	38.7	26.7	49.2	48.7	41.3	35.3	31.5	38.5
Conv.	47.9	38.8	32.7	48.8	51.8	48.0	37.3	38.9	40.8
Reduced	46.7	39.5	26.3	45.8	51.6	46.2	37.7	34.5	38.5
Spr. till	48.9	37.0	26.2	47.1	45.4	44.4	36.5	33.1	38.2
$LSD_{0.05}$	1.5	1.4	1.5	2.6	2.6	3.5	2.0	2.9	1.4

VARIABLE INPUT CROP MANAGEMENT SYSTEMS AT THE SOUTHWEST EXPERIMENT STATION

L.D. Klossner, D.R. Huggins, D.J. Fuchs[1]

ABSTRACT

The development of methods to replace or supplement off-farm inputs and energy with on-farm resources is an important goal of agricultural sustainability. Cropping systems with minimum input, lower purchased input, higher purchased input and organic inputs were established with two crop rotations and two prior levels of external inputs in 1989. It was found that minimum input management level generally produced the lowest crop yields for all the crop rotations regardless of the previous external input history. The greatest yields varied among crop rotations with the highest yields occuring in the LPI, HPI and ORG management levels.

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 (VICMS) 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.

METHODS AND MATERIALS

The study began in 1989 with treatments including two prior levels of external (off-farm) input: 1) VICMS I located on the Koch Farm with 30 years of minimal inputs; and 2)VICMS II located on the Southwest Experiment Station with 30 years of high external inputs. Each study has 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) corn/soybeans/oat/alfalfa (CSOA) and 2) corn/soybean (CS). Every crop is grown each year for every rotation.

MIN management systems receive no fertilizer treatments, 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, P & K fertilizers are applied in a 2x2 band for corn and soybeans, nitrogen is applied in a 2x2 band in corn, fertilizer is broadcast on the oats and alfalfa. Fertilizer rates are based on soil tests, previous crop and realistic yield goals. Weed control is mechanical only, which includes rotary hoe and row cultivation.

HPI management systems are planted as soon as possible. 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.

ORG management systems are planted 1 to 2 weeks later than normal (corn and soybeans). The CSOA corn rotation receives solid beef manure, and the CS corn rotation liquid hog manure. The rates are based on soil tests and previous manure application rates. Weed control is mechanical only, which includes rotary hoe and row cultivation.

Tables 1- 6 show the detailed 1994 plot management information for VICMS I, Tables 7-12 show the detailed 1994 plot management information for VICMS II.

RESULTS

VICMS I crop yields for 1994 are summarized in Table 13. CSOA rotation corn yields ranged from 77.1 bu/A in the MIN management level to 161.8 bu/A for LPI. There was no significant difference between LPI, HPI, or ORG management levels. CS rotation corn yields ranged from 79.4 bu/A in the MIN to 182.2 bu/A for HPI. All of the management levels were significantly different from each other. SOAC soybean yields ranged from 34.6 bu/A for LPI to 45.3 bu/A for ORG. HPI and ORG treatments were not significantly different, but were significanly greater than MIN and LPI. SC rotation soybean yields ranged from 29.9 bu/A in MIN to 41.3 bu/A in HPI. The MIN management level was significantly less than the LPI, HPI, and ORG management levels. ACSO rotation alfalfa yields ranged from 2.7 T/A in MIN to 5.4 T/A for HPI, with the MIN treatment significantly less than LPI, HPI and ORG management levels. OACS rotation oat yields ranged from 65.1 bu/A in LPI to 88.2 bu/A in ORG. The 1994 yield data revealed that the MIN management levels were the lowest yielding in 4 out of 6 different crop rotations. The highest yields were dispersed among the LPI, HPI, and ORG management levels.

VICMS II crop yields for 1994 are summarized in Table14. CSOA rotation corn yields ranged from 137.9 bu/A in MIN to 162.4 bu/A in HPI management levels. CS rotation corn yields ranged from 86.3 bu/A in MIN and 87.3 bu/A in ORG, to 158.3 bu/A in LPI. SOAC rotation soybeans ranged from a low of 40.1 bu/A in MIN to 50.7 bu/A in the HPI. SC rotation soybeans were significantly less in the ORG (28.4 bu/A) and MIN (28.9 bu/A) than the LPI (36.5 bu/A) and HPI (41.2 bu/A) management levels. ACSO rotation alfalfa ranged from 5.2 T/A in MIN to 6.2 T/A in ORG, with the MIN being significantly less than the LPI, HPI and ORG management levels. OACS rotation oats ranged from 102.5 bu/A in LPI to 121.8 bu/A in ORG, with none of the management levels being significantly different from each other. VICMS II was similar to VICMS I in that the MIN management levels were the lowest yielding in 4 of the 6 crop rotations, and the highest yielding crop rotations were in the LPI, HPI, and ORG rotations.

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Table 1. Variable Input Crop Management System I Plot Management - CSOA rotation, Soybeans, 1994

Mgt Level	Fall Tillage	Spring Tillage	Seed	Fertilizer	Herbicide	Rotary Hoe	Row Cult.
MIN	Moldboard Fall 93	Digger 5/12 5/23 5/27	Parker 158,000/A 5/27	None	None	5/31	6/14 6/24 7/12
LPI	Chisel Fall 93	Digger 5/12	Parker 158,000/A 5/12	TSP 0-35-0 lb/A Band 5/12	Pursuit 3 oz/A Select 8 oz/A Band 6/11	5/18	6/10 6/24
HPI	Moldboard Fall 93	Digger 2 passes 5/12	Parker 158,000/A 5/12	TSP 0-50-0 lb/A Broadcast 5/12	Sonolan 1 lb/A Sencor 0.25 lb/A Broadcast 5/12	None	6/10
ORG	Moldboard Fall 93	Digger 5/12 5/23 5/27	Parker 158,000/A 5/27	None	None	5/31	6/4 6/24 7/12

Table 2. Variable Input Crop Management System I Plot Management - CSOA rotation, Oats, 1994

Mgt Level	Fall Tillage	Spring Tillage	Seed	Fertilizer	Herbicide	Rotary Hoe	Row Cult.
MIN	Chisel Fall 93	Digger 4/19 Drag & Pack 4/22	Dane 70 lb/A Pioneer 5262 12 lb/A alfalfa 4/21	None	None	None	None
LPI	Chisel Fall 93	Digger 4/19 Drag & Pack 4/22	Dane 70 lb/A Pioneer 5262 12 lb/A alfalfa 4/21	MAP + Urea + KCl 50-50-50 lb/A (N-P_2O_5-K_2O) Broadcast 4/19	Buctril 1 pt/A Band 6/1	None	None
HPI	Chisel Fall 93	Digger 4/19 Drag & Pack 4/22	Dane 70 lb/A Pioneer 5262 12 lb/A alfalfa 4/21	MAP + Urea + KCl 50-50-50 lb/A (N-P_2O_5-K_2O) Broadcast 4/19	Buctril 1 pt/A Broadcast 6/1	None	None
ORG	Chisel Fall 93	Digger 4/19 Drag & Pack 4/22	Dane 70 lb/A Pioneer 5262 12 lb/A alfalfa 4/21	None	None	None	None

Table 3. Variable Input Crop Management System I Plot Management - CSOA rotation, Alfalfa, 1994

Mgt Level	Fall Tillage	Spring Tillage	Seed	Fertilizer	Herbicide	Rotary Hoe	Row Cult.
MIN	None	None	With Oats	None	None	None	None
LPI	None	None	With Oats	TSP 0-100-0 lb/A Broadcast 6/10	None	None	None
HPI	None	None	With Oats	TSP 0-100-0 lb/A Broadcast 6/10	None	None	None
ORG	None	None	With Oats	None	None	None	None

Table 4. Variable Input Crop Management System I Plot Management - CSOA rotation, Corn, 1994

Mgt Level	Fall Tillage	Spring Tillage	Seed	Fertilizer	Herbicide	Rotary Hoe	Row Cult.
MIN	Moldboard Fall 93	Digger 5/7 5/12	Pioneer 3769 29,000/A 5/13	None	None	5/19 5/27 5/31	6/10 6/20
LPI	Moldboard Fall 93	Digger 5/9	Pioneer 3769 29,000/A 5/9	MAP + KCl 20-45-25 lb/A Band 5/1	Stinger 0.66 pt/A 6/1 Accent 0.031 lb/A Band 6/3	5/13 5/27	6/10
HPI	Moldboard Fall 93	Digger 4/23 5/7 5/9	Pioneer 3769 29,000/A 5/9	Urea + MAP + Kcl 40-90-50 lb/A Broadcast 4/22	Eradicane 2.5 lb/A 5/7 Bladex 1.5 lb/A 5/7 Stinger 0.66 pt/A Broadcast 6/1	None	6/3
ORG	Moldboard Fall 93	Digger 5/7 5/12	Pioneer 3769 (untreated) 29,000/A 5/13	Beef Manure 177-75-126 lb/A (N-P_2O_5-K_2O) Fall 93	None	5/19 5/27 5/31	6/10 6/20

Table 5. Variable Input Crop Management System I Plot Management -CS rotation, Soybean, 1994

Mgt Level	Fall Tillage	Spring Tillage	Seed	Fertilizer	Herbicide	Rotary Hoe	Row Cult.
MIN	Moldboard Fall 93	Digger 5/12 5/23 5/27	Parker 158,000/A 5/27	None	None	5/31	6/14 6/24 7/12
LPI	Chisel Fall 93	Digger 5/12	Parker 158,000/A 5/12	Inorganic TSP 0-35-0 lb/A Band 5/12	None	5/17	6/13 6/24
HPI	Moldboard Fall 93	Digger 5/12	Parker 158,000/A 5/12	Inorganic TSP 0-50-0 lb/A Broadcast 5/12	Treflan 0.75 lb/A Sencor 0.25 lb/A Broadcast 5/12	None	6/10
ORG	Moldboard Fall 93	Digger 5/12 5/23 5/27	Parker 158,000/A 5/27	None	None	5/31	6/14 6/24 7/12

Table 6. Variable Input Crop Management System I Plot Management - CS rotation, Corn, 1994

Mgt Level	Fall Tillage	Spring Tillage	Seed	Fertilizer	Herbicide	Rotary Hoe	Row Cult.
MIN	Chisel Fall 93	Digger 5/7 5/12	Pioneer 3769 29,000/A 5/13	None	None	5/19 5/27 5/31	6/10 6/20
LPI	None	Digger 5/9	Pioneer 3769 29,000/A 5/9	Urea + MAP + KCl 115-45-25 lb/A ($N-P_2O_5-K_2O$) Band 5/9	Stinger 0.66 pt/A 6/1 Accent 0.031 lb/A Band 6/3	5/27	6/10
HPI	Chisel Fall 93	Digger 4/23 5/7 5/9	Pioneer 3769 29,000/A 5/9	Urea + MAP + KCl 130-90-50 lb/A ($N-P_2O_5-K_2O$) Broadcast 4/22	Eradicane 2.5 lb/A 5/7 Bladex 1.5 lb/A 5/7 Stinger 0.66 pt/A Broadcast 6/1	None	6/3
ORG	Chisel Fall 93	Digger 4/23 5/7 5/12	Pioneer 3769 (untreated) 29,000/A 5/13	Liquid Hog Manure 283-104-87 lb/A ($N-P_2O_5-K_2O$) Spring 94	None	5/19 5/27 5/31	6/10 6/20

Table 7. Variable Input Crop Management System II Plot Management - CSOA rotation, Soybeans, 1994

Mgt Level	Fall Tillage	Spring Tillage	Seed	Fertilizer	Herbicide	Rotary Hoe	Row Cult.
MIN	Moldboard Fall 93	Digger 5/12 5/23 5/27	Parker 158,000/A 5/27	None	None	5/31	6/14 6/28 7/12
LPI	Chisel Fall 93	Digger 5/12	Parker 158,000/A 5/12	None	Pursuit 3 oz/A Select 8 oz/A Band 6/3	5/17	6/10 6/24
HPI	Moldboard Fall 93	Digger 2 passes 5/12	Parker 158,000/A 5/12	None	Sonolan 1 lb/A Sencor 0.25 lb/A Broadcast 5/12	None	None
ORG	Moldboard Fall 93	Digger 5/12 5/23 5/27	Parker 158,000/A 5/27	None	None	5/31	6/14 6/24 7/12

Table 8. Variable Input Crop Management System II Plot Management - CSOA rotation, Oats, 1994

Mgt Level	Fall Tillage	Spring Tillage	Seed	Fertilizer	Herbicide	Rotary Hoe	Row Cult.
MIN	Chisel Fall 93	Digger 4/19 Drag & Pack 4/22	Dane 70 lb/A Pioneer 5262 -12 lb/A alfalfa 4/21	None	None	None	None
LPI	Chisel Fall 93	Digger 4/19 Drag & Pack 4/22	Dane 70 lb/A Pioneer 5262 12 lb/A alfalfa 4/21	MAP + Urea + KCl 50-50-50 lb/A ($N-P_2O_5-K_2O$) Broadcast 4/19	Buctril 1 pt/A 5/26	None	None
HPI	Chisel Fall 93	Digger 4/19 Drag & Pack 4/22	Dane 70 lb/A Pioneer 5262 12 lb/A alfalfa 4/21	MAP + Urea + KCl 50-50-50 lb/A ($N-P_2O_5-K_2O$) Broadcast 4/19	Buctril 1 pt/A 6/1	None	None
ORG	Chisel Fall 93	Digger 4/19 Drag & Pack 4/22	Dane 70 lb/A Pioneer 5262 12 lb/A alfalfa 4/21	None	None	None	None

Table 9. Variable Input Crop Management System II Plot Management - CSOA rotation, Alfalfa, 1994

Mgt Level	Fall Tillage	Spring Tillage	Seed	Fertilizer	Herbicide	Rotary Hoe	Row Cult.
MIN	None	None	With Oats	None	None	None	None
LPI	None	None	With Oats	TSP 0-40-0 lb/A Broadcast 6/13	None	None	None
HPI	None	None	With Oats	TSP 0-40-0 lb/A Broadcast 6/13	None	None	None
ORG	None	None	With Oats	None	None	None	None

Table 10. Variable Input Crop Management System II Plot Management - CSOA rotation, Corn, 1994

Mgt Level	Fall Tillage	Spring Tillage	Seed	Fertilizer	Herbicide	Rotary Hoe	Row Cult.
MIN	Moldboard Fall 93	Digger 5/7 5/12	Pioneer 3769 29,000/A 5/13	None	None	5/17 5/19 5/27 5/31	6/10 6/20
LPI	Moldboard Fall 93	Digger 5/9	Pioneer 3769 29,000/A 5/9	Urea 25-0-0 lb/A Band 5/9	Buctril 1 pt/A Band 6/3	5/13 5/19 5/27	6/10 6/20
HPI	Moldboard Fall 93	Digger 4/23 5/7 5/9	Pioneer 3769 29,000/A 5/9	Urea + MAP 40-50-0 lb/A Broadcast 4/22	Eradicane 2.5 lb/A 5/7 Bladex 1.5 lb/A 5/7 Stinger 0.66 pt/A Broadcast 6/1	None	6/3 6/20
ORG	Moldboard Fall 93	Digger 5/7 5/12	Pioneer 3769 (untreated) 29,000/A 5/13	Beef Manure 59-25-42 lb/A ($N-P_2O_5-K_2O$) Fall 93	None	5/17 5/19 5/27 5/31	6/10 6/20

Table11. Variable Input Crop Management System II Plot Management - CS rotation, Soybean, 1994

Mgt Level	Fall Tillage	Spring Tillage	Seed	Fertilizer	Herbicide	Rotary Hoe	Row Cult.
MIN	Moldboard Fall 93	Digger 5/12 5/23 5/27	Parker 158,000/A 5/27	None	None	5/31	6/14 6/24 7/12
LPI	Chisel Fall 93	Digger 5/12	Parker 158,000/A 5/12	None	Pursuit 3 oz/A Select 8 oz/A Band 6/3	5/17	6/10 6/13 6/28
HPI	Moldboard Fall 93	Digger 2 passes 5/12	Parker 158,000/A 5/12	None	Treflan 0.75 lb/A Sencor 0.25 lb/A Broadcast 5/12	None	6/10
ORG	Moldboard Fall 93	Digger 5/12 5/23 5/27	Parker 158,000/A 5/27	None	None	5/31	6/14 6/28 7/12

Table12. Variable Input Crop Management System II Plot Management -CS rotation, Corn, 1994

Mgt Level	Fall Tillage	Spring Tillage	Seed	Fertilizer	Herbicide	Rotary Hoe	Row Cult.
MIN	Chisel Fall 93	Digger 5/7 5/12	Pioneer 3769 29,000/A 5/13	None	None	5/19 5/27 5/31	6/10 6/20 7/12
LPI	None	Digger 5/9	Pioneer 3769 29,000/A 5/9	Urea 125-0-0 lb/A Band 5/9	Buctril 1 pt/A Band 6/3	5/13 5/19 5/27	6/10 6/20
HPI	Chisel Fall 93	Digger 4/23 5/7 5/9	Pioneer 3769 29,000/A 5/9	Urea + MAP 145-35-0 lb/A Broadcast 4/22	Eradicane 2.5 lb/A 5/7 Bladex 1.5lb/A Broadcast 5/7	None	6/3 6/20
ORG	Chisel Fall 93	Digger 4/23 5/7 5/12	Pioneer 3769 (untreated) 29,000/A 5/13	Liquid Hog Manure 339-125-104 lb/A (N-P_2O_5-K_2O) Spring 94	None	5/19 5/27	6/10 6/20 7/12

Table 13. 1994 Variable Input Crop Management Systems Yields

Rotation	Crop	MIN	LPI	HPI	ORG	$LSD_{0.05}$
		Management Level				
		bu/A				
CSOA	Corn	77.1	161.8	157.1	150.6	13.0
CS	Corn	79.4	152.0	182.2	133.7	15.3
SOAC	Soybeans	36.4	34.6	43.2	45.3	3.9
SC	Soybeans	29.9	40.9	41.3	37.8	3.7
ACSO	Alfalfa*	2.7	5.3	5.4	4.9	0.8
OACS	Oats	72.3	65.1	73.0	88.2	22.6

*Alfalfa yields are (T/A)

Table 14. 1994 Variable Input Crop Management Systems II Yields

Rotation	Crop	MIN	LPI	HPI	ORG	$LSD_{0.05}$
		Management Level				
		bu/A				
CSOA	Corn	137.9	150.3	162.4	147.2	13.5
CS	Corn	86.3	158.3	138.7	87.3	32.0
SOAC	Soybeans	40.1	46.7	50.7	42.0	4.7
SC	Soybeans	28.9	36.5	41.2	28.4	6.9
ACSO	Alfalfa*	5.2	5.9	5.9	6.2	0.6
OACS	Oats	107.1	102.5	118.3	121.8	41.7

*Alfalfa yields are (T/A)

Organic Crop Rotation Study

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ABSTRACT

Crop rotations can increase crop yields and improve weed control, and are considered to be fundamental to organic production systems. Crop rotations consisting of continuous corn, corn-soybean, corn-soybean-oat, and corn-soybean-oat-alfalfa, with and without composted poultry manure, were established in 1990. Corn yields were greater when other crops were added to the rotation , as compared to continuous corn. Manure applications increased corn yield in all rotations. Oat yields were low and variable due to poor stands and high weed pressure and, no significant response to crop rotation or manure application occurred. Soybean yields were increased with crop rotation, but, manure had little effect on yield. Alfalfa yields were doubled where manure was applied. The reported results are preliminary, and the value and meaning of the study will increase with time

INTRODUCTION

This study was designed to evaluate the effects of crop rotation, with and without fertilizer (poultry manure), on plant growth, crop yield, and weed control. Crop rotations consist of 1 to 4 years with continuous corn, corn/soybean, corn/soybean/oat, corn/soybean/oat/alfalfa. The site, located on the Koch farm next to the Southwest Experiment Station, has a history of low synthetic fertilizer and herbicide use, and high weed pressure. Soil tests from the fall of 1988 showed Bray 1 phosphorus at 10 ppm and potassium tests of 171 ppm. This study was started in 1990 following soybeans with the first yields taken in the fall of 1990. There are no chemical weed control practices used, only mechanical weed control methods.

METHODS and MATERIALS

The study is a randomized complete block, split plot design, with four replications. Main plots (60' x 155'), consist of crop rotation, with each crop represented in each year, and subplots (30' x 155') consist of control (no manure) and composted poultry manure applications. The manure rate is based on soil test results from the previous fall sampling and University of Minnesota Extension recommendations. Soil samples for phosphorus and potassium were taken to a depth of 1 foot with 8 composite cores per plot. Soil nitrate samples were taken in 1 foot increment down to 5 feet with 2 cores per plot.

Composted poultry manure with an $N\text{-}P_2O_5\text{-}K_2O$ analyses of 5.4-3.66-4.31 was used (Table 1). The rate was selected to meet the crop requirement of the most limiting nutrient (P or N). The manure was broadcast on the plot and incorporated prior to secondary tillage in the spring.

After planting oats, and oats under seeded with alfalfa, plots were harrowed and packed (Table 1). This was done to increase weed control and soil to seed contact. The corn and soybean plots were rotary-hoed as often as needed to increase weed control (Table 1). Cultivations of corn and soybean were done as necessary to obtain maximum weed control. Tillage and rotary hoeing in like crops in all rotations were treated the same, but cultivation in corn varied from manure to no manure treatments. All treatments except oat 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. Three samples four feet long and 2.5 feet wide were taken in corn and soybean for grassy weeds. In oats and alfalfa five 1 foot squares per plot were collected for both grassy weeds and broadleaf weeds. Three samples, 150 feet by 2.5 feet, were taken for broadleaf weeds in corn and soybean plots.

RESULTS

In 1994, corn yields were significantly increased with the addition of manure across all rotations, however, the only significant increase in yield due to rotation effects was comparing continuous corn to the three year rotation (Table 2). The three year crop rotation with manure increased soybean yields significantly over the two year rotation (Table 3). There was a decrease in soybean yield when manure was applied across all rotations. This could be due to greater weed numbers from increased fertility (Table 3). Low oat yields were caused by a low population of oat and a high density of weeds. Yields were not taken with a plot combine due to early harvest of oat to prevent weed seed from reaching physiological maturity. Yields were taken using three, one meter squares per plots. Oat seed was separated from the biomass, weighed and calculated accordingly (Table 4). Adding manure to alfalfa more than doubled the yield in 1994 (Table 5).

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[1] S.R. Quiring, D.R. Huggins, D.J. Fuchs, and J.H. Ford are Sr. Research Technician, Assistant Professor, Former Scientist, and Professor at the Southwest Experiment Station, Lamberton, MN 56152.

Table 1. Organic Rotation Plot management information

Rotation	Spring Tillage	Seed	Rotary Hoe	Cultivation	Fertilizer
Continuous Corn	Digger 4/22 5/7 5/12	Pioneer 3769 29000 Seeds/A 5/13	5/17 5/19 5/27 5/31	6/10 6/24*	2.86 tons/A ** 5.4-3.66-4.31 4/22
Corn/Soybean	Digger 4/22 5/7 5/12	Pioneer 3769 29000 Seeds/A 5/13	5/17 5/19 5/27 5/31	6/10 6/24*	4.02 tons/A ** 5.4-3.66-4.31 4/22
Corn/Soybean/ Oat	Digger 4/22 5/7 5/12	Pioneer 3769 29000 Seeds/A 5/13	5/17 5/19 5/27 5/31	6/10 6/24*	5.2 tons/A ** 5.4-3.66-4.31 4/22
Corn/Soybean/ Oat/Alfalfa	Digger 4/22 5/7 5/12	Pioneer 3769 29000 Seeds/A 5/13	5/17 5/19 5/27 5/31	6/10 6/24*	0.9 tons/A ** 5.4-3.66-4.31 4/22
Soybean/Corn	Digger 4/22 5/7 5/12 5/23 5/27	Parker 158000 Seeds/A 5/27	5/31	6/14 6/24	0.63 tons/A ** 5.4-3.66-4.31 4/22
Soybean/Oat/ Corn	Digger 4/22 5/7 5/12 5/23 5/27	Parker 158000 Seeds/A 5/27	5/31	6/14 6/24	0.63 tons/A ** 5.4-3.66-4.31 4/22
Soybean/Oat/ Alfalfa/Corn	Digger 4/22 5/7 5/12 5/23 5/27	Parker 158000 Seeds/A 5/27	5/31	6/14 6/24	0.9 tons/A ** 5.4-3.66-4.31 4/22
Oat/Corn/ Soybean	Digger 4/22 Harrow/Pack 4/23	Dane 80 lbs/A 4/22			0.5 tons/A ** 5.4-3.66-4.31 4/22
Oat/Alfalfa/ Corn/Soybean	Digger 4/22 Harrow/Pack 4/23	Dane 64 lbs/A 4/22 Pioneer 5262 12 lbs/A 4/22			0.5 tons/A ** 5.4-3.66-4.31 4/22
Alfalfa/Corn/ Soybean/Oat		Pioneer 5262			1.19 tons/A ** 5.4-3.66-4.31 4/22

* Cultivation on 6/24 was on no manure corn only.

** Split plot design where only half the plot received manure.

Table 2. Crop rotation and manure effects on corn yields

	1990		1991		1992		1993		1994	
	Manure		Manure		Manure		Manure		Manure	
Rotation	+	-	+	-	+	-	+	-	+	-
	bu/a									
CC	84.6	74.5	85.4	55.7	93.3	63.7	42.5	11.2	149.5	57.3
CS	85.7	73.1	112.7	70.8	123.3	75.1	57.7	23.8	168.2	91.8
CSO	101.7	78.0	90.8	57.9	133.1	70.5	69.2	24.5	174.7	99.9
CSOA	82.9	70.9	116.2	69.1	140.4	98.7	69.5	46.2	156.6	93.3
$LSD_{0.05}$	22.4	28.5	23.8	19.8	16.3	40.6	19.9	12.5	18.9	37.4

Table 3. Crop rotation and manure effects on soybean yields

	1990		1991		1992		1993		1994	
	Manure		Manure		Manure		Manure		Manure	
Rotation	+	-	+	-	+	-	+	-	+	-
	bu/a									
SC	42.5	38.1	40.0	35.8	26.6	28.4	33.3	24.3	20.4	23.9
SOC	43.7	41.2	35.7	35.4	28.4	27.8	35.7	23.2	27.1	30.6
SOAC	43.7	40.7	36.3	33.8	28.5	28.3	33.6	21.3	26.7	29.1
$LSD_{0.05}$	7.9	9.0	9.6	11.8	6.6	10.6	7.4	7.2	6.3	6.3

Table 4. Crop rotation and manure effects on oat yields

	1990		1991		1992		1993		1994	
	Manure		Manure		Manure		Manure		Manure	
Rotation	+	-	+	-	+	-	+	-	+	-
	bu/a									
OCS	93.7	70.0	39.9	38.7	89.1	83.6	30.8	15.7	21.2	21.3
OACS	89.1	65.9	39.4	38.2	69.0	66.0	26.9	16.6	18.5	18.5
$LSD_{0.05}$	6.2	23.4	9.2	5.4	40.7	27.5	21.2	13.8	2.6	22.5

Table 5. Crop rotation and manure effects on alfalfa yields

	1991		1992		1993		1994	
	Manure		Manure		Manure		Manure	
Rotation	+	-	+	-	+	-	+	-
	ton/a							
ACSO	5.4	4.5	4.3	2.9	4.8	3.3	6.6	3.1

WEST CENTRAL EXPERIMENT STATION
WEATHER SUMMARY - 1994

Month/ Period	Dates/ Period	Precipitation 1994	Precipitation 100-yr. average	Precipitation Dev. from av.	Air Temperature 1994	Air Temperature 100-yr. average	Air Temperature Dev. from av.	Soil Temperature (10 cm depth) 1994	Soil Temperature (10 cm depth) 10-yr. average
January	1-31	1.00	0.68	+ 0.32	- 2.5	8.0	-10.5	31.4	20.7
February	1-28	0.71	0.67	+ 0.04	5.1	12.8	- 7.7	28.6	23.9
March	1-31	0.78	1.13	- 0.35	29.5	26.7	+ 2.8	31.9	29.2
April	1-10	0.22	0.57	- 0.35	38.4	38.0	+ 0.4	38.5	
	11-20	0.67	0.64	+0.03	48.4	44.4	+ 4.0	44.5	
	21-30	4.68	1.05	+3.63	44.9	48.3	- 3.4	44.5	
Total/ av.		5.57	2.26	+3.31	43.9	43.6	+ 0.3	42.5	41.4
May	1-10	0.14	0.77	- 0.63	47.5	52.0	- 4.5	49.0	
	11-20	0.35	0.95	- 0.60	65.2	55.8	+ 9.4	63.9	
	21-31	0.63	1.25	- 0.62	67.1	60.0	+ 7.1	69.8	
Total/av.		1.12	2.97	- 1.85	60.1	56.1	+ 4.0	61.2	57.1
June	1-10	0.02	1.29	- 1.27	65.8	63.0	+ 2.8	71.4	
	11-20	1.23	1.30	- 0.07	68.4	66.3	+ 2.1	68.3	
	21-30	1.25	1.37	- 0.12	69.4	68.1	+ 1.3	72.1	
Total/av.		2.50	3.96	- 1.46	67.9	65.8	+ 2.1	70.6	69.3
July	1-10	5.29	1.44	+3.85	68.0	70.1	- 2.1	70.5	
	11-20	0.69	1.06	- 0.37	68.6	71.4	- 2.8	73.2	
	21-31	0.18	1.01	- 0.83	67.6	71.4	- 3.8	73.1	
Total/av.		6.16	3.51	+2.65	68.1	70.9	- 2.8	72.3	76.7
August	1-10	1.20	1.04	+0.16	66.8	70.4	- 3.6	73.7	
	11-20	0.28	0.93	- 0.65	65.2	69.0	- 3.8	68.0	
	21-31	0.68	1.04	- 0.36	66.6	66.9	- 0.3	71.4	
Total/av.		2.16	3.01	- 0.85	66.2	68.7	- 2.5	71.0	73.9
September	1-30	1.98	2.20	- 0.22	62.6	59.0	+ 3.6	64.0	61.5
October	1-31	3.13	1.74	+1.39	49.3	47.2	+ 2.1	49.1	47.8
November	1-30	0.73	0.97	- 0.24	34.6	29.7	+ 4.9	36.1	33.6
December	1-31	0.41	0.68	- 0.27	19.4	15.2	+ 4.2	29.4	23.4
Growing Season	4/1-8/31	17.51	15.71	+1.80	61.3	61.0	+ 0.3	63.6	63.8
Annual	1/1-12/31	26.25	23.78	+2.47	42.2	42.0	+ 0.2	49.2	46.7

CONTINUOUS CORN SILAGE[1]

S.D. Evans[2]

Abstract

This long-term study addresses the effects of removal of continuous corn silage and corn grain on soil properties and yield. In 1994 there were significant effects of fertilizer level only. The 28-year averages show no yield differences due to the removal of silage versus grain. A significant difference in yield does exist between the long-term high and low fertilizer rates.

Objective

This is the 28th year of a continuing study initiated in 1965 on a McIntosh silt loan soil. The study was initiated to determine the effects of removal of continuous corn silage and fertilizer rate on soil properties and yield. Half the plots receive a fertilizer rate of 74+48+48 ($N+P_2O_5+K_2O$) lb/A and the other half a rate of 148+96+96, fall applied. Silage and shelled corn samples were collected.

Experimental Procedure

The experiment is designed as a latin square with 4 treatments: (1) silage, low fertility (2) silage, high fertility (3) grain, low fertility (4) grain, high fertility. In 1993 the corn plants were severely stunted due to excessive rain and cool temperatures. The corn failed to reach maturity and was chopped down with a flail chopper and disked under on September 9 and moldboard plowed on October 28, 1993. The study was field cultivated on May 13 and again on May 16 and seeded to Pioneer 3751 corn at 30,000 seeds/A in 30-inch rows on May 17, 1994. Force 1.5G was band applied at seeding at 10 lb/A. Lasso @ 3 lb/A active ingredient (a.i.) + Bladex @ 2.2 lb/A a.i. were applied pre-emergence broadcast on May 20. The study was row cultivated on June 10 and again on June 22. Dates of tasseling and silking were recorded. Silage yields were obtained from chopping 3 10-foot rows on September 20 and grain yields were calculated from 2 45-foot rows harvested with a plot combine on October 14. Yields were also taken, as in past years, on an adjacent unfertilized (check) area where only the grain is removed.

Results and Discussion

Silage Yields

There were significant differences in silage yields between high and low fertility treatments in 1994 (Table 1). There were no significant differences in silage yields due to the continuous removal of grain or silage at the low fertility level or at the high fertility level in 1994. The 28-year average shows no effect on silage yields with regard to continuous grain or silage removal but does show significant differences between high and low fertility treatments.

Grain Yields

The 1994 grain yields (Table 2) show a significant difference in grain yield between the high and low fertility treatments of 52.1 bu/A. The long-term 28-year average also shows a significant grain yield advantage for high fertility over low fertility treatments of 7.0 bu/A.

This study will be continued in 1995.

[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	1994 Yield	1966-1994 Yield
	dry matter, tons/A	dry matter, tons/A
Silage, low fertility	5.47	5.59
Silage, high fertility	8.06	6.19
Grain, low fertility	6.33	5.69
Grain, high fertility	7.66	6.10
Signif. Levels (%)		
Treatment	96	>99
Year	--	>99
Treatment x Year	--	>99
LSD, Treatment (.05)	1.95	0.16

Table 2. Effect of fertilizer level on grain and silage yields.

Treatment	1994 Yield	1966-1994 Yield
	bu/A @ 15.5% Moist	bu/A @ 15.5% Moist
Grain, low fertility	127.3	91.3
Grain, high fertility	179.4	98.3
Signif. Levels		
Treatment	98	>99
Year	--	>99
Treatment x Year	--	>99
LSD, Treatment (.05)	33.5	2.9
Grain, check (bu/A)	63.8	47.8
Silage, check (D.M. tons/A)	2.81	3.47

ANHYDROUS AMMONIA KNIFE SPACING STUDY[1]

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

Abstract

A field study was initiated at Morris, MN in 1994 to study the effect of sidedressed anhydrous ammonia knife spacing on corn yield. Additional treatments were included to evaluate urea application at sidedress stage with and without incorporation. There was an increase in corn yield up to 72 lb N/A as anhydrous ammonia, but no difference due to knife spacing. There was no influence of urea incorporation at the 72- and 108-lb N rates and no difference between the urea N source and anhydrous ammonia. This study will be continued for 1 or 2 more years.

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 6-10 inches deep. Horsepower 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 horsepower 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 5-leaf stage of corn with a conventional anhydrous ammonia applicator.

Experimental Procedures

An experiment was established in 1994 on a Nutley clay soil (2 reps) and Flom loam soil (2 reps). The individual plots were 6 rows (15 ft) wide and 45 ft long. The experimental design was a randomized complete block with 4 replications. The experimental site was in oats in 1993 and fall chisel plowed. The fall NO_3-N (0-2 ft) was 14 lb/A. Other initial soil tests are shown in Table 1. The study was field cultivated once and then seeded with a 6-row planter to Ciba-Geigy 4172 corn at 30,000 seeds/A in 30-inch rows on May 9. Force 1.5G was band applied at 10 lb/A at seeding. Lasso @ 3.0 lb/A active ingredient (a.i.) + Bladex @ 2.2 lb/A a.i. was applied preemergence on May 16. Anhydrous ammonia was sidedress applied with 30 and 60 inches between knives on June 8. Nitrogen was applied at rates of 32, 72, 108, and 144 lb/A at 30- and 60-inch knife spacings. A check treatment (no N) was also included by running knives at 30- and 60-inch spacings through the check plots without applying any nitrogen. Corn was in the 5-leaf, 3-collar stage at the time of nitrogen application. The study was cultivated with 6-row equipment on June 8, prior to nitrogen application and again on June 27. Four urea treatments were also included into the study for comparative purposes. Urea applications of 72 and 108 lb N/A were broadcast applied prior to cultivation on June 8, and thus incorporated via row cultivation. The unincorporated urea treatments of 72 and 108 lb N/A were broadcast applied after row cultivation on June 8. The urea treatments were also cultivated on June 27. Tasseling and silking dates were recorded. The study was harvested for grain on September 28 with a plot combine.

Results

The check treatments tasseled and silked about 1 day later than all other treatments. There were significant differences in grain yield due to nitrogen rate (Table 2.). There were no significant effects on grain yield due to knife spacing or the knife spacing x treatment interaction. Yield was maximized at about 72 lb N/A. The comparison of urea incorporated, urea unincorporated, and ammonia at 2 N rates showed no siginficant differences (Table 3). The surface applied urea was probably incorporated by rainfall that fell soon after application. On days 3 and 4 following application a total of 0.28 inch was recorded and an additional 0.61 inch on days 6 through 9 after application.

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[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 1. Analysis of initial soil samples.

	Organic Matter	pH	Olsen P	Bray P	K	Zn
	%		ppm	ppm	ppm	ppm
Average	5.7	- -	- -	34	227	2.6
Range	4.9-7.2	7.0-7.8	30-43*	21-50	200-250	1.5-4.3

* Values from only 2 reps with pH <7.4.

Table 2. Effect of anhydrous ammonia applicator knife spacing on corn grain yield.

Nitrogen Rate	30-in. Knife Spacing	60-in. Knife Spacing	Mean
lb/A	- - - - - - - - - bu/A @ 15.5% M - - - - - - - -		
0	80.5	80.5	80.5
32	106.9	113.5	110.2
72	150.3	148.9	149.6
108	142.7	153.3	148.0
144	159.3	159.8	159.5
Signif. Levels (%)			
Rep			62
Knife Spacing (KS)			34
N Treatment (N)			>99
LSD, Trt. (.05)			28.5
KS x N.			2

Table 3. Effect of incorporation, knife spacing, and N source on corn grain yield.

N Source	Nitrogen Rate	Knife Spacing	Incorporated	Yield
	lb/A			bu/A @15.5% M
NH_3	72	30	Yes	150.3
NH_3	72	60	Yes	148.9
NH_3	108	30	Yes	142.7
NH_3	108	60	Yes	153.3
Urea	72	- -	No	127.5
Urea	72	- -	Yes	133.8
Urea	108	- -	No	139.6
Urea	108	- -	Yes	124.9
Signif. Levels (%)				
Rep				89
Trt.				74
LSD (.05)				NS

ESTIMATION OF DIRECT AND RESIDUAL N AVAILABILITY FROM APPLIED LIQUID SWINE AND DAIRY MANURE[1]

S.D. Evans, G.N. Nelson, C.F. Reece, R.L. Robertson, P.R. Goodrich, and A.E. Olness[2]

Abstract

The effects of liquid swine and liquid dairy manure applied at four rates on soil NO_3-N content and various crop parameters were evaluated for one and two years following fall manure injection and compared to four rates of urea and a check. The first year following application, all but the lowest manure rates increased soil NO_3-N levels at emergence, V5, and post-harvest over the check treatment. Soil NO_3-N levels from the 2nd year following manure application were significantly higher than the check treatment at emergence and V5 only with the highest manure rate from both sources. Post-harvest soil NO_3-N levels of the two highest rates of both manures were higher than the check in the 2-5 ft depth zone. Differences in chlorophyll meter readings on the residual manure study were significant only on July 11, the pre-tassel stage. On the study the first year after manure application, chlorophyll meter readings were affected by treatment at both V5 and pre-tassel stages. On both studies the range in readings was wider at pre-tassel than at V5. Plant height, total N upake, grain N removal, silage yield, and grain yield were all significantly affected by treatment on both studies. The effects were much larger on the 1st year following manure application as compared to the 2nd year. There was a positive relationship between soil NO_3-N to a 2-ft depth at corn stage V5 and corn grain yield. This study will be continued for one more crop year.

Introduction

Animal agriculture is an important part of the farm economy in west central Minnesota. Most manure is used as a nutrient source on cropland, but most farmers tend to give less credit to manure than suggested because 1) N fertilizer is cheap and 2) a little extra N gives them a cushion in case of unexpected N losses or reduced N availability from manure. It would be helpful if farmers had some technique to determine the N status and predicted N need before the period of maximum N uptake and early enough so that supplemental N could be applied. This is particularly important for slow release N sources such as manure. Early season soil and plant tests will be used to evaluate the apparent N mineralization rate and N status of the corn crop. Climatic variables will also be measured on a limited number of plots in another phase of the overall nutrient recycling effort so that apparent N mineralization can be modeled. Corn grain yields and N uptake will be used as the final measure of N availability over a growing season.

Experimental Procedures

The experimental site was established in the fall of 1992 on a predominately Aastad clay loam (Pachic Udic Haploboroll, fine loamy, mixed) located on the West Central Experiment Station, Morris, MN. The 1992 crop was corn and was harvested as corn silage on October 1-2, 1992. Two trial sites were established; one to commence with manure and fertilizer applications in the fall of 1992 (Site 1) and the other to commence with manure and fertilizer applications in the fall of 1993 (Site 2).

Treatment areas were staked out on both sites on October 5. The design for each site was a randomized complete block with 4 replications. Plot size was 15 ft wide (6 rows) by 47.5 ft long. Thirteen treatments included a check, 4 rates of urea, 4 rates of liquid swine manure, and 4 rates of liquid dairy manure (Table 2). Site 1 was grid sampled on October 6, 1992 on the corners of every second plot to determine the depth of topsoil, soil drainage characteristics, soil pH, soil organic matter content, and depth to carbonates. The same measurements

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[1] Support for this project was provided by the Legislative Commission on Minnesota Resources, the West Cent. Exp. Sta., the Soil Science Dept., and the Agricultural Eng. Dept., Univ. of Minnesota.

[2] S.D. Evans and G.N. Nelson are Professor and Asst. Scientist, West Cent. Exp. Sta., Univ. of Minnesota; C.F. Reece and R.L. Robertson are Asst. Professor and Senior Lab. Tech., Univ. of Minnesota; P.R. Goodrich is Professor, Agricultural Eng. Dept., Univ. of Minnesota; and A.E. Olness is Soil Scientist, USDA-ARS, Morris, MN.

were made on Site 2 on September 1, 1994. Samples were air dried and saved for analysis. Fertilizer was applied broadcast to Sites 1 and 2 on October 14, 1992 to provide 75 lb/A P_2O_5 and 75 lb/A K_2O.

Manure treatments were applied to Site 1 on October 19-20, 1992 and to Site 2 on October 21-22, 1993. Target application rates were 80, 160, 240, and 320 lb N/A. All manure treatments were applied with an experimental Agricultural Engineering Department manure applicator. Samples of each manure were taken directly from the applicator in the field for subsequent analysis. The N contents of the manures are given in Table 1. The applicator was weighed using portable load cells before and after each application treatment to calculate actual application rates. The applied manure rates were calculated from these weights (Table 2). The manure was metered through 4 hydraulically driven pumps, one for each injector, to provide an accurate uniform application. The applicator was outfitted with 4 18-inch sweeps, 24 inches on center, for a total applicator width of 7.5 feet. Two passes were required for each plot. Manure was applied at a 4-5 inch depth for all manures and rates except for the 320-lb dairy rate in 1992 which was applied at 5-6 inches on the first pass and 3-4 inches on the second pass. Inorganic fertilizer as urea was applied to provide 40, 80, 120, and 160 lb N/A. Urea was applied to Site 1 on October 22, 1992 and then field cultivated to incorporate the urea and remove wheel tracks from the manure applicator. Urea was applied to Site 2 on October 18, 1993 and then field cultivated to incorporate the urea and remove wheel tracks from the manure applicator on October 22, 1993. Urea was also applied to urea treatments in Site 1 in the fall of 1993 and to both sites in the fall of 1994. This study will be continued for one more crop year with only residual manure as compared to annual urea treatments.

2nd Year Residual Availability - Site 1 (1993-1994)

For the second year of the study on Site 1 the site was field cultivated for seedbed preparation on May 9, 1994 Ciba-Geigy 4172 corn was seeded at 30,000 seeds/A on May 9. Force 1.5G was applied at seeding at 10 lb/A. A tank mix of Lasso @ 3 lb/A active ingredient (a. i.) + Bladex @ 2.2 lb/A a. i. was applied broadcast preemergence on May 16.

The plots were soil sampled at the emergence stage (2-leaf) of corn on May 24-25. Plots consisted of 6 rows and were sampled to a depth of 2 ft in 1-ft increments. Each soil sample was a composite of 6 subsample probes (two in the corn row, two 7.5 inches from the row to the north, and two 15 inches from the row to the north). Soil samples were dried at 95°F for 24 hours, ground, and analyzed for NH_4-N and NO_3-N.

On June 1 Accent @ 2/3 ounce/A was applied broadcast for grass control. On June 8 the plots were row cultivated. The plots were soil sampled at the V5 stage of corn of corn in the same manner as the emergence sampling on June 13-14. On June 16 chlorophyll meter readings were taken on 10 plants/plot. Plant heights were measured on June 28 (10 plants/plot, extended leaf) and a plant population count was taken on June 29. Chlorophyll meter readings were taken a 2nd time on July 11 just prior to tasseling. Corn tasseling and silking dates were recorded.

Corn was hand harvested for silage yields from 45 ft of row on September 14-15. Silage samples were dried at 150°F for 48 hours and saved for N analysis. On September 22, 10 basal stalk samples were collected from each plot, each stalk was an 8-inch section located 6 to 14 inches from the soil surface. Corn grain was harvested from 2 45-ft rows using an Almaco combine on September 27. The plots were soil sampled using the same method as at the emergence sampling except they were sampled to a depth of 5 ft in 1-ft increments on October 10-11. Corn stalks were chopped on October 21 and urea fertilizer was applied on October 24 to the same plots and rates as in the fall of 1993. The study was chisel plowed on October 25.

1st Year Availability - Site 2 (1994-95)

For the first year of the study in Site 2 the field procedures, planting dates, hybrids, herbicides, plant and soil sampling procedures and dates were the same as in Site 1 with the following exceptions: emergence soil samples were taken on May 25-26, corn silage was harvested on September 15, and fall soil samples were taken on October 11-13.

Results and Discussion

2nd Year Residual Availability - Site 1 (1993-1994)

Soil N Content: There were significant effects of treatment on soil NO_3-N for emergence and V5 sampling dates and depth combinations shown in Table 3 for Site 1. The fall harvest date was only significant at the 0-5 ft depth indicating that 2 years after manure application the mineralized N had either been used up or leached out of the 0-1 and 1-2 ft increments. There were no significant effects of treatment on soil NH_4-N values on Site 1.

Plant Measurement: Relative chlorophyll meter readings, grain yield, silage yield, and plant height were significantly affected by treatment at Site 1 shown in Table 5. Relative chlorophyll meter readings were significant on July 11 but not on June 16. July 11 readings gave a good indication of yield range but were not precise enough to indicate yield levels and July 11 is too late to apply additional N. Grain yield and silage yields behaved similarly with treatments F3, F4, and D4 yielding the most. Due to heavy rainfall and/or low soil NO_3-N it is possible maximum yield was not reached at this site. Treatment effects for plant height, taken on June 27, were significant with taller plants generally yielding more than shorter plants but no close correlation was evident. There were no differences in grain moisture and grain bushel weight (Table 5) or in stover total N, grain total N, and basal stalk NO_3-N (Table 7). There were highly significant differences in total N uptake and N removed in the grain (Table 8). The C.V.'s were very high in the residual manure study indicating the extreme variability in the N availability. All basal stalk NO_3-N values were less that 20 ppm indicating very little available N in the soil at the end of the season (Table 7).

1st Year Availability - Site 2 (1994-95)

Soil N Content: Treatments affected soil NO_3-N for all sample dates and depth combinations shown in Table 4 for Site 2. V5 nitrates were lesser than those at emergence but there were still significant treatment effects. Greatest grain yields were associated with V5 0-2 ft NO_3-N soil tests of 9.8 ppm or greater. There were no effects of treatment on soil NH_4-N values on Site 2.

Plant Measurements: Relative chlorophyll meter readings, grain yield and moisture, silage yield, and plant height were significantly affected by treatment at Site 2 (Table 6). Relative chlorophyll meter readings were significant for both June 16 and July 11 and generally reflect greater yields associated with higher readings but not accurately for purposes of determining N status of the plant. Grain yield and silage yield responded in a similar manner with greatest yields at treatments F3, F4, S2, S3, S4, D3, and D4. Plant height on June 27 generally corresponded well with final yield. Stover total N, grain total N, and basal stalk NO_3-N were significantly affected by treatment at Site 2 (Table 7). In 1993 grain N and stover N were also significant for differentiating high yielding from low yielding treatments in 1993 but did not correlate with 1994 yields from manure treatments. Basal stalk NO_3-N was excellent for indicating excess inorganic N in the soil profile during the growing season as shown in S2, S3, and S4. There were highly significant effects of treatment on total N uptake on N removed in the grain from 1st year manure and urea applications (Table 8). The C.V.'s of the 1st year data were much lower than in the residual manure data. Basal stalk NO_3-N values of three of the swine manure treatments were above 200 ppm (Table 7) indicating substantial available N in the soil at the end of the growing season. This was also shown in the soil NO_3-N measurements (Table 4).

Yield - Soil Nitrate-N Relationship

In 1993 we found a close relationship between corn grain yield and soil NO_3-N (0-2 ft) at leaf stage V5. Similar data for 1994 is plotted in Fig. 1. With all treatments included (both sites) the $r^2 = 0.79$. A slightly better relation was found when including only the organic plots ($r^2 = 0.85$). It appears that a soil NO_3-N (0-2 ft) of about 10 ppm for corn leaf stage V5 was sufficient to reach about 95% of maximum yield.

Table 1. Nitrogen content of manure used.

Manure Source[a]	Site 1, N Applied fall 1992 Total	Org.	NH_4-N	Avail (93)[b]	Avail. (94)[c]	Site 2, N Applied fall 1993 Total	Org.	NH_4-N	Avail. (94)[b]
	lb/1000 gallons								
Swine	31.6	18.2	13.4	18.9	1.91	54.0	9.6	44.4	47.3
Dairy	35.6	17.4	18.3	23.5	1.83	31.4	13.2	18.2	22.2

[a] Sampled from the manure applicator just prior to application.
[b] Available N 1st year = NH_4-N + 30% of organic N.
[c] Available N 2nd year = 15%(remaining 70% of organic N).

Table 2. Treatments, target N rates, manure applied, and actual N applied, 1992 & 1993.

Trt.	N Source	Site 1, N Applied fall 1992 Manure Applied	93 Avail. Rates[a](	94 Avail. Rates[b](	Site 2, N Applied fall 1993 Target Rates	Manure Applied	94 Avail. Rates[a]
		-gal/A-	-lb/A-			-gal/A-	-lb/A-
CK	None	0	0	0	0	0	0
F1	Urea	0	40	40	40	0	40
F2	Urea	0	80	80	80	0	80
F3	Urea	0	120	120	120	0	120
F4	Urea	0	160	160	160	0	160
S1	Swine manure	2440	46	5	80	1740	82
S2	Swine manure	4880	92	9	160	5070	240
S3	Swine manure	7180	136	14	240	7400	350
S4	Swine manure	9740	184	19	320	9860	466
D1	Dairy manure	3880	91	7	80	2290	51
D2	Dairy manure	7860	185	14	160	4906	109
D3	Dairy manure	11300	266	21	240	6830	151
D4	Dairy manure	15700	370	29	320	8680	192

[a] Based on actual weight of manure applied and available N values from Table 1.
[b] Based on actual weight of manure applied and residual N values from Table 1.

Table 3. Effect of N source and rate on nitrate-N in the soil profile at emergence and V5 stage of corn growth, Site 1, 1994.

N Source	Avail. N Rate	Emergence NO_3-N 0-1 ft	Emergence NO_3-N 0-2 ft	V5 NO_3-N 0-1 ft	V5 NO_3-N 0-2 ft	Post Fall Harvest NO_3-N 0-1 ft	Post Fall Harvest NO_3-N 0-2 ft	Post Fall Harvest NO_3-N 0-5 ft
	lb/A	ppm						
Check	0	5.2	3.9	4.9	3.6	2.3	1.2	1.1
Urea[a]	40	6.2	5.5	5.1	4.5	1.3	0.9	1.5
Urea	80	12.4	9.5	7.9	7.4	2.2	1.2	1.8
Urea	120	7.9	8.7	7.5	8.6	1.2	0.8	3.4
Urea	160	12.5	12.4	9.6	9.1	2.3	1.5	3.1
Swine[a]	5	4.6	3.5	4.4	3.6	1.9	1.1	1.4
Swine	9	4.9	3.8	4.5	3.4	1.6	1.0	1.8
Swine	14	6.7	5.4	5.1	4.1	3.2	1.8	2.4
Swine	19	5.6	4.4	4.1	4.0	2.4	1.3	4.4
Dairy[a]	7	6.1	4.7	5.3	4.2	1.8	1.0	1.5
Dairy	14	6.0	4.5	4.9	3.7	2.4	1.3	2.6
Dairy	21	6.0	4.9	4.7	3.8	2.5	1.4	3.3
Dairy	29	7.4	6.5	7.0	6.6	2.1	1.2	4.8
Pr > F		.0001	.0001	.0019	.0001	.1019	.1406	.0001
BLSD(.05)		2.9	2.0	2.6	1.9	NS	NS	1.1
C.V. (%)		24.8	20.8	25.2	23.1	32.1	30.6	24.5

[a] Manure was applied fall of 1992, inorganic N was applied fall of 1992 and fall of 1993.

Table 4. Effect of N source and rate on nitrate-N in the soil profile at emergence and V5 stage of corn growth, Site 2, 1994.

N Source	Avail. N Rate	Emergence NO_3-N 0-1 ft	Emergence NO_3-N 0-2 ft	V5 NO_3-N 0-1 ft	V5 NO_3-N 0-2 ft	Post Fall Harvest NO_3-N 0-1 ft	Post Fall Harvest NO_3-N 0-2 ft	Post Fall Harvest NO_3-N 0-5 ft
	lb/A	ppm						
Check	0	6.0	4.8	4.3	4.1	2.3	1.3	2.0
Urea[a]	40	7.2	6.2	6.2	5.8	2.0	1.2	2.6
Urea	80	9.9	9.1	8.2	8.3	2.2	1.4	2.3
Urea	120	13.0	11.2	10.3	9.8	2.0	1.3	1.9
Urea	160	19.1	16.6	14.8	12.9	3.4	2.0	3.4
Swine[a]	82	7.4	7.2	5.9	6.4	2.6	1.6	2.8
Swine	240	15.8	15.9	13.7	12.7	4.2	2.6	3.6
Swine	350	23.9	20.4	19.9	17.8	6.1	5.4	5.9
Swine	466	33.7	29.0	30.2	25.1	13.2	11.9	8.2
Dairy[a]	51	6.2	6.0	5.2	5.2	2.0	1.1	1.7
Dairy	109	10.2	9.7	8.3	8.2	2.1	1.2	2.7
Dairy	151	10.1	9.9	10.2	9.9	3.1	1.8	3.2
Dairy	192	13.2	12.1	11.9	10.8	2.9	1.7	2.9
Pr > F		.0001	.0001	.0001	.0001	.0001	.0001	.0001
BLSD(.05)		5.9	3.5	7.6	4.9	3.8	2.2	1.6
C.V. (%)		32.6	22.0	47.4	34.4	71.5	59.2	34.2

[a] Manure and inorganic N were applied in the fall of 1993.

Table 5. Influence of nitrogen source and rate on plant measurements: chlorophyll meter readings, grain yield, grain moisture, grain bushel weight, plant height, and silage yield, Site 1, 1994.

N Source	Avail. N Rate	Relative Chlorophyll[b] Jun 16	Relative Chlorophyll[b] Jly 11	Grain Yield	Grain Moisture	Grain Weight	Plant Height Jun 27	Silage Yield
	lb/A			-bu/A-	--%--	-lb/bu-	- - in - -	-lb/A-
Check	0	0.90	0.73	75.8	27.7	53.1	42.5	8050
Urea[a]	40	0.98	0.86	101.2	25.4	52.9	45.2	9600
Urea	80	0.97	0.96	122.2	24.0	53.7	51.9	11700
Urea	120	1.02	0.96	127.4	25.3	53.7	48.7	13000
Urea	160	1.00	1.00	139.5	25.2	53.8	50.4	13400
Swine[a]	5	0.88	0.79	70.7	26.1	53.8	42.8	8570
Swine	9	0.89	0.76	92.6	25.9	53.6	44.7	9600
Swine	14	0.93	0.85	94.1	24.8	53.9	47.4	10100
Swine	19	0.93	0.85	98.1	24.4	53.8	46.7	10400
Dairy[a]	7	0.88	0.80	75.3	25.2	53.1	45.0	8830
Dairy	14	0.93	0.93	108.4	23.7	54.3	50.8	11100
Dairy	21	0.95	0.95	104.8	24.5	53.9	49.4	11600
Dairy	29	0.97	0.94	132.1	26.1	53.3	50.4	12600
Pr > F		.1150	.0023	.0100	.6720	.4609	.0001	.0006
BLSD(.05)		------	0.14	42.4	-------	------	5.5	2394
C.V. (%)		6.5	8.7	21.4	8.3	1.3	4.5	12.9

[a] Manure was applied fall of 1992, inorganic N was applied fall of 1992 and fall of 1993.
[b] Actual chlorophyll meter readings for each rep were divided by the reading on treatment F4 for that rep.

Table 6. Influence of nitrogen source and rate on plant measurements: chlorophyll meter readings, grain yield, grain moisture, grain bushel weight, plant height, and silage yield, Site 2, 1994.

N Source	Avail. N Rate	Relative Chlorophyll[b] Jun 16	Relative Chlorophyll[b] Jly 11	Grain Yield	Grain Moisture	Grain weight	Plant Height Jun 27	Silage Yield
	lb/A			-bu/A-	--%--	-lb/bu-	- - in - -	-lb/A-
Check	0	0.89	0.76	108.5	27.7	53.2	47.8	11000
Urea[a]	40	0.89	0.80	117.4	25.6	52.6	50.7	11500
Urea	80	0.98	0.92	142.4	24.7	53.2	55.6	14000
Urea	120	0.99	0.91	160.0	22.8	53.6	59.0	15700
Urea	160	1.00	1.00	171.4	24.9	52.9	59.9	16500
Swine[a]	82	0.97	0.88	128.3	24.6	53.5	55.7	13700
Swine	240	0.97	0.94	180.6	24.8	53.0	62.3	17300
Swine	350	1.02	0.98	188.4	25.8	52.1	65.4	17800
Swine	466	1.00	0.99	187.2	26.6	52.8	64.4	19200
Dairy[a]	51	0.88	0.79	116.3	26.9	52.5	50.8	12000
Dairy	109	0.97	0.90	147.2	26.3	53.4	58.6	15000
Dairy	151	0.94	0.92	166.6	25.9	52.9	59.9	16500
Dairy	192	0.99	0.98	174.2	23.6	53.5	62.9	16300
Pr > F		.0015	.0001	.0001	.0413	.1322	.0001	.0001
BLSD(.05)		0.07	0.05	14.9	3.3	------	3.1	1780
C.V. (%)		5.0	4.0	7.5	7.2	1.3	4.1	8.9

[a] Manure and inorganic N were applied fall of 1993.
[b] Actual chlorophyll meter readings for each rep were divided by the reading on treatment F4 for that rep.

Table 7. Influence of nitrogen source and rate on total N content of stover, total N content of grain, and NO3-N concentration of plant basal stalk, 1994, Site 1 and 2.

1994 Site 1					1994 Site 2				
N Source[a]	Avail. N Rate	Stover Total N	Grain Total N	Basal Stalk NO_3-N	N Source[b]	Avail. N Rate	Stover Total N	Grain Total N	Basal Stalk NO_3-N
	lb/A	--- % ----		-ppm-		lb/A	-%-	-%-	-ppm-
Check	0	0.36	0.85	1.14	Check	0	0.30	0.85	7.06
Urea	40	0.38	0.89	0.75	Urea	40	0.32	0.90	1.78
Urea	80	0.47	0.93	5.57	Urea	80	0.36	1.02	1.58
Urea	120	0.39	0.95	12.90	Urea	120	0.42	1.05	2.41
Urea	160	0.39	1.05	18.10	Urea	160	0.44	1.20	11.70
Swine	5	0.33	0.89	0.96	Swine	82	0.38	0.98	0.81
Swine	9	0.33	0.90	0.81	Swine	240	0.50	1.18	215.00
Swine	14	0.38	0.94	1.43	Swine	350	0.47	1.30	512.00
Swine	19	0.41	1.00	4.22	Swine	466	0.55	1.24	976.63
Dairy	7	0.37	0.87	0.70	Dairy	51	0.37	0.88	0.83
Dairy	14	0.35	0.84	1.94	Dairy	109	0.33	1.04	1.91
Dairy	21	0.37	0.98	1.76	Dairy	151	0.36	1.07	1.35
Dairy	29	0.41	1.07	5.63	Dairy	192	0.47	1.25	22.30
Pr>F		.7244	.1052	.1666			.0001	.0001	.0001
BLSD .05		NS	NS	NS			0.09	0.12	180.3
C.V. (%)		20.4	10.0	172.5			15.7	8.6	101.9

[a] Manure was applied fall of 1992, inorganic N was applied fall of 1992 and fall of 1993.
[b] Manure and inorganic N were applied in the fall of 1993.

Table 8. Influence of nitrogen source and rate on total N uptake and total N removed in the grain, 1994.

1994 - Site 1				1994 - Site 2			
N Source[a]	Avail. N Rate[b]	Total N Uptake	Total N Removed in Grain	N Source[c]	Avail. N Rate[d]	Total N Uptake	Total N Removed in Grain
	------- lb/A ------				------- lb/A -------		
Check	0	49	37	Check	0	67	52
Urea	40	66	51	Urea	40	75	60
Urea	80	87	64	Urea	80	103	82
Urea	120	89	67	Urea	120	121	95
Urea	160	105	82	Urea	160	146	115
Swine	5	48	36	Swine	82	92	70
Swine	9	60	47	Swine	240	154	119
Swine	14	66	49	Swine	350	171	138
Swine	19	74	57	Swine	466	175	130
Dairy	7	51	36	Dairy	51	77	57
Dairy	14	68	51	Dairy	109	107	86
Dairy	21	76	58	Dairy	151	123	100
Dairy	29	103	81	Dairy	192	153	122
Pr>F		.0080	.0141			.0001	.0001
BLSD .05		35	31			18	16
C.V. (%)		25.7	28.6			11.5	13.2

[a]Manure was applied fall of 1992, inorganic N was applied fall of 1992 and fall of 1993.
[b]Available N 1st year = NH4-N + 30% of organic N.
[c]Manure and inorganic N were applied in the fall of 1993.
[d]Available N 2nd year = 15%(remaining 70% of organic N).

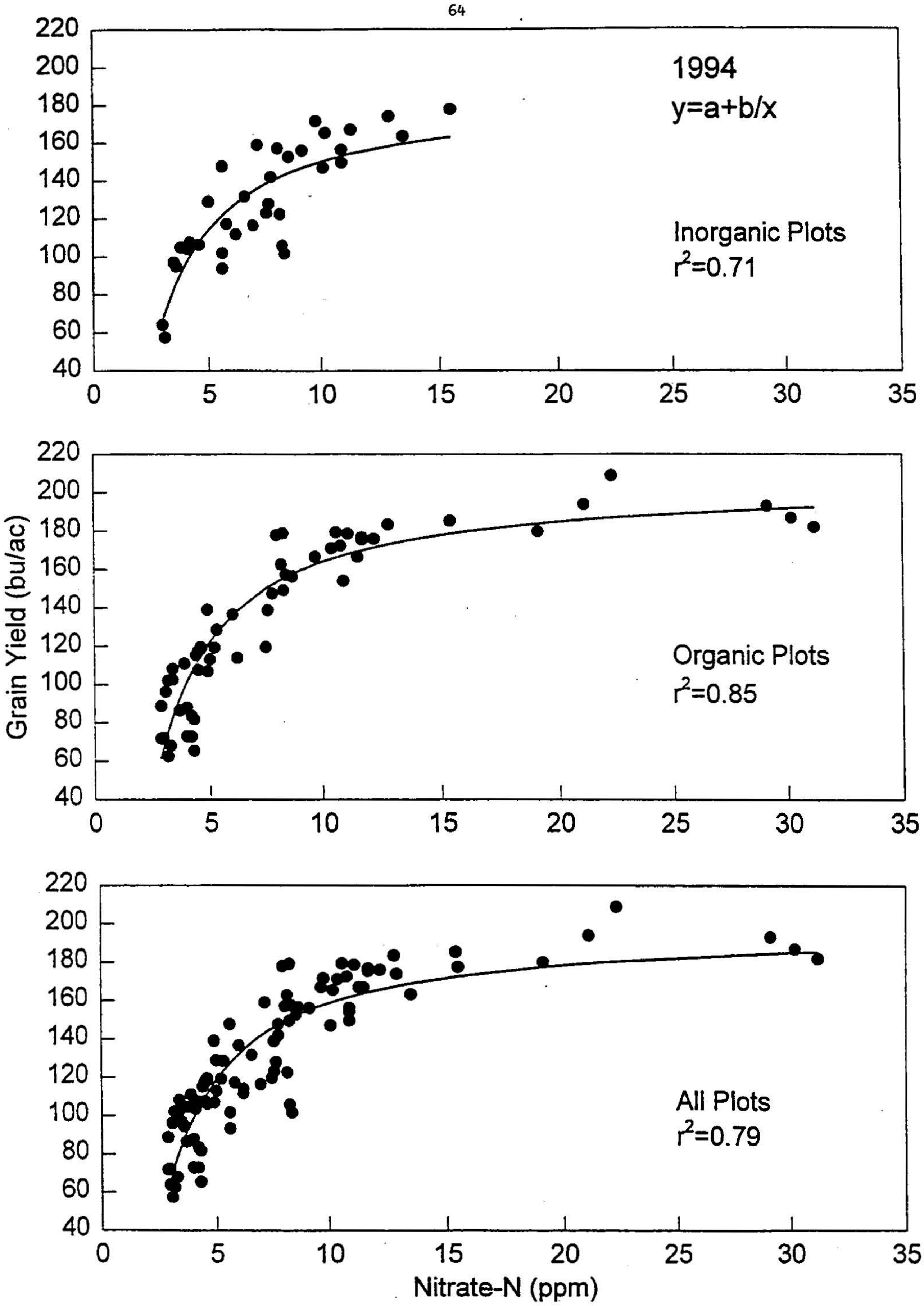

Figure 1. Relationship between soil nitrate-N (0-2 ft. at corn stage V-5) and grain yield.

ASSESSMENT OF THE EFFECTS OF TILLAGE AND MANURE APPLICATION ON SEDIMENT AND P LOSS DUE TO RUNOFF IN 1994[1]

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Abstract

In the RT system, snowmelt-runoff was the predominant source of the annual runoff and phosphorus loss; On the contrary, in the PL system, rainfall-runoff was the predominant source of the annual runoff and phosphorus loss. Sediment loss in snowmelt-runoff was a negligible contribution to the annual sediment loss. Therefore the annual sediment loss was mainly from rainfall-runoff. The PL systems resulted in 11.8 times higher sediment loss compared to RT system. The annual TP loss in the PL systems was 1.9 times higher than TP from RT systems. Particulate-P from PL plots was 3.9 times higher than that of the RT systems. The RT system resulted in 3.7 times higher DMRP loss compared to the PL system. One time manure application in 1992 did not significantly influence the annual runoff, PP, DMRP and TP loss. Manure application significantly reduced rainfall-runoff and sediment loss.

Tillage had no significant influence on grain yield, number of ears, and number of plants at harvest. The RT system resulted in a significantly higher grain moisture content. Manure application significantly influenced grain yield although did not significantly influence grain moisture, number of ears, or number of plants at harvest. There was no significant difference in earleaf-P concentration.
In Rt plots, manure application resulted in increased yield of 1.1 Mg ha-1, whereas in the PL system, manure application resulted in no grain yield increase. Tillage systems were not significantly different in grain-P uptake and grain-P concentration. Manure application significantly resulted in greater grain-P uptake, grain P concentration and grain yield. Differences in grain-P Uptake and concentration was in part due to the increase of soil-P with manure application.

Introduction

Importance of agriculture as non-point source of pollutants lies in the significant association between sediment or total phosphorus increases in natural water bodies and various measures of agricultural land use. Sediment is the most visible of agriculturally derived pollutants. Sediments not only contribute to costly dredging requirements at lake, ports and marinas but also carry sediment-bound pollutants, such as particulate P, to surface waters such as lakes. Researchers indicated that for water quality management adoption of conservation tillage reduces sediment and P loading to surface water. There is considerable concern regarding the contamination of surface waters from land applied manure phosphorus. The concern over phosphorus with respect to water quality is focused with stimulation of algae and other aquatic plant growth due to phosphorus eutrophication. For most water bodies, phosphorus is the key limiting nutrient for aquatic plant growth. Since, focusing only on total phosphorus for eutrophication control could result in no improvement in water quality, It is recommended that eutrophication control measures be directed toward controlling algal available P. Long term studies showed that reducing sediments will not necessarily lead to a reduction in phosphorus eutrophication.

In Minnesota, the problem of non-point source pollution in the Minnesota River Basin is confounded by the extensive hog, dairy and poultry farming in the area. Manure application to land is a regular management practice for crop production in the Minnesota River Basin. 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 erosive losses of sediment and phosphorus. The objectives of the study are:

1. To evaluate the effects of moldboard vs. ridge tillage in combination with and without manure application on phosphorus and sediment loss in surface runoff both during frozen and unfrozen periods.

2. To evaluate the effects of manure residue on the yield and plant P-uptake.

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Materials and Methods

Tillage and manure interactions on sediment and phosphorus transport in surface runoff are being evaluated in the field at Morris, MN. Soil at the experimental site is a Barnes loam (fine-loamy mixed Udic Haploboroll, 12 % slope with south-eastern aspect). The initial soil test in 1992 for pH, Olson-P, Bray-P and ammonium acetate extractable K were 8.0, 17 ppm, 23 ppm and 155 ppm respectively.

The experimental design is a randomized complete block with split plots three replications (tillage main plots and manure the subplots). Twelve erosion plots, 22 m by 3 m (to accommodate four rows of corn) were marked and isolated using corrugated steel plates. At the end of each plot the runoff was routed with a trough made of a polyvinyl chloride (PVC) sheet (3 m by .3 m) and then channeled through a PVC pipe to a collecting system. The collecting system consists of three barrels of 210 L each. The first barrel collects very coarse sediments. The overflow from the first barrel is 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.

Tillage treatments include ridge tillage and moldboard plowing systems. Moldboard plowing practically allows complete soil incorporation of manure. In the moldboard system, fall moldboard plowing was followed in the spring by a field cultivation prior to planting. Ridge tillage represents an intermediate level of soil incorporation. Plant residue were concentrated between plant rows during winter and spring. Ridging was done on 24 June. Detailed cultural practices are presented in Table 1.

Manure treatments are with and without. Solid beef manure was applied once at the rate of 56 ton/ha in the spring of 1992. The manure contained approximately 161 kg TP/ha which contained 64 kg inorganic P/ha.

The runoff volume in each barrel was measured using a calibrated dip stick. After volume measurement, the runoff suspension was thoroughly stirred and samples were taken for sediment and phosphorus measurements. Sediments were measured by evaporating 200 mL of suspension followed by drying at 105 C. For each treatment sediment measurements were done in duplicate.

Total phosphorus was measured using perchloric acid digestion as described in EPA standard procedure (US EPA, 1981). For total P analysis 20 mL of suspension was pipetted while magnetically stirred to obtain a well mixed sample.

Dissolved molybdate reactive soluble phosphorus (DMRP) was measured from the solution after separation of solid phase from the runoff suspension. Total phosphorus and DMRP were determined with ascorbic acid method of Murphy and Riley (1962). Phase separation in DMRP analysis was achieved with centrifugation at 15,000 rpm (22,700 x g) for 5 minutes (10 minutes total time) at 25 °C.

Corn was planted on the twelve erosion plots at the seeding rate of 79,000 seeds/ha. Seeding was done up and down the slope. After planting, soil sample for determination of soil-P soluble in sodium bicarbonate (Olson-P) was taken at 0-5, 5-10, 10-15 cm depth. Olson-P analytical procedures was described in Olsen and Sommer (1982). Chemicals used for weed control are listed in Table 1. Grain and stover yield was measured. Corn ears, grain yield (after drying at 60 °C) and corn stands at harvest were estimated from rows of 15 m long. Stover yield was estimated by harvesting randomly 10 corn plants. The plants were chopped above the ground, shredded and a sample was taken for moisture determination. Determination of TP concentration in grain and stover involved digesting sample with perchloric acid (Olsen and Sommers, 1982) and measuring the intensity of blue molybdate as a coloring agent at wave length of 882 nm after ascorbic acid addition (Murphy and Riley, 1962).

Table 1. Cultural practices at the West Central Agricultural Experimental Station, Morris, MN.

Tillage

1992 No-till
Ridge till (July 21, 1992)
Spring moldboard (May 6, 1992) -
1993 Fall Moldboard (Oct 27, 1992)
Spring Moldboard(Apr. 28, 1993)
Ridge till (July 6, 1993)
1994 Fall Moldboard (Oct. 27, 1993)
Spring Moldboard (Apr. 28, 1994)
Ridge tillage (June 24, 1994)

Cropping History

1991-Alfalfa
1992-Corn Pioneer-3751
-Corn Pioneer-3617
-Corn Pioneer-3921
1993-Corn Pioneer-3751
1994-Corn Pioneer-3751

Planting and Harvest Dates

Corn - was planted with a Hiniker 4 row planter with 76 cm row spacing.
In 1992, corn was replanted due to plant damage from gophers, using an Almaco Planter

Crop	Planting/Replanting Date	Planting/Replanting Rate	Harvested
Corn	May 7,1992	79,072 seeds/ha	Oct. 23, 1992 Corn was chopped, and left on field
	May 29, 1992	98,840 seeds/ha	
	June 15, 1992	148,260 seeds/ha	
	April 29, 1993	79,319 seeds/ha	Oct. 13, 1993 Two rows of 30 feet long each.
	May 5, 1994	79,000 seeds/ha	Oct. 11, 1994 Two rows of 25 feet long each.

1992 Applied-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	available N	Total N	Total P205	Total K20	DMRP
			kg/ha								
Beef	56 Mg/ha	May 6/92	120.4	2.8	123.2	358.4	212.8	481.6	370.7	374.1	63.7

It is assumed that 25 % of organic N and all of mineral N is available in the year of application.

1993

No manure is applied.
Non-manure plots received a topdress application of 50.4 kg N/ha (NH_4NO_3) in 7/6/93.

1994

No manure was applied
The manured and non-manured moldboard plowed plots received 111 and 134 kg N/ha, respectively (6/6/94).
The manured and non-manured ridge tilled plots received 134 and 157 kg N/ha, respectively (6/6/94).

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.

Pest Control

1992
Lorsban 15G , 11.1 kg/ha (May 7, 1992)
Ranger 1.1 kg/ha+2,4-D ester 0.6 kg/ha+Banvel 0.3 lb/A+Lasso EC 4.5 kg/ha+Bladex DF (90%) 2.5 kg/ha (5/8/92)
Ranger 1.1 kg/ha only on no till plot to kill grasses and alfalfa (5/22/92)

1993
Round-up, 2.5 L/ha on ridge till for controlling volunteer alfalfa (4/21/93)
Counter 15 G 11.1 kg/ha over the furrow at seeding (4/29/93)
Lasso 4.5 kg/ha + Bladex 2.5 kg/ha to control volunteer alfalfa + Separate application of Round-up 2.47 L/ha (4/30/93)
Atrazine 0.84 lb/A for post emergence quack grass control (5/20/93)

1994
Round-up, 3.5 L/ha on ridge till for controlling quackgrass (4/22/94)
Force 15 G, 11 kg/ha for insect control (5 May, 1994)
Lasso 3.4 kg/ha + Bladex 2.5 kg/ha + Round-up (2.3 kg/ha) as tank mix for preemergent herbicide (May 6, 1994).
Atrazine 2.2 kg/ha + Buctril 1.2 L/ha and vegetable oil as tank mix for post-emergent weed control (June 1, 1994)

Results and Discussion-1994

I. Surface Runoff, Erosion and Phosphorus Loss.

Ridge Till (RT) vs. Moldboard Plow (PL)

The annual runoff was not different between RT or PL system (Table 2). For the RT system, snowmelt-runoff was the predominant source of the annual runoff; On the contrary, for the PL system, rainfall-runoff was the predominant source of the annual runoff (Figure 1). Greater snow runoff in RT system was due to greater snow depth trapped by standing corn residue and lack of surface depressional storage in RT system. Water depth equivalence of snow in RT and PL systems was 9.9 and 5.9 cm, respectively.

Contribution of snow sediment loss to the annual sediment loss was negligible (Figure 1). Therefore the annual sediment loss was mainly from rainfall-runoff. The PL systems resulted in 11.8 times higher sediment loss compared to RT system (Table 2). The rainfall-runoff sediment loss from two sequential rain events in early spring contributed the most to the annual sediment loss (Figure 1). At these events, no crop was grown, and surface residue cover was low in the PL system. In the RT system, the presence of residue cover increased infiltration, and protected the soil against soil detachment and thus reduced soil erosion significantly. Although a heavier rainfall (10.3 cm 24 hour rainfall) occurs in July 5, only a slight increase of sediment loss was observed both in RT and PL system. At this stage, corn canopy cover reduced rainfall impacts on soil erosion. In this particular event, the RT system resulted in significantly lower sediment loss compared to the PL system.

Total phoshorus (TP) in runoff suspension consists of sediment associated phosphorus, soluble organic phosphorus and soluble inorganic phosphorus. The soluble inorganic phosphorus that is usually detected with ammonium molybdate is referred to as dissolved molybdate reactive phosphorus (DMRP). The difference of TP and DMRP is called particulate phosphorus (PP). The DMRP is for the most part bioavailable for algal growth. Whereas the PP, which consisted of the sediment associated phosphorus and organic material in runoff, may constitute a long term source of potentially bioavailable in lakes (Sharpley et al., 1991).

Annual total phosphorus (TP) loss was higher in PL system compared to RT systems. The annual TP loss in the PL systems was 1.9 times higher than TP from RT systems (Table 2). For the RT system, TP from snowmelt-runoff was the predominant source of TP loss. On the contrary, for the PL system, erosion was the predominant source of TP loss, and the annual TP loss was solely due to the rain occurred in early spring (Figure 2).

Annual particulate-P (PP) was significantly influenced by tillage (Table 2). Particulate-P from PL plots was 3.9 times higher than that of the RT plots which was mainly due to the two rainfall events in early spring (Figure 2). In the RT system, snowmelt-runoff was the predominant source of PP loss, whereas in the PL plots, rainfall-runoff was the predominant source of PP loss. The significance of PP loss from snowmelt in RT system were over shadowed by two early spring rainfall-runoff events in the PL system (Figure 2).

Tillage significantly influence annual dissolved molybdate reactive P (DMRP) loss. The RT systems resulted in 3.7 times higher DMRP loss compared to PL system (Table 2). In RT system, 54 percent of TP was

DMRP. In PL system, 8 percent of TP was DMRP. This indicated that DMRP in RT system, which is mainly from snowmelt, was a significant portion of annual TP. For the RT system, the majority of the annual DMRP loss occurred during the snowmelt-runoff whereas for PL system, DMRP loss was similar during the snowmelt-runoff and rainfall-runoff events (Figure 2). This comparison showed that the DMRP from rainfall was not significant compared to snowmelts, regardless of the major rainfall-runoff and erosion in early spring.

No Manure vs. Manure

Manure application did not significantly influence the annual runoff, PP, DMRP and TP loss (Table 2). Manure application did not influence PP or TP loss in snowmelt-runoff or rainfall-runoff (Figure 4). The significance of manure application was observed mainly on individual rainfall-runoff events. Differences of snowmelt-runoff were overshadowed by two rainfall runoff events in non-manured plots (Figure 3). Manure application significantly reduced rainfall-runoff and sediment loss, although did not significantly reduced the annual sediment loss. However, during major runoff events, manured plots resulted significantly less erosion (Figure 3).

II. Corn Yield

In 1994 rainfall was better distributed during the growing season. Tillage had no significant influence on grain yield, number of ears, and number of plants at harvest. The RT systems resulted in a significantly higher grain moisture content. Manure application significantly influenced grain yield although it did not significantly influence grain moisture, number of ears, or number of plants at harvest. During the growing season, it was qualitatively observed that manured plots resulted in greater plant height. This observation encouraged an earleaf sampling for TP determination. However, there was no significant difference in earleaf-P concentration (Table 3).

There was a significant tillage by manure interaction on grain yield (Table 3). In Rt plots, manure application resulted in increased yield of 1.1 Mg ha-1, whereas in the PL system, manure application resulted in no grain yield increase. The tillage by manure interaction was also significant for stover yield. In the RT system, greater grain yield with manure application resulted in the 0.7 mg ha^{-1} reduction of stover yield whereas in the PL system, lower grain yield with manure application resulted in 0.5 Mg ha^{-1} increase of stover yield. Differences in grain yield due to manure application was in part due to soil-P. In both the RT and PL systems, manure application resulted in significantly soil-P test. Soil was sampled after planting, taken between plant rows in 0-5, 5-10 and 10-15 cm deep. The average soil test is presented in Table 4.

Phosphorus Uptake in Grain and Stover

Tillage systems were not significantly different in grain-P uptake and grain-P concentration (Table 3). Lack of significance in grain yield and grain P concentration due to tillage resulted in insignificant differences in grain P uptake. Stover-P uptake and stover P concentration, however, was significantly influenced by tillage, although stover yield was not influenced by tillage. Therefore greater stover-P uptake was mainly due to greater stover-P concentration in the RT system. Greater stover-P concentration was in part due to soil-P test. Tillage system significantly influenced soil test. Soil test in RT plots was 24.5 mg P kg^{-1} compare to 12.7 mg P kg^{-1} in PL plots.

Manure application significantly resulted in greater grain-P uptake, grain P concentration and grain yield. Both greater yield and greater P concentration in grain resulted in greater P uptake in manured plots (Table 3). However, there was no manure influence on stover-P uptake and stover P concentration. There was no tillage by manure interaction for P uptake in grain and stover.

Table 2. The effects of tillage and manure application on the geometric means† of snowmelt, rainfall, and the annual losses of runoff, sediment, and phosphorus (2/22/94 (spring thaw) to 8/24/94).

	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											
Runoff (mm)	23.9	32.9	28.0	10.1	17.8	13.4	15.5	24.2	0.310	0.561	0.868
Sediment (kg/ha)	43.6	46.5	45.0	22.7	36.6	28.4	31.4	40.7	0.091	0.686	0.759
Total-P (g/ha)	159	284	212	30	60	43	120	142	0.044	0.408	0.954
PP (g/ha)	69.6	62.2	71.6	13.8	20.7	17.2	30.9	37.2	0.094	0.323	0.528
DMRP (g/ha)	89	222	141	17	39	26	39	93	0.042	0.250	0.954
Rain-Runoff											
Runoff (mm)	8.5	7.6	8.0	30.1	21.8	25.6	16.0	12.8	0.008	0.061	0.294
Sediment (kg/ha)	107	90	98	2512	1238	1763	518	334	0.002	0.095	0.256
Total-P (g/ha)	99	117	108	818	564	680	285	260	0.016	0.709	0.355
PP (g/ha)	62	65	64	789	538	652	252	220	0.008	0.538	0.473
DMRP (g/ha)	36.7	51.7	43.6	29.1	25.8	27.4	32.7	36.5	0.286	0.648	0.359
Annual Runoff											
Runoff (mm)	39.4	42.2	40.8	41.2	39.9	40.7	40.3	41.1	0.988	0.970	0.919
Sediment (kg/ha)	162	142	152	2536	1275	1798	640	425	0.004	0.233	0.391
Total-P (g/ha)	307	458	375	850	627	730	511	536	0.105	0.915	0.450
PP (g/ha)	165	169	172	804	561	675	429	398	0.018	0.415	0.686
DMRP (g/ha)	142	290	203	47	65	55	82	138	0.065	0.345	0.715

† Logarithmic transformation on the data is done to meet the normal distribution in statistical analysis.

Table 3. The effects of tillage and manure application on corn yield and phosphorus concentration and uptake at the West Central Experiment Station, Morris, MN, 1994.

	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											
Grain (Mg/ha)	9.2	10.2	9.7	9.5	9.3	9.4	9.3	9.8	0.217	0.061	0.017
Ears (1000/ha)	68.0	72.3	70.2	74.6	70.6	72.6	71.3	71.5	0.271	0.956	0.164
Plants (1000/ha)	67.2	70.9	69.0	72.3	70.6	71.5	69.8	70.8	0.432	0.802	0.508
Grain Moisture (%)	24.9	24.2	24.6	21.2	19.6	20.4	23.1	21.9	0.038	0.718	0.518
Stover (Mg/ha)	7.0	6.3	6.7	6.5	7.0	6.7	6.7	6.6	0.481	0.606	0.019
P- Concentration and Uptake											
Earleaf Conc. (g/kg)	0.88	1.00	0.94	0.99	1.10	1.04	0.93	1.05	0.610	0.357	0.937
Grain-P Uptake (kg/ha)	18.6	24.7	21.7	19.0	22.3	20.6	18.8	23.5	0.395	0.019	0.307
Grain-P Conc. (g/kg)	2.02	2.42	2.22	1.98	2.39	2.19	2.00	2.44	0.737	0.017	0.939
Stover-P Uptake (kg/ha)	2.98	2.28	2.63	2.02	2.38	2.17	2.50	2.30	0.040	0.816	0.566
Stover-P Conc. (g/kg)	0.42	0.37	0.39	0.31	0.34	0.32	0.36	0.35	0.045	0.951	0.742

Table 4. The effects of manure application on soil Olson-P test (May 3, 1994), two years after manure application (May 6, 1992), at the West Central Agric. Exp. Sta. Morris, MN.

Year	Tillage	No Manure mg kg^{-1}	Manure mg kg^{-1}
1994	RT	18.3	30.8
	MB	7.0	16.5

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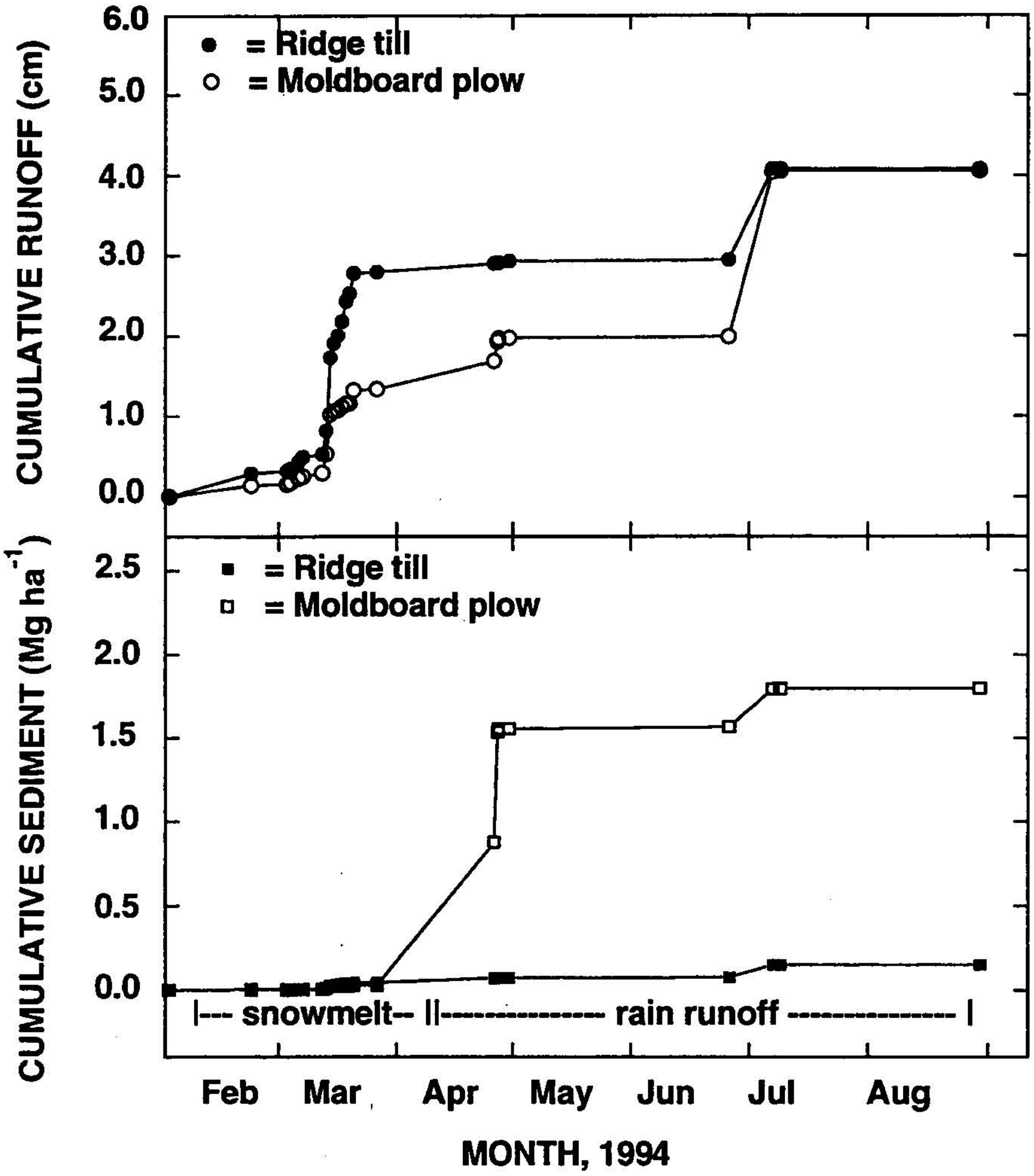

Figure 1. Tillage effects on runoff and sediment loss

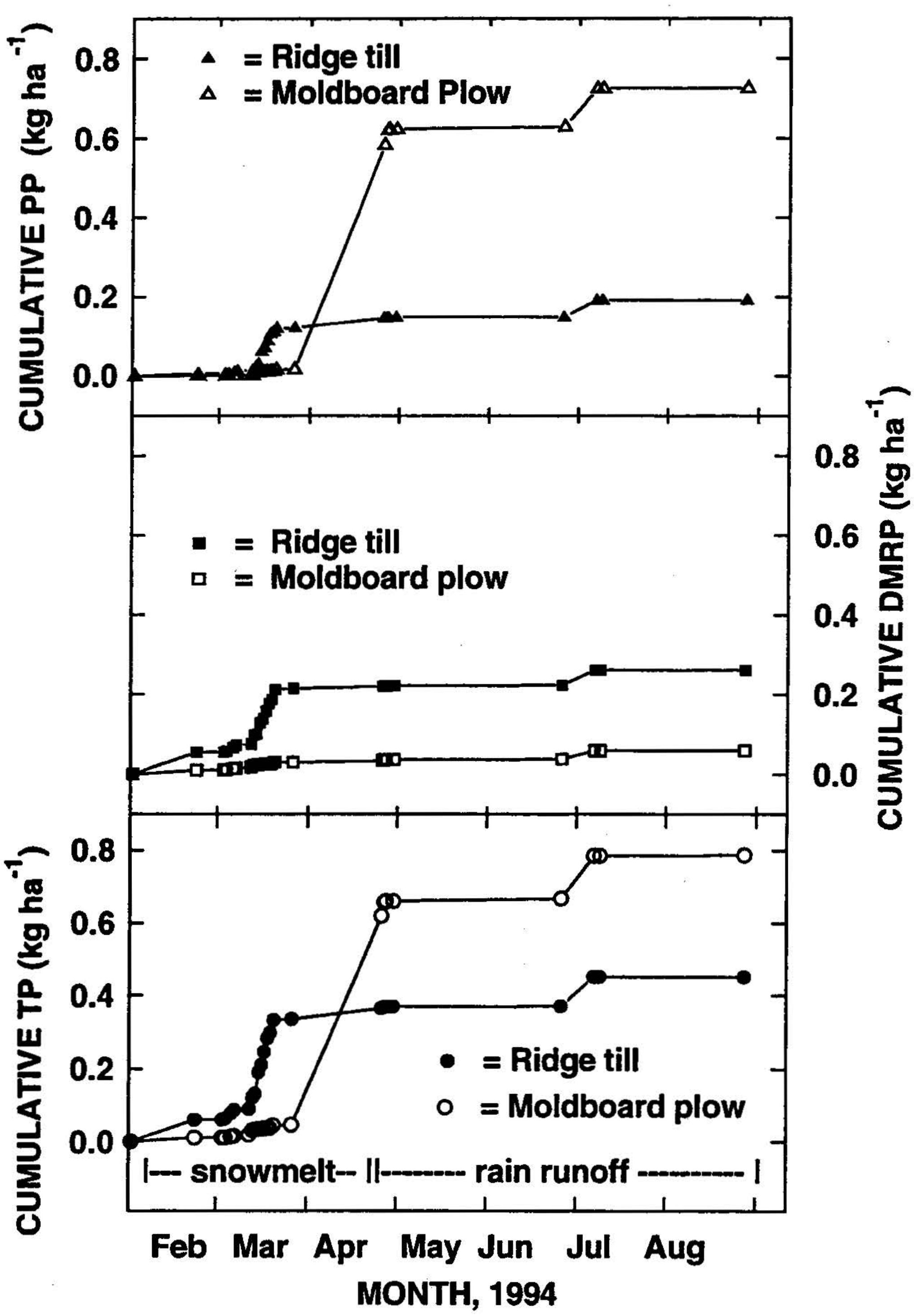

Figure 2. Tillage effects on PP, DMRP and TP

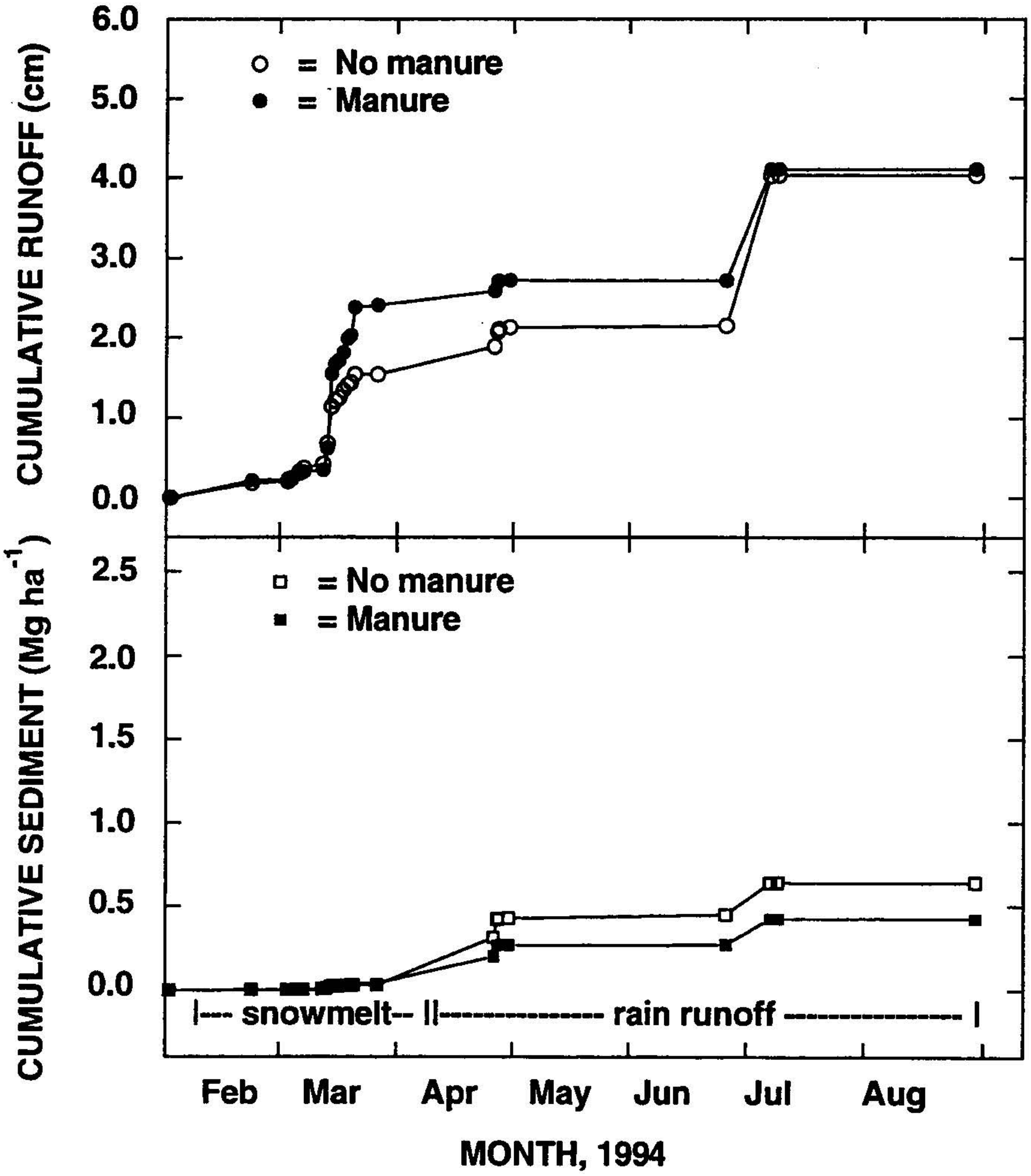

Figure 3. Manure effects on runoff and sediment

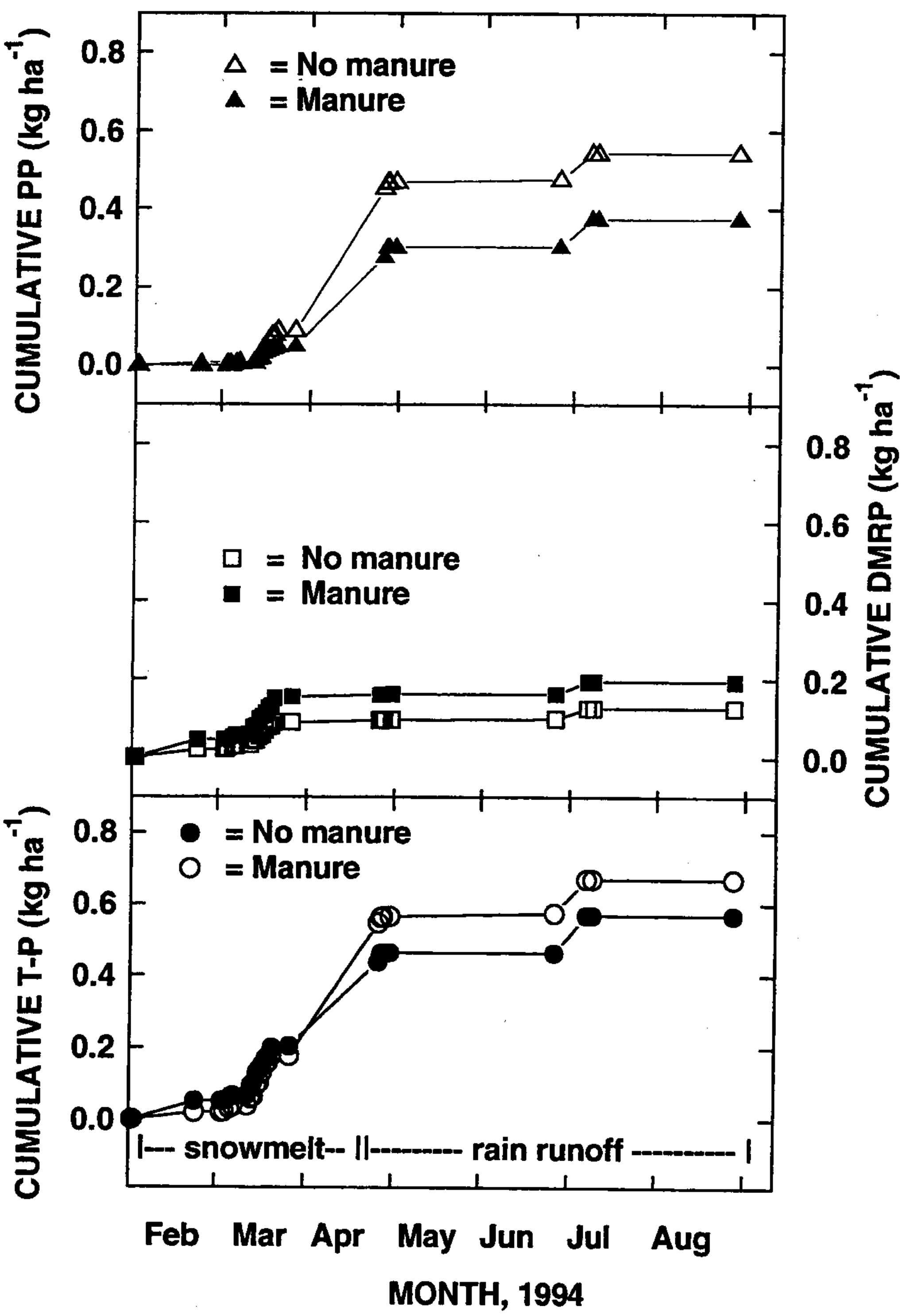

Figure 4. Manure effects on PP, DMRP and TP

CARROT RESPONSE TO FERTILIZER ON AN IRRIGATED SANDY SOIL[1]

Carl Rosen, Norman Krause, Mel Wiens, Gary McVey, Dave Birong, and Shelly Johnson[2]

Abstract: Two fertilizer studies were conducted at Staples to refine fertilizer recommendations for carrot production on sandy soils. Soil K was medium, P was high, B was low, and S was low. Nitrate-N before planting was less than 10 lb/A in the top two feet. Potassium applications of 60 to 120 lb K_2O/A increased carrot diameter, but did not significantly affect total yield. Nitrogen application did not affect total yield, but increasing N rate increased carrot diameter. Carrot dry matter percentage was not affected by K or N fertilizer. Final stand count decreased with increasing N and K fertilizer rates, suggesting that disk incorporation of fertilizer prior to planting is not adequate for fertilizer incorporation. Application of B, P and S fertilizers did not consistently affect carrot yield or quality. Nutrient concentrations in leaves during the growing season and in tops and roots at harvest are presented.

Carrot production in northern Minnesota has increased substantially in the past five years. In part, this increased production has occurred in response to an increased demand by a processing plant for dehydrated carrots. While dehydration has spurred interest in processing carrots, there is also interest in growing carrots for other types of processing, as well as for fresh market. The soils of central Minnesota tend to be coarse-textured and require irrigation for production of specialty crops such as carrot. The main advantage of these soils is that they tend to warm up faster in the spring, which enables earlier planting and an earlier maturing crop. Growing carrots on these soils would provide a longer season for processing and would also allow carrots to be marketed earlier. There has been very little research that defines the nutrient requirements of carrots grown on coarse-textured soils. Too little fertilizer applied will negatively affect yields, while excessive rates applied can potentially lead to poor carrot quality and environmental degradation. One of the fundamental needs for successful carrot production in central Minnesota is to determine nutrient input requirements for a high quality product. The objectives of this research were to: 1) Determine potassium (K) requirements of carrots on low to medium testing K soils. 2) Characterize carrot response to nitrogen (N) application in terms of quality and dry matter production. 3) Determine boron (B), phosphorus (P), and sulfur (S) needs for carrot production.

Procedures

Two carrot fertility experiments were conducted at Staples during the 1994 growing season. The soil is a Verndale sandy loam with an organic matter content of 2 to 3%. The first study evaluated carrot response to K fertilizer. A second study evaluated carrot response to N, P, S and B fertilizer. For the K experiment, the previous crop was corn and selected soil chemical properties were as follows: pH, 7.1; Bray P, 43 ppm; K, 61 ppm. For the N, P, B and S experiment, the previous crop was small grains and selected soil chemical properties (0-6") were as follows: pH, 6.9; Bray P, 52 ppm; K, 82 ppm; S, 2 ppm; B, 0.3 ppm. For the N,P,B,S study, extractable nitrate-N levels in the 0-1 and 1-2 ft depths were 7.8 and 2.3 lbs/A, respectively.

For the two experiments, the following fertilizer treatments were evaluated:

K_2O Experiment — Fertilizer Treatment

#	N	P_2O_5	K_2O
	lb/A		
1.	120	50	0
2.	120	50	60
3.	120	50	120
4.	120	50	180
5.	120	50	240

N, P_2O_5, B & S Experiment — Fertilizer Treatment

#	N	P_2O_5	K_2O	B	S
	lb/A				
1.	0	50	150	0	0
2.	60	50	150	0	0
3.	120	50	150	0	0
4.	180	50	150	0	0
5.	240	50	150	0	0
6.	120	0	150	0	0
7.	120	25	150	0	0
8.	120	50	150	2	0
9.	120	50	150	0	30
10.	120	50	150	2	30

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For the K experiment, half the N (urea) and all the P (0-46-0) and K (0-0-60) fertilizer were broadcast and incorporated by disking on May 3, 1994. The remainder of the N was sidedressed on June 27. For the N, P, B and S experiment, all phosphorus (0-46-0), potassium (0-0-60), boron (solubor) and sulfur (ammonium sulfate) applications were broadcast and incorporated by disking on May 3, 1994. Half the nitrogen (urea) was applied on May 3 and the remainder was sidedressed on June 27. Some urea was eliminated from the sulfur treatment to compensate for the N added with ammonium sulfate. Carrots were planted on May 4, 1994. Each plot consisted of 8 rows 22" apart. The population was originally set to be at 15 plants per foot; however, final plant population was measured at 4 to 7 plants per foot. The planting depth was 0.75". The variety used was 'Legend'. Each treatment was replicated four times. Recently matured leaf samples were collected on July 8 for nutrient analyses. For both experiments, two 10 foot sections of row were harvested from each plot (August 25 for N, P, B and S; September 1 for K). Top and root weight were recorded and subsamples were taken for dry matter determination and nutrient analyses. Soil samples were collected from the 0-1 and 1-2 ft depths in N treatments following harvest to determine residual soil nitrate.

Results

I. Potassium study

Yield and stand: Potassium fertilizer tended to increase yield of the larger diameter carrots (Table 1). Total yield was not significantly affected by K fertilizer application although there was a trend for increasing yield with 60 to 120 lb K_2O/A. Final stand count tended to decrease with increasing K application, suggesting that increased salt from the fertilizer damaged seed emergence. Disking of the fertilizer may not be adequate incorporation. Root dry matter percentage was not significantly affected by K fertilizer.

Tissue nutrient concentrations: Increasing K fertilizer increased K concentrations in leaves sampled in July (Table 2). Leaf concentrations N and Mg tended to decrease with K fertilizer application. At harvest, concentrations of K in root and tops increased with increasing K application (Tables 3 and 4). Approximately 0.37 lb/cwt is removed in the carrot root. A typical carrot harvest of 400 cwt/A would contain about 150 lb K/A and in the roots and 40 lb K/A in the tops. To convert to K_2O, these values should be multiplied by 1.2.

II. N, P, B and S study

Yield and stand: Increasing N fertilizer increased carrot size but had no effect on total yield (Table 5). As in the K study, fertilizer application tended to decrease final stand count, suggesting that disk incorporation is not adequate. Because of decreasing stand count with increasing N fertilizer, it is not possible to determine whether increased carrot size was due to N fertilizer or lower plant populations. Application of P, B, and S either had no effect or inconsistent effect on yield. Root dry matter percentage was also not consistently affected by fertilizer treatment.

Tissue nutrient concentrations: Increasing rates of N, P, B and S fertilizer had minimal effects on concentrations of these nutrients in carrot leaves sampled in July (Table 6). At harvest, however, concentrations N, P and S increased with corresponding increases in fertilizer application (Table 7). Increasing N rate increased N concentrations in carrot roots (Table 8). Application of P and K fertilizer had no effect on P and K concentrations in carrot roots. Boron at 2 lb B/A had no effect on B concentrations of tops or roots at harvest. A typical carrot harvest of 400 cwt/A would contain about 70 lb N/A in the roots and 40 lb N/A in the tops.

Table 1. Effect of potash fertility treatments on carrot yield and quality; harvested September 1, 1994.

Fertilizer Treatment #	N	P_2O_5	K_2O	Forks, Culls	Root Diameter <⅞"	Root Diameter ⅞ to 1¾"	Root Diameter >1¾"	Total Yield	Dry Matter Root	Dry Matter Roots	Dry Matter Tops	Dry Matter Total	Carrot population
	lb/A	lb/A	lb/A	cwt/A	cwt/A	cwt/A	cwt/A	cwt/A	%	Tons/Acre	Tons/Acre	Tons/Acre	plants/ft
1.	120	50	0	43.9	14.5	241.2	80.0	379.6	12.6	2.4	1.6	4.0	7.54
2.	120	50	60	48.1	11.2	219.8	132.4	411.5	13.2	2.7	1.2	3.9	6.63
3.	120	50	120	44.9	13.8	214.0	155.0	427.7	13.1	2.8	1.2	4.0	6.94
4.	120	50	180	58.0	13.7	228.4	129.8	429.9	12.5	2.7	1.2	3.9	6.74
5.	120	50	240	43.1	12.0	216.2	154.6	425.9	12.7	2.7	1.2	3.9	6.13
Significance				NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
BLSD (5%)				--	--	--	--	--	--	--	--	--	--
Contrasts													
Lin Rate K				NS	NS	NS	++	NS	NS	NS	NS	NS	++
Quad Rate K				NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS = Not significant; ++ = significant at the 10% level.

Table 2. Effect of potash fertility treatments on the nutrient concentrations of carrot leaves; sampled July 8, 1994.

Fertilizer Treatment #	N	P_2O_5	K_2O	N	P	K	Ca	Mg	Fe	Mn	Cu	Zn	B
	lb/A	lb/A	lb/A	%	%	%	%	%	ppm	ppm	ppm	ppm	ppm
1.	120	50	0	3.63	0.49	3.03	1.35	0.34	196	41	7	31	28
2.	120	50	60	3.46	0.50	3.58	1.27	0.31	190	40	7	30	28
3.	120	50	120	3.43	0.51	3.57	1.28	0.30	180	41	7	31	30
4.	120	50	180	3.43	0.52	3.75	1.30	0.30	172	39	7	32	28
5.	120	50	240	3.34	0.51	3.85	1.31	0.30	190	39	7	30	29
Significance				NS	NS	**	NS	*	NS	NS	NS	NS	NS
BLSD (5%)				--	--	0.38	--	0.03	--	--	--	--	--
Contrasts													
Lin Rate K				*	NS	**	NS	*	NS	NS	NS	NS	NS
Quad Rate K				NS	NS	NS	NS	++	NS	NS	NS	NS	NS

NS = Not significant; **, *, ++ = significant at the 1%, 5% and 10% level, respectively.

Table 3. Effect of potash fertility treatments on the nutrient concentrations of carrot tops; sampled September 1, 1994.

Fertilizer Treatment #	N	P_2O_5	K_2O	N	P	K	Ca	Mg	Fe	Mn	Cu	Zn	B
	lb/A	lb/A	lb/A	%	%	%	%	%	ppm	ppm	ppm	ppm	ppm
1.	120	50	0	1.85	0.29	1.23	2.66	0.53	1266	129	5	21	28
2.	120	50	60	1.69	0.31	1.53	3.00	0.57	929	107	5	20	33
3.	120	50	120	1.90	0.30	1.70	3.23	0.55	867	106	5	20	31
4.	120	50	180	1.88	0.27	1.83	2.88	0.50	957	106	5	19	27
5.	120	50	240	1.71	0.29	2.01	2.76	0.46	1244	129	5	22	30
Significance				NS	NS	NS	++	NS	NS	NS	NS	NS	++
BLSD (5%)				--	--	--	0.48	--	--	--	--	--	4
Contrasts													
Lin Rate K				NS	NS	*	NS	++	NS	NS	NS	NS	NS
Quad Rate K				NS	NS	NS	*	NS	++	NS	NS	NS	NS

NS = Not significant; *, ++ = significant at the 5% and 10% level, respectively.

Table 4. Effect of potash fertility treatments on the nutrient concentrations of carrot roots; sampled September 1, 1994.

Fertilizer Treatment				Nutrient									
#	N	P_2O_5	K_2O	N	P	K	Ca	Mg	Fe	Mn	Cu	Zn	B
	---- lb/A ----			------------ % ------------					----------- ppm -----------				
1.	120	50	0	1.44	0.43	2.06	0.39	0.15	37	11	4	19	20
2.	120	50	60	1.29	0.40	2.31	0.39	0.15	57	10	4	17	19
3.	120	50	120	1.37	0.44	2.66	0.40	0.14	36	10	5	19	19
4.	120	50	180	1.35	0.42	2.72	0.41	0.15	40	11	4	18	19
5.	120	50	240	1.27	0.40	2.68	0.40	0.13	35	10	4	18	19
Significance				NS	NS	*	NS	NS	NS	NS	NS	NS	NS
BLSD (5%)				--	--	0.55	--	--	--	--	--	--	--
Contrasts													
Lin Rate K				NS	NS	**	NS	NS	NS	NS	NS	NS	NS
Quad Rate K				NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS = Not significant; **, * = significant at the 1% and 5% level, respectively.

Table 5. Effect of various fertility treatments on carrot yield and quality; harvested August 25, 1994.

Fertilizer Treatment				Forks, Culls	--- Root Diameter ---			Total Yield	Dry Matter Root	--- Dry Matter ---			Carrot population
#	N	P_2O_5	K_2O		<1¼"	1¼ to 2½"	>2½"			Roots	Tops	Total	
	--- lb/A ---			---------------- cwt/A ----------------					%	--- Tons/Acre ---			plants/ft
1.	0	50	150	29.2	135.7	176.0	0.0	340.8	12.1	2.1	0.8	2.9	6.28
2.	60	50	150	13.9	113.1	181.5	5.7	314.3	11.8	1.8	0.8	2.6	4.79
3.	120	50	150	34.2	94.6	203.0	2.2	334.0	11.5	1.9	0.9	2.8	5.11
4.	180	50	150	22.9	62.2	201.6	14.5	301.2	12.5	1.9	0.8	2.7	3.89
5.	240	50	150	27.6	90.6	225.3	8.4	351.9	12.2	2.2	1.0	3.2	4.80
6.	120	0	150	24.6	97.1	195.0	8.9	325.5	11.7	1.9	0.9	2.8	4.94
7.	120	25	150	27.3	89.0	234.7	14.2	365.2	12.0	2.2	1.1	3.3	4.65
8.	120	50	150 +B	33.0	95.9	213.6	9.1	351.7	12.5	2.2	1.0	3.2	4.85
9.	120	50	150 +S	39.6	90.6	242.2	8.7	381.1	12.1	2.3	1.2	3.5	5.36
10.	120	50	150 +B,S	17.9	103.2	203.1	8.6	332.8	13.1	2.1	0.9	3.0	4.76
Significance				++	NS	NS	NS	NS	NS	++	**	*	++
BLSD (5%)				18.9	--	--	--	--	--	0.4	0.2	0.5	1.47
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 P (6,7,3)				++	NS	NS	NS	NS	NS	NS	NS	NS	NS
Quad Rate P (6,7,3)				NS	NS	NS	NS	NS	NS	++	NS	*	NS
0 vs 50 P (6,4)				NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
0 vs Boron (3,8)				NS	NS	NS	NS	NS	NS	++	NS	NS	NS
0 vs Sulfur (3,9)				NS	NS	NS	NS	++	NS	*	*	**	NS
0 vs B+S (3,10)				*	NS	NS	NS	NS	*	NS	NS	NS	NS

NS = Not significant; **, *, ++ = significant at the 1%, 5% and 10% level, respectively.

Table 6. Effect of various fertility treatments on nutrient concentrations of carrot leaves; sampled July 8, 1994.

Fertilizer Treatment				Nutrient										
#	N	P_2O_5	K_2O	N	P	K	Ca	Mg	S	Fe	Mn	Cu	Zn	B
	--- lb/A ---			%						ppm				
1.	0	50	150	3.08	0.49	3.95	1.44	0.26	--	205	43	6	37	31
2.	60	50	150	3.21	0.46	3.81	1.38	0.25	--	195	49	5	36	27
3.	120	50	150	3.35	0.49	3.76	1.36	0.26	0.34	189	45	5	37	28
4.	180	50	150	3.23	0.47	4.04	1.33	0.25	--	185	45	5	38	29
5.	240	50	150	3.21	0.48	3.95	1.40	0.25	--	181	46	5	37	28
6.	120	0	150	3.28	0.48	3.96	1.32	0.24	--	173	44	5	38	28
7.	120	25	150	3.42	0.48	3.67	1.39	0.28	--	209	46	5	36	28
8.	120	50	150 +B	3.32	0.47	3.82	1.39	0.27	--	200	44	4	37	30
9.	120	50	150 +S	3.31	0.46	3.80	1.36	0.25	0.36	189	44	5	35	27
10.	120	50	150 +B,S	3.25	0.49	3.87	1.28	0.24	0.36	202	45	5	39	31
Significance				NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*
BLSD (5%)				--	--	--	--	--	--	--	--	--	--	3
Contrasts														
Lin Rate N (1,2,3,4,5)				NS	NS	NS	NS	NS	--	++	NS	NS	NS	++
Quad Rate N (1,2,3,4,5)				++	NS	NS	NS	NS	--	NS	NS	NS	NS	++
Lin Rate P (6,7,3)				NS	NS	NS	NS	NS	--	NS	NS	NS	NS	NS
Quad Rate P (6,7,3)				NS	NS	NS	NS	*	--	++	NS	NS	NS	NS
0 vs 50 P (6,4)				NS	NS	NS	NS	NS	--	NS	NS	NS	NS	NS
0 vs Boron (3,8)				NS	NS	NS	NS	NS	--	NS	NS	NS	NS	NS
0 vs Sulfur (3,9)				NS	NS	NS	NS	NS	++	NS	NS	NS	NS	NS
0 vs B+S (3,10)				NS	NS	NS	NS	NS	++	NS	NS	NS	NS	++

NS = Not significant; *, ++ = significant at the 5% and 10% level, respectively.

Table 7. Effect of various fertility treatments on nutrient concentrations of carrot tops; sampled August 25, 1994.

Fertilizer Treatment				Nutrient										
#	N	P_2O_5	K_2O	N	P	K	Ca	Mg	S	Fe	Mn	Cu	Zn	B
	--- lb/A ---			%						ppm				
1.	0	50	150	1.64	0.29	2.91	3.59	0.37	--	811	106	5	27	37
2.	60	50	150	1.80	0.24	2.65	3.25	0.42	--	687	101	4	26	33
3.	120	50	150	1.98	0.27	2.66	3.20	0.44	0.26	655	90	5	22	33
4.	180	50	150	2.16	0.26	2.91	3.42	0.43	--	622	99	4	25	32
5.	240	50	150	2.07	0.25	2.85	3.28	0.38	--	595	105	4	25	32
6.	120	0	150	1.97	0.26	2.52	3.31	0.43	--	609	96	5	24	31
7.	120	25	150	2.04	0.27	2.52	3.30	0.45	--	602	89	5	21	32
8.	120	50	150 +B	2.03	0.28	2.61	3.56	0.47	--	540	92	4	26	36
9.	120	50	150 +S	1.98	0.28	2.48	2.94	0.45	0.37	597	84	5	25	31
10.	120	50	150 +B,S	1.94	0.23	2.55	3.26	0.42	0.39	750	109	4	27	34
Significance				*	NS	NS	NS	*	**	NS	NS	NS	NS	NS
BLSD (5%)				0.29	--	--	--	0.07	0.06	--	--	--	--	--
Contrasts														
Lin Rate N (1,2,3,4,5)				**	NS	NS	NS	NS	--	*	NS	NS	NS	*
Quad Rate N (1,2,3,4,5)				NS	NS	NS	NS	**	--	NS	NS	NS	NS	NS
Lin Rate P (6,7,3)				NS	NS	NS	NS	NS	--	NS	NS	NS	NS	NS
Quad Rate P (6,7,3)				NS	NS	NS	NS	NS	--	NS	NS	NS	NS	NS
0 vs 50 P (6,4)				NS	NS	NS	NS	NS	--	NS	NS	++	NS	NS
0 vs Boron (3,8)				NS	NS	NS	NS	NS	--	NS	NS	*	NS	NS
0 vs Sulfur (3,9)				NS	NS	NS	NS	NS	**	NS	NS	++	NS	NS
0 vs B+S (3,10)				NS	++	NS	NS	NS	**	NS	++	*	++	NS

NS = Not significant; **, *, ++ = significant at the 1%, 5% and 10% level, respectively.

Table 8. Effect of various fertility treatments on nutrient concentrations of carrot roots; sampled August 25, 1994.

Fertilizer Treatment #	N	P_2O_5	K_2O	N	P	K	Ca	Mg	S	Fe	Mn	Cu	Zn	B
	--- lb/A ---			---------------- % ----------------						------------- ppm -------------				
1.	0	50	150	1.19	0.42	3.21	0.41	0.13	--	56	15	4	23	20
2.	60	50	150	1.52	0.45	3.45	0.44	0.14	--	43	15	4	25	21
3.	120	50	150	1.48	0.46	3.27	0.44	0.14	0.13	61	15	4	22	20
4.	180	50	150	1.48	0.42	3.11	0.42	0.14	--	53	15	3	25	20
5.	240	50	150	1.61	0.45	3.21	0.42	0.14	--	57	16	4	26	19
6.	120	0	150	1.50	0.44	3.14	0.43	0.15	--	57	16	4	22	21
7.	120	25	150	1.48	0.44	2.95	0.41	0.14	--	59	13	4	21	20
8.	120	50	150 +B	1.37	0.42	2.95	0.38	0.13	--	45	13	3	21	20
9.	120	50	150 +S	1.45	0.42	2.89	0.40	0.14	0.14	43	14	3	23	19
10.	120	50	150 +B,S	1.42	0.41	3.18	0.41	0.14	0.15	49	13	3	22	21
Significance				NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
BLSD (5%)				--	--	--	--	--	--	--	--	--	--	--
Contrasts														
Lin Rate N (1,2,3,4,5)				**	NS	NS	NS	NS	--	NS	NS	NS	NS	NS
Quad Rate N (1,2,3,4,5)				NS	NS	NS	NS	NS	--	NS	NS	NS	NS	NS
Lin Rate P (6,7,3)				NS	NS	NS	NS	NS	--	NS	++	NS	NS	NS
Quad Rate P (6,7,3)				NS	NS	NS	NS	NS	--	NS	*	NS	NS	NS
0 vs 50 P (6,4)				NS	NS	NS	NS	NS	--	NS	NS	NS	NS	NS
0 vs Boron (3,8)				NS	NS	NS	*	NS	--	++	NS	NS	NS	NS
0 vs Sulfur (3,9)				NS	NS	++	NS	NS	NS	++	NS	NS	NS	NS
0 vs B+S (3,10)				NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS = Not significant; **, *, ++ = significant at the 1%, 5% and 10% level, respectively.

Table 9. Effect of nitrogen treatment on residual soil nitrate-N (lbs/A) in the top two feet after carrot harvest.

Fertilizer Treatment #	N	P_2O_5	K_2O	Sample depth (inches) 0 - 12	12 - 24	Total
	--- lb/A ---			------------ lbs nitrate-N/A ------------		
1.	0	50	150	13.67	14.24	27.91
2.	60	50	150	18.16	51.96	70.12
3.	120	50	150	15.23	20.06	35.29
4.	180	50	150	21.84	49.07	70.91
5.	240	50	150	25.46	49.54	75.00
Significance				NS	NS	NS
BLSD (5%)				--	--	--
Contrasts						
Lin Rate N (1,2,3,4,5)				++	NS	NS
Quad Rate N (1,2,3,4,5)				NS	NS	NS

NS = Not significant; ++ = significant at the 10% level.

THE EFFECT OF INOCULATION, N RATE, AND SEED TREATMENT ON RED KIDNEY BEAN (*Phaseolus vulgaris*) YIELDS, STAPLES, MN, 1994[1]

J.F. Moncrief, C.J. Rosen, M.J. Wiens, B. Sheets, B.J. Johnson, and P.M. Bongard[2]

Abstract: Four N rates (27, 77, 127, and 177 pounds per acre) applied as broadcast urea at 3-4 trifoliates, two inoculation treatments (with and without Rhizobium) and two seed treatments (with and without streptomycin) were evaluated on red kidney beans (*Phaseolus vulgaris*) grown under irrigation on a sandy loam soil in north central MN. Yields were in the 3,000 pound per acre range. Bean yields responded over the range in applied N (392 pounds per acre). Inoculation with Rhizobium resulted in a 59 pound per acre yield response. Main effects of seed treatment with streptomycin were not significant although there were significant interactions with N rate and inoculation.

Introduction

Most of the dry edible beans in MN are grown on sandy soils overlying surficial aquifers vulnerable to contamination by nitrate nitrogen. The current N recommendation for kidney beans is 120 pounds per acre usually applied in split applications. One potential method of reducing the cost of production and potential environmental degradation by nitrate loss is by increasing the effectiveness of N fixation. This study was designed to evaluate the interactions between N rate; seed inoculation with Rhizobium; and seed treatment with streptomycin (an antibiotic).

Methods and Materials

The study design was a randomized complete block with two levels of split plots. Main plots were N rate (8 rows wide by 40 feet long), subplots were inoculation (four rows wide), and subsubplots were seed treatment with streptomycin (2 rows wide). There were six replications.

The previous crop was corn which was preceded by potatoes. Tillage was spring moldboard plowing with a plow packer. The soil is a Verndale sandy loam (coarse-loamy mixed, Udic Argiboroll) with a slope of 0 to 2 percent. Irrigation was based on the checkbook method and delivered through a solid set system.

Starter fertilizer (20-5-10-20; N,P,K,S) was applied at 135 pounds per acre with the planter on May 20, 1994. This resulted in 27 pounds N per acre. The main nitrogen application was broadcast applied as urea on 6/16/94 (3-4 trifoliate) at 0, 50, 100, 150 pounds per acre).

The red kidney bean variety was Montcalm (771 beans/pound, 90% germination, planted at 120,000 seeds per acre). An eight row planter with 30" row spacing was used. Four contiguous rows had seed treated with 400 gms of HiStick inoculant per 50 pounds of seed (2×10^9 Rhizobium leguminosarum Biovar. phaseoli per gram) and the other four contiguous rows did not (this treatment is referred to as"inoculation"). Within these four row subplots, two contiguous rows received seed treated with Captan fungicide (N-[(tichloromethyl)thio]-4cyclohexene-1,2-dicarboximide) and Lorsban insecticide (Chlorpyrifos [0,0-Diethyl 0-(3,5,6-Trichloro-2Pyridyl) Phosphorothioate]). This treatment is referred to "untreated seed". The other two rows were treated with Streptomycin Sulfate in addition to Captan and Lorsban. This is treatment is referred to as "seed treatment".

Treflan was applied at 1pt/acre preplant incorporated on 5/18/94. On 5/25 Dual at 2pt/acre was applied preemergence. No insecticides or fungicides were applied after planting. Weed control was excellent and there was very little white mold late in the season. Beans were knifed on 9/15/94 and threshed on 9/20/94. The harvest area was two 40 foot rows. Bean moisture levels were determined with an electrical resistance based meter and by oven drying at 120°F until there was no weight loss. The reported yields were calculated using the oven dry moisture determinations.

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Results and Discussion

The statistically significant main effects on bean moisture were for seed treatment with Streptomycin Sulfate only. Seed treatment reduced oven dried seed moisture by .4%.

Kidney bean yields were affected by N rate and inoculation. There were also interactions between seed treatment and N rate as well as seed treatment and inoculation although the main effects of seed treatment was not statistically significant. Kidney beans responded over the entire range of applied N (392 pounds per acre). There was a 59 pound per acre response to inoculation. It did not interact with N rate however.

The interaction between seed treatment and N rate and inoculation are shown at the bottom of table 1. The greatest response to seed treatment was at the 127 pounds N per acre rate. There was a response to inoculation and seed treatment alone or in combination. If neither seed treatment nor inoculation was not present, yields were reduced about 130 pounds per acre.

The comparison between the two moisture determination methods is shown in table 2. The bean moisture determined with the meter was 3.4% higher than when oven drying. Seed treatment affected bean moisture determination with oven drying but not using the moisture meter.

Table 1. Effect of nitrogen rate, inoculation, and seed treatment on harvest moisture and kidney bean yield at Staples, 1994.

N rate	Inocu-lation	Seed treatment	Harvest moisture[1]	Yield
			----%-----	--lb/A--
27	Yes	Yes	10.7abcd[2]	2916ef
		No	11.2ab	3076cdef
	No	Yes	10.6abcd	2886f
		No	10.6abcd	2993ef
77	Yes	Yes	10.05cd	3087cde
		No	10.6abcd	3036cdef
	No	Yes	10.5abcd	3114cde
		No	10.8abc	2932ef
127	Yes	Yes	10.1bcd	3162bcd
		No	10.8abcd	3108cde
	No	Yes	9.7d	3248abc
		No	11.0abc	2949def
177	Yes	Yes	11.0abc	3343ab
		No	11.1abc	3411a
	No	Yes	11.2ab	3362ab
		No	11.4a	3252abc
Main effects of N rate, inoculation, and seed treatment				
27			10.8a	2950c
77			10.5a	3042bc
127			10.4a	3117b
177			11.2a	3342a
	Inoc.		10.7a	3142a
	No inoc.		10.7a	3083b
		Seed trt.	10.5b	3140a
		No seed trt.	10.9a	3086a

Table 1. (cont.)

N rate	Inocu-lation	Seed treatment	Harvest moisture[1]	Yield
			----%-----	lb/A
N rate by seed treatment interaction				
27		Yes		2991d
		No		3000cd
77		Yes		3101bc
		No		2984cd
127		Yes		3205ab
		No		3029cd
177		Yes		3353a
		No		3331a
Inoculation by seed treatment interaction				
	Yes	Yes		3127a
		No		3158a
	No	Yes		3153a
		No		3014b
Pr>F			moisture	yield
N rate			0.27	0.002
Inoculation			0.82	0.09
N rate x inoculation			0.62	0.92
Seed treatment			0.04	0.17
Seed trt x N rate			0.46	0.08
Seed trt x inoculation			0.99	0.03
N rate x inoc x seed treatment			0.81	0.94

1. Bean moisture was determined by oven drying at 120°F until there was no longer weight loss.
2. Data followed by the same letter in the same column group are not significantly different at the 0.10 level.

Table 2. Effect of seed treatment and moisture testing method on kidney bean harvest moisture at Staples, 1994.

Treatment	Moisture Method	Harvest Moisture
		--%--
Seed trt.	oven dry	10.5
	meter	14.1
No seed trt	oven dry	10.9
	meter	14.2
Seed treatment		12.3b[1]
No seed treatment		12.5a
	oven dry	10.7b
	meter	14.1a
Pr>F		
N rate		0.26
Inoculation		0.89
N rate x Inoculation		0.69
Seed		0.06
N x Seed		0.71
Inoc. x Seed		0.92
N x Inoc x Seed		0.64
Method		0.001
N x Method		0.24
Inoc x Method		0.77
Seed x Method		0.03
N x Inoc x Method		0.61
N x Seed x Method		0.20
Inoc x Seed x Method		0.95
N x Inoc x Seed x Method		0.80

[1]Data followed by the same letter in the same column group are not significantly different at the 0.10 level.

Nitrogen Source Effects on Corn/Potato Yields and Nitrate Leaching, 1994[1]

J.T. Waddell, J.F. Moncrief, C.J. Rosen, S.C. Gupta, M.J. Weins, B. Sheets, and B.J. Johnson[2]

Abstract

Plots were established at Staples, MN to evaluate the following nitrogen sources: anhydrous ammonia, turkey manure, urea-ammonium nitrate (28%), granular urea and a control. An attempt was made to give each treatment (except the control) approximately 200 lbs N per acre, however the turkey manure treatment received 250 lbs N per acre. No differences in yield or moisture content was observed in corn grain supplied with different N sources. Potato tubers and vines did respond to different N sources. Measurement of N lost below the root zone indicates that turkey manure increased losses, however more N was applied in this treatment. Water use by corn was slightly lower during the early part of the growing season when percolation losses were highest. Except in the case of turkey manure, there was more nitrate leaching under corn.

Introduction

Crop production on sandy soils in Minnesota has been improved by the introduction of irrigation systems. Wright and Bergsrud (1991) produced an irrigation schedule termed 'the Checkbook Method' which predicts daily water use for several different crops in Minnesota using overhead sprinkler irrigation. It has been shown by Dylla et. Al. (1980) that these tables to predict water use are comparable to estimates obtained by more precise methods. While the checkbook method may be a valuable tool for predicting irrigation scheduling, the variability of climate from year to year plays a major role in assessing the risks of loosing nitrogen to sub-surface reservoirs.

It has been shown that varying the nitrogen source can have an effect on yields and contribute to contamination of groundwater (Nathan et al., 1992 and Sexton, 1993). Typically, growers in the central sands region of Minnesota have used urea as a nitrogen source. This source of nitrogen is readily available to plants once it is hydrolyzed. However, it may be rapidly leached into subsurface reservoirs during heavy rainfall events. Another nitrogen source is turkey manure. Minnesota is the second leading producer of turkeys in the United States. As a result, turkey manure is abundant and its disposal is of growing concern. Turkey manure is unique as a nitrogen source since its components include primarily ammonium and organic nitrogen compounds. The ammonium portion is readily available to plants while the organic N portion is more slowly made available for uptake throughout the growing season and into the next.

It was the purpose of this study to discern the effect of nitrogen sources on corn/potato yields. Another goal of this project is to quantitatively describe N movement below the root zone.

Materials and Methods

The test plots were located on a Verndale sandy loam soil. The site had a maximum slope of 2% with little or no runoff. Soils of the area are unique. An illuvial soil horizon of limiting hydraulic conductivity (0.54 in h^{-1}) exists with a clear upper boundary at approximately 10 inches and a gradual lower boundary at 16 inches below the surface (Sexton, 1993). Visual observations of the soil showed a limited number of preferential flow paths (macropores) due primarily to ant burrows. Earthworms are less common on soils of such a sandy nature.

Individual plots were 20 x 40 square feet. Corn (Pioneer 3921) was planted on 5 May in 30 inch rows at a rate of approximately 32,000 seeds per acre. A blended starter fertilizer was applied at rates of 30 N, 128 P_2O_5, 68 K_2O, 11 S (pounds per acre). On 6 May, the herbicides Bladex (cyanozine) and Dual (metalachlor) were applied at rates of 2.5 pounds and 2 pints per acre, respectively. No insect of fungus control procedures were needed in the corn. Weed control was good with a few weeds (quackgrass, lambsquarter and nightshade).

Potato (Russet Burbank) was planted on 26 April in 36 inch rows with a density of 17,424 seed pieces per acre. A blended starter fertilizer (7.5-32-17-3.1) was applied at a rate equivalent to 400 pounds per acre. Pre-plant and post-harvest knock down herbicide Diaquat was applied at rates of 1.5 pints per acre, otherwise weeds were controlled during the growing season by cultivation on 14 June. Furadan was applied on 27 July after noticing Colorado Potato Beetle infestation. Fungicide (Bravo) was applied weekly at rates of 1.5 pints per acre. Some Early Blight was detected during the growing season.

Nitrogen (approximately 170 pounds per acre) was applied preplant (anhydrous ammonia) or in two applications (urea and 28%) to both corn and potato plots totaling 200 pounds per acre except for the turkey manure treatment (Table 1). The plots were structured as a completely random design with four replications. This conservative rate of 200 lbs per acre was used in order to

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[1] *Support for this project was provided by the Legislative Commission on Minnesota Resources. Their support is greatly appreciated.*

[2] *J.T. Waddell, Graduate Research Assistant, J.F. Moncrief and C.J. Rosen, Extension Specialists, S.C. Gupta, Professor of Soil, Water, and Climate, University of Minnesota, St. Paul, Minnesota. M.J. Weins is the University of Minnesota Senior Plot Coordinator, Central Minnesota Economic Development, Research and Education Center, Staples, MN. B. Sheets and B.J. Johnson, Magnificent Technicians, CMEDREC and U of M, respectively.*

discern differences if any in the uptake and loss of nitrogen. Table 1 shows the application rates and schedules of the various treatments. Anhydrous ammonia was placed pre-plant below the row for potato and between the row for corn sidedress on 10 June.

Irrigation scheduling was based on the Checkbook Method (Wright and Bergsrud, 1991), with attempts to apply 0.75 inches (Figure 1). During the corn stages from planting to 12 leaf, irrigation was applied at a deficit of 60% of the available water (1.42 inches); from 12 leaf to first dent, the irrigation trigger was 0.95 inches (40%); and from first dent to maturity, irrigation was initiated at 66% (1.6 inches) depletion. For potatoes, an irrigation deficit of 50% was used from planting to tuberization and from tuberization to maturity a 40% deficit was used. Rainfall events which exceeded half of field capacity were followed by two days of cumulative soil water deficits at zero. Whenever the water deficit by the Checkbook Method became close to exceeding the water holding capacity, suction was applied to suction cup samplers. Also, suction was applied to samplers before irrigation events or when the chance of precipitation was 50% or greater.

Table 1. Nitrogen sources, application rates and dates.

Treatment	Potato			Corn		
	Rate	Date	Total§	Rate	Date	Total
Anhydrous Ammonia	206 (170)† lbs/ac	21 April	200 lbs/ac	206 (170) lbs/ac	10 June	200 lbs/ac
Urea	364 (85) lbs/ac	3 & 14 June	200 lbs/ac	364 (85) lbs/ac	3 & 14 June	200 lbs/ac
Urea Ammonium Nitrate (28%)	300 (85) gal/ac	7 & 24 June	200 lbs/ac	300 (85) gal/ac	7 & 24 June	200 lbs/ac
Turkey Manure	9.0 (245)‡ tons/ac	23 April	245 lbs/ac	9.2 (244) tons/ac	23 April	255 lbs/ac

§ Represents total nitrogen applied to individual plots including starter fertilizer.
† Values in parenthesis represent the calculated applied N (pounds per acre) for each source. Note that an additional 30 pounds N per acre was applied to potato and corn in starter application.
‡ Estimated available nitrogen = 100% mineral N(16.5 lbs/ton) + 30% organic N (34.9 lbs/ton). Moisture content was 32.9% by weight.

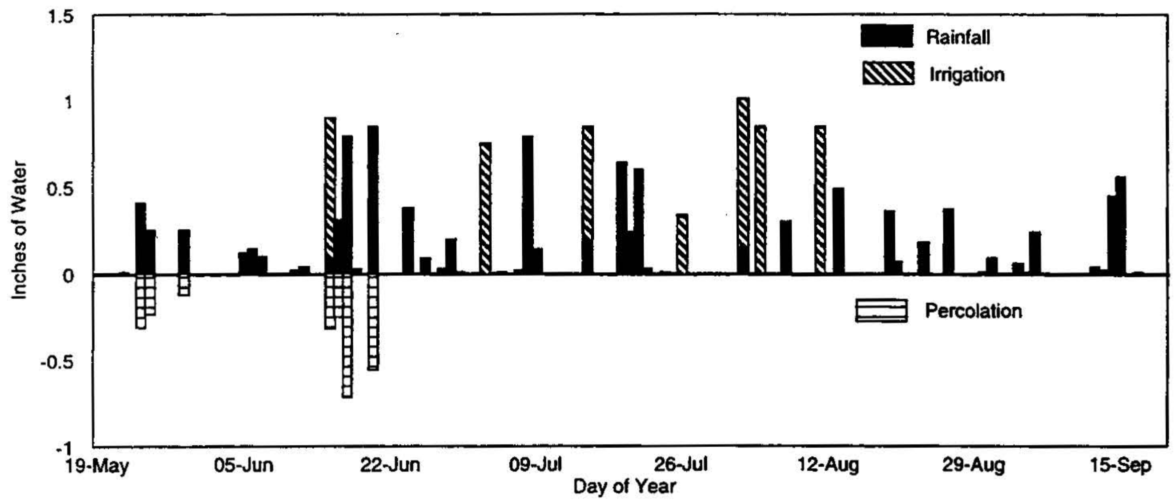

Figure 1 Rainfall and irrigation for the 1994 growing season. Percolation calculated by water budget approach using averaged values for water use for corn and potato.

Suction samplers were made from high flow (1 bar) porous ceramic cups (2 inch diameter) glued to poly vinyl chloride (PVC) pipe. Access tubes were inserted through a rubber stopper from which suction was used for collection of soil water percolate. Suction samplers were installed in plots amended with urea and turkey manure along with control plots. Suction samplers were installed at the 24 inch depth. Samples collected were quickly frozen and taken to the analytical lab where nitrate and ammonia concentrations were measured.

Corn was harvested by hand on 21 September. Stover and grain moisture content, yield and nitrogen content were determined. Potatoes were harvested on 16 September with biomass, N accumulation and quality parameters determined.

Results and Discussion

Rainfall and irrigation events are shown in Figure 1. Percolation values were calculated from a water budget using the equation:

$$Percolation = Rain + Irrigation - WaterUse - \Delta Storage$$

It is obvious that leaching losses below the root zone were prevalent early in the growing season just after fertilizer side dressing. Percolation losses in figure 1 were averaged from water use both for corn and potato. Water use (estimated from the Checkbook Method) for potato was greater than that of corn until day 200 (19 July) when uses were equal. After this time, corn water use was slightly greater than potato. During the latter portion of the growing season the center pivot irrigation device malfunctioned and corn may have been slightly stressed.

Corn

Corn yields are shown in table 2. All treatments yielded more grain than the control. The turkey manure treatment yielded highest with 232 bushels per acre. An explanation causing significantly higher yields with turkey manure include higher N fertilizer rates. Preliminary analysis of turkey manure indicated lower estimated available N than when we applied the manure to the plots. Other sources of nitrogen showed no significant difference in yield of corn grain (187 bu/ac). No difference in moisture content of the grain was observed. Stover yields for the 1994 growing season showed similar trends as did the grain. Turkey manure yielded the most stover producing over 2 tons per acre. The urea and turkey manure treatment yields were significantly higher than the control.

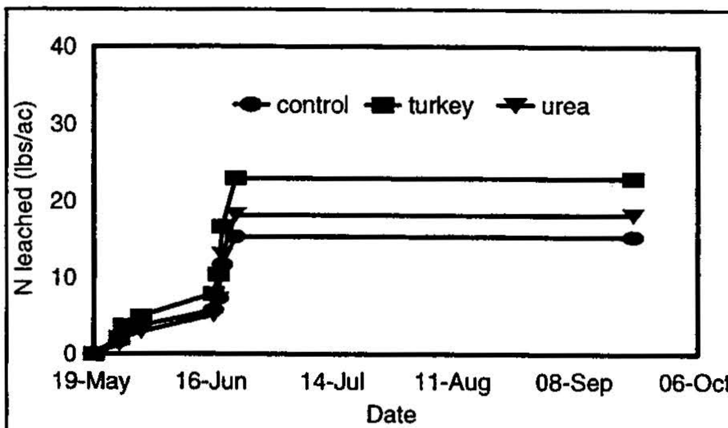

Figure 2 Cumulative nitrogen (principally nitrate) leached under corn plots instrumented with suction cup samplers during 1994 growing season.

Nitrogen uptake in corn grain had the exact trend as did the grain yield (table 2). Corn plots amended with turkey manure showed the highest N uptake, followed by plots ammended with the three chemical N forms, all yielding higher than the control. Similarly, nitrogen in stover was significantly higher in the turkey manure amended plots. Interestingly, the uptake of nitrogen from stover in the 28% plots was not significantly higher than than the control. One component of the nitrogen budget (N lost below the root zone) is shown in figure 2. Nitrogen leached was calculated by multiplying nitrogen concentrations obtained from suction cup samplers by the volume of water

Table 2. Response of corn to different nitrogen sources.

Nitrogen Source	Grain Yield	Grain Moisture	Stover Yield	Stover Moisture	Nitrogen Uptake		
					Grain	Stover	Total
	bu/ac	%	lbs/ac	%	-------lbs/ac-------		
Anhydrous Ammonia	185.9b	30.3a	3225bc	16.3b	118.6b	18.5b	137.1bc
Urea	197.8b	25.9a	3478b	20.1ab	131.5b	19.4b	150.9b
28%	177.9b	27.2a	2728c	18.5ab	114.0b	13.2bc	127.1c
Turkey Manure	232.3a	27.2a	4825a	27.8ab	158.2a	33.1a	191.4a
Control	112.2c	30.1a	3351bc	32.1a	44.5c	9.5c	45.0d

Means within a column followed by the same letter are not significantly different using Duncan's Multiple Range Test (α=0.1).

estimated from figure 1. Because only three treatments (turkey manure, urea, and control) were instrumented, some questions arise from leaching of the other sources and cannot be answered without further study. Because of the lack of leaching events occurring this year, not much N was leached in either treatments compared to the control. Still, the general trend of N leaching follows closely the amount of nitrogen applied with the turkey manure treatment being highest followed by urea as a nitrogen source and finally the control.

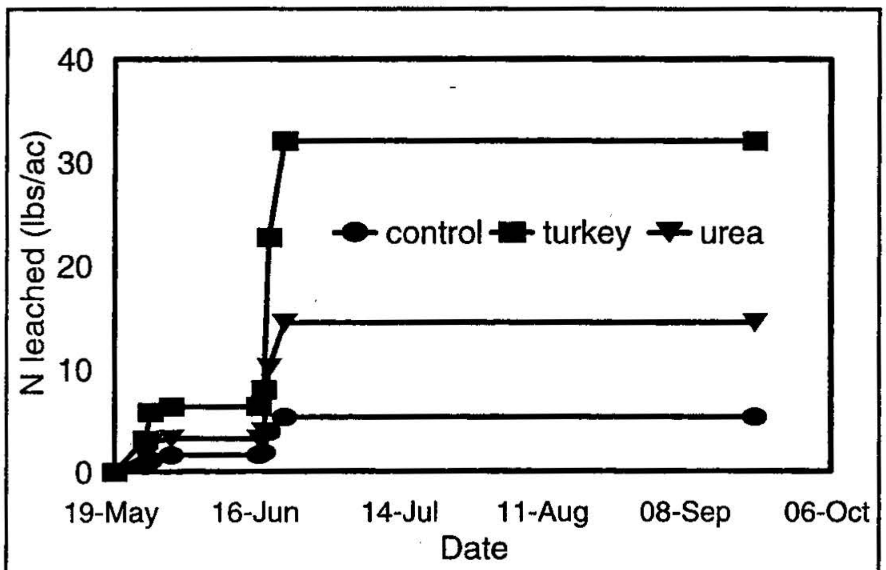

Figure 3 Cumulative nitrogen (principally nitrate) leached beyond the potato root zone during the 1994 growing season.

Potato

Potato yields are shown in table 3. Marketable tuber yields for the different nitrogen treatments were not significantly different while all were higher than the control. Total tuber yields were highest for the turkey manure, anhydrous ammonia and urea treatments leading to a conclusion that the extra N applied to potatos was not effective in increasing tuber yield. However, increased vine growth occurred with higher N rates supplied from turkey manure. Another interesting occurrence is the abundant quantity of knobs (misshappen tubers) for plots amended with urea. It is unknown why this occurred, except that this particular treatment had the highest standard deviation.

The quality of tubers was influenced by the different nitrogen sources for this particular growing season (table 4). Plots with turkey manure applied as the nitrogen source had the lowest density relative to water. This value was significantly lower than the other chemical N sources but not different than the control. The incidence of hollow heart determined from 25 tubers showed that the fewest occurred in nitrogen treatments other than anhydrous ammonia amended plots. While potato scab was qualitatively measured, no significant differences occurred in the treatments with maximum percantages less than 8%(data not shown).

Nitrogen uptake and tuber water contents are also shown in table 4. While water contents in the tubers were not significantly different, vine watter contents were different. It was evident at the time of harvest that vines in plots with turkey manure were actively growing, while the other treatments (especially the control) had begun to senesce. Nitrogen used by tubers indicates that all N treatments were similar and greater then the control. Vine uptake of nitrogen was highest in the turkey manure plots possibly as a result of luxury consumption. The chemical N sources all had similar uptake patterns at harvest and the control was least. Because of the increased uptake of nitrogen by the vines, total N uptake was greatest for the turkey manure treatment followed by the other N ammended treatments, all of which were significantly higher than the control. Nitrogen leached below the potato root zone was determined by multiplying the concentration of nitrogen from suction cup samplers by the percolation values obtained from the water budget. A plot of N leached throughout the growing season is shown in figure 3. The data indicates that highest leaching of N occurred under plots with turkey manure. This was probably due to the higher N rate as stated in the discussion section for corn.

Table 3. Response of potato tubers to different nitrogen sources.

Nitrogen Source	Culls	Ones	Twos	Jumbo	Knobs	Market‡	Total	Vine Yield
	cwt/ac							lbs/ac
Anhydrous Ammonia without N serve	35.4a†	157.2b	214.8a	24.3a	16.8b	372.0a	448.5ab	1775b
Urea	29.0a	185.1ab	188.8a	20.3a	46.0a	373.9a	469.1ab	1806b
28%	26.0a	183.9ab	189.3a	24.7a	16.0b	373.1a	439.9b	1505b
Turkey Manure	37.2a	208.6a	208.2a	21.3a	21.7b	372.0a	497.0a	2788a
Control	26.9a	72.7c	197.3a	2.5b	4.7b	269.9b	304.0c	628c

† Means within a column followed by the same letter are not significantly different using Duncan's Multiple Range Test (α=0.1).

‡ Market refers to marketable tubers which is the sum of ones, twos and jumbos.

Table 4. Some quality parameters and nitrogen uptake values along with moisture content of tubers.

Nitrogen Source	Specific Gravity	Hollow Heart	Tuber N uptake	Tuber Water Content	Vine N uptake	Vine Water Content	Total N uptake
	g cm^{-1}	%	lbs / ac	%	lbs / ac	%	lbs / ac
Anhydrous Ammonia	1.0961a	12.5ab	153.9a	74.7a	26.4b	46.0cd	180.3b
Urea	1.0957a	8.3bc	170.8a	74.6a	26.3b	72.5ab	197.0b
28%	1.0948a	3.1c	160.0a	75.3a	24.0b	50.9bc	184.1b
Turkey Manure	1.0913b	6.3c	177.9a	75.9a	57.0a	87.2a	235.0a
Control	1.0934ab	15.6a	66.3b	75.0a	4.0c	27.7d	70.4c

Means within a column followed by the same letter are not significantly different using Duncan's Multiple Range Test (α=0.1).

Conclusions

The 1994 growing season was excellent with respect to potato/corn yield and nitrogen losses during the growing season. For corn, the amount of N (as seen in grain yields in table 2) may have been limiting as increased yields occurred in the turkey manure plots with 55 lbs/ac more N applied. The same is not true for potato yield since the increased N rates from turkey manure did not significantly increase tuber yield. Generalizations on the effectiveness or efficiency of turkey manure on yields and N leaching cannot be made since the N rate was much higher. Nitrogen forms other than turkey manure produced similar yields in corn grain and marketable tuber yield. However, as costs of nitrogen fertilizers are almost guaranteed to rise, the use of turkey manure may increase as a cheap effective source on nitrogen.

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WEATHER DATA - 1994

Month	Period	Precipitation 1994	Precipitation Normal[1]	Avg. Air Temp. 1994	Avg. Air Temp. Normal[1]	Growing Degree Units 1994	Growing Degree Units Normal[1]
		---- inches ----		----- °F -----			
January	1 - 31	2.43	0.98	3.5	10.2		
February	1 - 28	0.89	0.97	8.9	16.1		
March	1 - 31	0.49	2.28	33.2	19.1		
April	1 - 30	5.59	2.97	45.0	43.1		
May	1 - 10	0.33		48.7		54.0	
	11 - 20	0.33		64.0		146.0	
	21 - 31	1.03		67.8		196.5	
	Total	1.69	3.65	60.4	57.7	396.5	327
June	1 - 10	2.05		64.8		153.0	
	11 - 20	0.84		75.4		245.0	
	21 - 30	0.43		70.3		203.0	
	Total	3.32	4.11	70.2	67.1	601.0	515
July	1 - 10	2.86		69.2		191.5	
	11 - 20	1.65		68.8		187.5	
	21 - 31	0.41		66.7		184.5	
	Total	4.92	4.21	68.2	71.3	563.5	646
August	1 - 10	3.75		66.7		170.5	
	11 - 20	0.54		65.3		160.0	
	21 - 31	0.68		67.7		195.5	
	Total	4.97	4.20	66.6	68.4	526.0	567
September	1 - 30	4.35	3.56	64.1	59.9	447.0	316
October	1 - 31	4.50	2.45	51.8	47.9	60.5	31
November	1 - 30	1.82	1.72	37.4	32.3		
December	1 - 31	0.70	1.35	24.0	16.2		
Year	Jan-Dec	35.67	32.45	44.6	43.4	2594.5[2]	2402
Growing Season	May-Sep	19.25	19.73	66.8	64.9	2534.0	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 10 - - - 3.21"
2) Growing degree units 8% above normal for season, 8th highest since 1950.
3) Highest temperature on May 31 and June 15 - - - 94°F.
4) Last spring frost - - - May 1.
5) First fall frost - - - October 10.
6) Solar radiation for May was 18% above normal and highest in 22 yrs of record keeping.

1994 Soil Moisture

0-5′ Profile, Webster Clay Loam

Continuous Corn

Southern Experiment Station, Waseca, MN 56093

Depth	4/18	5/2	5/16	6/1	6/14	7/5	7/15	8/1	8/15	9/1	9/19	9/30	10/15	11/1
inches	inches available water in zone													
0 - 6[1/]	0.93	1.15	0.73	0.87	1.21	0.69	0.99	0.60	0.93	0.66	0.99	0.92	1.01	0.92
6 - 12	0.60	0.86	0.78	0.70	0.87	0.43	0.57	0.26	0.62	0.33	0.66	0.83	0.71	0.78
12 - 18	0.87	0.93	0.88	0.81	1.01	0.64	0.67	0.50	0.79	0.44	0.78	0.88	0.79	0.86
18 - 24	0.64	0.80	0.73	0.72	0.82	0.55	0.50	0.44	0.59	0.39	0.60	0.72	0.66	0.72
24 - 36	1.96	1.93	1.92	1.63	2.02	1.32	1.33	1.50	1.67	1.42	1.43	1.79	1.50	1.81
36 - 48	2.74	2.60	2.24	2.00	2.64	2.24	2.26	2.31	2.45	2.26	2.11	2.83	2.57	2.51
48 - 60	2.39	2.24	1.77	1.28	2.32	1.70	1.85	1.78	1.76	1.66	1.67	1.94	2.46	1.84
Total available water in 0-5′ profile (inches)	10.14	10.52	9.04	8.01	10.87	7.56	8.17	7.38	8.83	7.15	8.25	9.91	9.70	9.44
% of Capacity[2/]	92	95	82	72	98	68	74	67	80	65	75	90	88	85

[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 1994 growing season. Lowest soil moisture levels occurred in July during peak use and again in early September. With soil moisture conditions at 85% of field capacity in November, soil moisture entering the 1995 growing season will likely be at field capacity.

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

Waseca, 1994

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 silage N uptake and grain N uptake were 17 and 14% greater, respectively, in the plots that received urea compared to those that received dairy manure. Nitrogen source had no effect on tile flow, NO_3-N concentration and loss in tile water, and NO_3-N content in the 0-8' profile in the fall. Nitrate-N concentrations in porous suction cup samplers installed at 4 and 6 ft depths tended to be slightly higher in urea fertilized plots compared to those that received dairy manure. In 106 water samples, ortho-phosphate was never detected while total P was detected in 15% of the samples. Total P concentrations averaged < .10 mg/L and were not different between manure and urea.

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 22 at a rate of 8000 gal per acre and the plots were moldboard plowed immediately. On May 4, urea was broadcast-applied by hand to 4 plots at a rate of 140 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 all of the ammonium-N (109 lb) was available and 33% of the organic N (94 x 0.33 = 31 lb) was available for a total of 140 lb/A. Based on total N, this was 69% of the total applied N.

Corn (P3578) was planted on May 11 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 Lasso (3.5 lb ai/A) and Bladex (3 lb ai/A) applied May 18. 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. Tile water samples of the first two sampling dates from all the plots and selected samples in the subsequent sampling dates were also analyzed for ortho-P and total P content. Water samples collected on a twice-monthly basis from PSC samplers and piezometers were also analyzed for NO_3. All analyses were done by the Research Analytical Lab.

Soil NO_3-N in the 0-8' profile was determined from two cores/plot taken in 1-foot increments on November 4, 1994.

[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 Science, St.Paul.

RESULTS

Corn grown in plots that received urea had significantly greater ($P \leq 0.05$) silage N uptake (17%) and grain N removal (14%) than those plots that received liquid dairy manure (Table 2). Although not statistically significant, silage yield, grain yield, and grain N concentration tended to be higher in the plots that received urea compared to those that received dairy manure. This suggests that we may have overestimated "available" N when we assumed 100% of the NH_4-N and 33% of the organic N would become available.

Table 1. Nutrient analyses and application rate of liquid dairy manure applied in November, 1993.

Dry matter	Total N	NH_4-N	Organic N	Total P_2O_5	Total K_2O
%	lb/1000 gal				
6.7	25.4	13.6	11.8	10.8	32.5
	lb/acre				
	203	109	94	86	260

Table 2. Influence of nitrogen source on corn production and N utilization at Waseca in 1994.

Nitrogen source	Final Population	Silage Yield	Silage N uptake	Grain Yield	Grain N	Grain N removal	Grain H_2O
	x10^3	T DM/A	lb N/A	bu/A	%	lb N/A	%
Urea	28.2	7.43	141.9	197.3	1.25	116.1	20.8
Dairy Manure	28.6	6.91	121.6	184.8	1.16	101.4	21.7
Check[1/]	29.6	3.66	53.3	102.5	0.94	45.6	22.5
CV (%)	0.4	3.9	3.4	5.1	3.8	2.6	3.1
LSD (0.05)	NS	NS	15.9	NS	NS	9.8	NS

[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 in April was 2.6" above the normal while May rainfall was 2.0" below the normal. June through September rainfall was close to the normal and October rainfall was 2" above the normal. As a result, highest tile flow occurred in October followed by April (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 1994.

Month	Tile Flow	NO_3-N Concentration	NO_3-N Loss
	acre-in.	mg/L	lb/A
	Urea		
April	3.09	10.5	7.4
May	0.86	10.8	2.1
June	-	-	-
July	-	-	-
August	0.71	9.2	1.5
September	-	-	-
October	4.37	8.5	8.3
Total	9.03	Avg = 9.5	19.3
	Dairy manure		
April	2.77	11.2	6.9
May	0.98	10.8	2.4
June	-	-	-
July	-	-	-
August	0.50	10.5	1.2
September	-	-	-
October	4.67	8.6	9.1
Total	8.92	Avg = 9.7	19.6

Residual NO_3-N in the soil profile (Table 4) at the end of the 1994 growing season showed little difference between the two nitrogen sources.

Table 4. Influence of nitrogen source on residual NO_3-N in the soil profile in November, 1994.

Profile	Nitrogen Source	
Depth	Urea	Dairy manure
ft	----------- NO_3-N (lb/A) -----------	
0-1	15.5 (2.8)†	17.5 (2.0)
1-2	11.0 (2.8)	8.9 (0.8)
2-3	9.1 (2.0)	6.3 (0.8)
3-4	9.7 (1.2)	8.2 (1.2)
4-5	11.0 (1.2)	11.2 (1.2)
5-6	11.8 (1.2)	11.8 (1.2)
6-7	12.0 (0.8)	11.4 (1.2)
7-8	12.1 (0.8)	11.5 (1.2)
Total (0-8')	92.2	86.8

† Numbers in parentheses represent the standard error around the mean

Ortho phosphorus was not detected in any of the 51 water samples from dairy manure applied plots and 55 from urea fertilized plots (Table 5) indicating that manure application did not contribute to inorganic phosphorus losses in tile lines. However, 20% of the water samples from manured plots and 11% from urea fertilized plots had detectable amounts of total phosphorus, averaging only 0.08 and 0.05 mg P/L.

Table 5. Ortho-phosphorus and total phosphorus detects in tile water samples in 1994.

	Ortho-P		Total-P	
	Manure	Urea	Manure	Urea
Number of samples analyzed	51	55	51	55
Number of detects[1/]	0	0	10	6
% of samples with detects	0	0	20	11
Concentration range of detects (mg/L)	-	-	0.03-0.33	0.03-0.09
Average concentration among detects (mg/L)	0	0	0.08	0.05

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

Nitrate-N concentrations in the PSC samplers at 4 and 6 ft depths were consistently greater at all four sampling dates in the plots that received urea compared to those that received dairy manure (Fig 1). Nitrate-N concentrations at the 4-foot depth increased from August to October with both treatments, but was most dramatic with urea. At the 6-foot depth, NO_3-N concentrations were highly variable and did not show this increase with time in the urea plots. Concentrations of NO_3-N at the 8-foot depth were very low (< 2 mg/L) for both treatments. Water samples were only collected twice from the piezometers in 1994. Water was found in 62% of the piezometers on the first sampling date (September 22) and in 96% of the piezometers on the second sampling date (October 7). During the two sampling dates, all the samples from 4-ft depth piezometers had detectable amounts of NO_3-N while about one-half of piezometers from both 6- and 8-ft depths had less than detectable amounts of NO_3-N.

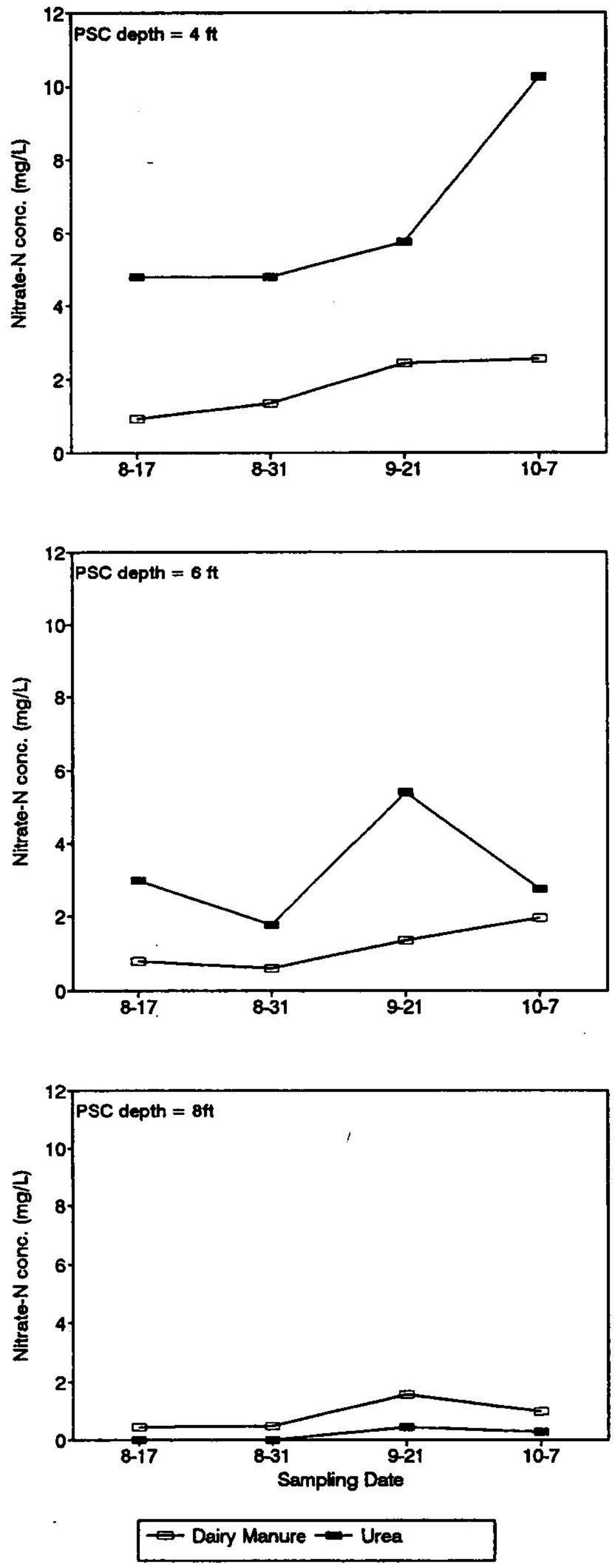

Fig 1.Nitrate-N concentrations in porous suction cup samplers in 1994.

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

Waseca, 1994

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

ABSTRACT: A study was conducted in 1994 to determine the influence of time of N application, N source, and nitrification inhibitor (NI) on the uptake of N by corn and the loss of NO_3 to tile drainage. Results from this first year showed significant yield improvement over the control with all N treatments. Fall application of N without NI gave the lowest yields and N use efficiency of the N treatments. Yields and N use efficiency were not different among the fall + NI, spring anhydrous ammonia (AA), and spring AA + N-Serve treatments. Highest yield was obtained with the preplant urea treatment. Tile lines flowed from mid-April through mid-May, intermittently in August and in October. Tile flow averaged 5.89" for corn and 4.82" for soybeans. Highest NO_3-N concentration and losses in the corn plots occurred with the fall application of N without NI, while the highest concentration and losses under soybean occurred with fall-applied AA + N-Serve applied to the previous corn crop. Nitrate-N concentrations and losses from continuous fallow plots that did not receive fertilizer N or a planted crop for eight years were 70% higher than from the fertilized corn. This was due to soil mineralization and no crop uptake over this 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 water in Minnesota since 1972. This research has focused primarily on the effects of rates and timing 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 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.

Anhydrous ammonia was applied at a rate of 120 lb/A for all N treatments. The nitrification inhibitor (XDE-474 in the fall and N-Serve in the spring) was applied at 0.5 lb/A. Fall treatments were applied on October 25, 1993. Average soil temperature at the 4" depth on that date was 52°F with an average of 44°F over the following 10-day period. Spring preplant treatments were applied on May 11. The sidedress treatment was applied at the V4 stage on June 16.

The corn area (1993 soybean area) was field cultivated once before planting, while the soybean area (1993 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 24,000 seeds/acre (sprocket combination error) on May 11 with a JD Max-Emerge planter equipped with waffle coulters. 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 18. 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 23) plus a post emergence application of Pursuit (4 oz/A) at the 1st trifoliate stage (June 22).

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. Stover and grain samples were taken at physiological maturity by hand harvesting 40' of row for stover yields and 60' of row for grain yields 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 the fallow plots on May 6 and from all plots on November 4. 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., Minnesota Agric. Exp. Stn., and Center for Agric. Impacts on Water Quality.

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RESULTS AND DISCUSSION

Plant

Stover N concentration at physiological maturity was significantly affected by fertilizer N but not by time of application (Table 1). Stover N was increased over the control by all N treatments with no difference among the N treatments. Stover yield was increased over the control by all of the fertilizer N treatments (Table 1). Highest stover yields were obtained with the spring preplant applications of urea and AA + N-Serve. Stover yield was not influenced by fall vs spring application of AA. Similar to stover yield, N uptake in the stover was increased above the control by all fertilizer N treatments (Table 1). Among the N treatments lowest N uptake in the stover occurred with the fall and preplant AA treatments without a NI and the sidedress AA treatment. Final plant population was much lower than desired due to an error in sprocket selection but was not significantly different among 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, and final popultn of corn following soybeans.

N Application		Stover			Final
Time	Inhibitor	N	Yield	N uptake	Population
		%	T DM/A	lb/A	ppA x 10^3
Primary trts					
AA Fall	No	0.51	2.45	24.7	22.2
AA Fall (10/25)	Yes	0.51	2.53	25.6	22.1
AA PP (5/11)	No	0.52	2.32	23.9	21.4
AA PP (5/11)	Yes	0.54	2.69	28.7	22.7
Additional trts					
Urea PP (5/11)	No	0.56	2.73	30.4	22.4
AA SD (6/16)	No	0.51	2.40	24.5	22.3
Check (No N)	- -	0.32	1.80	11.5	22.1
			Statistical Analysis		
Latin square (Primary trts)					
Significance Level (%)		21	90	97	55
LSD (.05)		–	–	2.8	–
CV (%)		10.0	6.8	6.4	5.0
Completely randomized (7 trts)					
Significance Level (%)		99	99	99	40
LSD (.05)		0.10	0.40	6.0	–
CV (%)		13.3	11.3	16.9	4.3

Grain and silage yields were increased significantly over the control by all of the N treatments (Table 2). Fall application of N without NI gave consistently lower grain and silage yields than the three other primary treatments. Yields among the fall with NI and spring N treatments were not different. Lowest grain moisture occurred with the check treatment, which is in contrast to previous years.

Grain N concentration was higher for all fertilizer N treatments compared to the control (Table 2). Among the four primary treatments, significantly higher grain N was found with the preplant AA + N-Serve treatment while the lowest grain N concentration occurred with the fall AA treatment without a NI. Grain N concentrations tended to be higher with the spring AA + N-Serve and the urea treatments compared to the fall and spring treatments without a NI. Nitrogen uptake in the harvested grain was lowest with the fall-applied N treatment without NI and highest for the spring urea treatment (Table 2). Total N uptake was increased over the control by 53.6 lb/A (89%) for fall without a NI, 66.8 lb/A (110%) for the fall + NI, 68.5 lb/A (113%) for the spring preplant AA without NI, 78.1 lb/A (129%) for the preplant AA + N-Serve, 88.0 lb/A (146%) for the preplant urea treatment, and 70.7 lb/A (117%) for the sidedress AA treatment. Among the four primarily treatments, total N uptake was significantly lower for the fall AA without a NI treatment and significantly higher for the spring preplant AA + N-Serve treatment.

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 an improvement in grain N concentration, grain yield, silage yield, grain N uptake, and silage N uptake (P=90% level) with an inhibitor added to the fall-applied N. Spring application of N showed significant advantages over fall-applied N for grain N concentration, grain yield, silage yield, grain N uptake and silage N uptake. Adding N-Serve to spring preplant AA improved the grain N concentration, stover and silage yield, and total N uptake in the silage.

Water

Weather conditions during the 1994 growing season were very close to normal. 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 5.89" with 2.27" range among the four time/method treatments. Soybeans showed slightly less tile drainage compared to corn with an average of 4.82" from the 16 plots and a range of 0.64" 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	Inhibitor	Yield	H_2O	N	N Uptake	Yield	uptake
		bu/A	%	%	lb/A	T DM/A	lb/A
Primary trts							
AA Fall (10/25)	No	161.5	25.9	1.17	89.3	6.27	114.0
AA Fall (10/25)	Yes	170.4	27.4	1.26	101.6	6.56	127.2
AA PP (5/11)	No	174.6	27.6	1.27	105.0	6.45	128.9
AA PP (5/11)	Yes	174.6	26.1	1.33	109.7	6.82	138.5
Additional trts							
Urea PP (5/11)	No	183.6	29.5	1.36	118.0	7.07	148.4
AA SD (6/16)	No	173.3	27.9	1.30	106.7	6.50	131.1
Check (No N)	--	117.1	24.7	0.89	48.9	4.57	60.4
Latin square (Primary trts)			Statistical Analysis				
Significance Level (%)		99	74	99	99	97	99
LSD (.05)		7.4	–	0.05	6.9	0.33	7.7
CV (%)		2.5	5.0	2.3	3.9	3.0	3.5
Completely randomized (7 trts)							
Significance Level (%)		99	99	99	99	99	99
LSD (.05)		15.9	2.1	0.07	12.0	0.69	15.2
CV (%)		6.6	5.4	4.1	8.4	7.4	8.5

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

	Contrast		
Parameter	Fall w/o Inhibitor vs Fall w/ Inhibitor	Fall vs Spring	Spring w/o Inhibitor vs Spring w/ Inhibitor
	----------	Significance Level (%)	----------
Stover N Concentration	0	56	44
Grain N Concentration	99	99	97
Grain Moisture	84	17	83
Grain Yield	97	99	1
Stover Yield	47	11	98
Silage Yield	92	93	97
Final Population	14	17	86
Stover N Uptake	52	78	99
Grain N Uptake	99	99	86
Silage N Uptake	99	99	98

Monthly flow-weighted NO_3-N concentrations in the corn plots showed little temporal variation throughout the year (Table 5). Nitrate-N concentrations remained high throughout the drainage season for both the fall AA without NI and spring preplant AA + N-Serve treatments. The only possible explanation for the high NO_3-N concentrations in April from the spring preplant AA + N-Serve treatment applied in May is carryover and accumulation of NO_3 in the 3 to 5' soil profile from the split-applied N treatment applied in 1992. Higher NO_3-N concentrations from these plots also were found in 1993 when soybeans were grown, and the soybeans may not have scavenged all of the NO_3 from this depth in the profile. Nitrate-N concentrations were quite uniform among all four replications. Flow-weighted NO_3-N concentrations for the year were highest for the fall treatment, lowest for the fall + NI and spring AA treatments, and intermediate for the spring AA + N-Serve treatment. These concentrations were similar to those found in 1993, but lower than in previous years. This was probably due to the high rainfall that occurred from 1991 through 1993. These data clearly show the susceptibility of fall-applied N without a NI to loss of NO_3 in tile drainage water even under normal growing season rainfall conditions.

In the soybean plots, where N had been applied either in the fall of 1992 or spring of 1993, NO_3-N concentrations were consistently lower throughout the season and never averaged greater than 10 mg/L (Table 5). Highest flow-weighted NO_3-N concentrations were found with the fall AA + N-Serve treatment, especially early in the season. Nitrate-N concentration under an 8-year continuous fallow system (no fertilizer N applied) were approximately 2 to 3 times higher than from the fertilized corn and soybean plots.

Table 4. Tile water discharge from the corn, soybean, and fallow plots in 1994.

N application		Month				Year
Time	Inhibitor	April	May	August	Oct.	Total
		acre-inches				
		Corn				
Fall (10/25)	No	2.75	0.22	0.19	2.85	6.01
Fall (10/25)	Yes	3.27	0.35	0.29	3.19	7.10
Spring (5/11)	No	2.57	0.33	0.26	2.46	5.62
Spring (5/11)	Yes	2.22	0.08	0.29	2.24	4.83
		Soybean				
Fall (Oct.)[1]	No	2.75	0.27	—	2.12	5.14
Fall (Oct.)[1]	Yes	2.63	0.26	—	2.20	5.10
Spring (April)[1]	No	2.20	0.27	—	1.96	4.50
Split[1]	No	2.28	0.29	—	1.97	4.54
		Fallow				
NONE		2.28	0.22	0.17	2.04	4.71

[1] N applied for the 1993 corn crop at 135 lb N/A (See 1993 report for treatment descriptions).

Table 5. Flow-weighted NO_3-N concentrations for each month from the corn, soybean, and fallow plots in 1994.

N application		Month				Year
Time	Inhibitor	April	May	August	Oct.	Total
		mg NO_3-N / L				
		Corn				
Fall (10/25)	No	12.7	10.3	13.1	11.8	12.3
Fall (10/25)	Yes	7.9	8.2	9.3	7.6	7.9
Spring (5/11)	No	7.5	6.9	7.7	8.0	7.8
Spring (5/11)	Yes	11.7	13.1	12.1	10.6	11.2
		Soybean				
Fall (Oct.)[1]	No	6.2	5.5	—	6.3	6.3
Fall (Oct.)[1]	Yes	8.8	6.8	—	6.7	7.9
Spring (April)[1]	No	5.5	5.5	—	6.5	6.0
Split[1]	No	6.7	6.5	—	7.0	6.8
		Fallow				
NONE		21.1	19.8	21.3	19.0	20.2

[1] N applied for the 1993 corn crop at 135 lb N/A (See 1993 report for treatment descriptions).

Nitrate-N losses in the drainage water were twice as high for corn as for soybeans (Table 6). Under corn greatest loss of NO_3 occurred with the fall application when NI was not applied. Losses were least with the spring applications of N without N-Serve. Nitrate-N losses under soybean were not greatly different among the treatments but did tend to be higher with the fall-applied treatment + N-Serve, which showed the highest NO_3-N concentration in April. Nitrate-N losses in the fallow system, when mineralization of the soil organic matter was the NO_3 source, was 40 to 220% 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 the fall without a NI and the spring preplant application of AA + N-Serve. Much lower values were found with the fall application of AA + NI and the spring application without NI. In the year following corn and its associated treatments, normalized losses ranked in the order fall without NI < fall + NI = spring without NI = split application. Apparently, sufficient N was not utilized by the corn and remained in the soil profile following the latter three treatments, 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 (1994) / split application (1993), intermediate for the fall application without a NI, and lowest for the fall application + NI, and spring preplant AA without a NI. 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 1994.

N application		Month				Year
Time	Inhibitor	April	May	August	Oct.	Total
		----------- lb NO_3-N / A -----------				
		Corn				
Fall (10/25)	No	7.2	0.5	0.5	7.2	15.5
Fall (10/25)	Yes	5.6	0.6	0.5	5.1	11.8
Spring (5/11)	No	4.3	0.5	0.4	4.2	9.4
Spring (5/11)	Yes	6.0	0.2	0.8	5.6	12.7
		Soybean				
Fall (Oct.)[1]	No	3.7	0.4	—	2.7	6.7
Fall (Oct.)[1]	Yes	5.1	0.4	—	3.1	8.6
Spring (April)[1]	No	3.1	0.4	—	3.5	7.2
Split[1]	No	3.7	0.5	—	3.2	7.3
		Fallow				
NONE		10.8	1.0	0.8	8.8	21.4

[1] N applied for the 1993 corn crop at 135 lb N/A (See 1993 report for treatment descriptions).

Table 7. "Flow-normalized" NO_3-N losses to tile drainage in a corn-soybean sequence in 1994.

Crop System[1]	Time/Method of N Application			
	Fall No Inhibitor	Fall Inhibitor	Spring No Inhibitor	Spring Inhibitor / Split
	----------- NO_3-N lost (lb/A/inch of drainage) -----------			
Corn	2.58	1.66	1.67	2.63
Soybean[2]	1.30	1.69	1.60	1.61
Corn Soybean System	1.94	1.68	1.64	2.12

[1] Continuous fallow (8 years without fertilizer N) = 4.54
[2] N applied for the 1993 corn crop at 135 lb N/A (See 1993 report for treatment descriptions).

Soil

Nitrate-N remaining in the 0-8' soil profile of the fallow system in late-April was about 65% higher compared to the spring of 1993 when NO_3-N accumulations were very low (Table 8). In November, NO_3-N levels above the tile lines were similar to those in April, however, slightly higher NO_3-N accumulations were found below the tile lines. 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. Nitrate-N in the soil profile of the fallow plots and all corn plots as influenced by N treatment.

Profile depth	Fallow NO_3-N		N Treatment for Corn						
	Spring	Fall	Fall AA	Fall AA+NI	PP AA	PP AA+NI	Urea	SD AA	Check (No N)
feet	--- lb/A ---		-------------------- lb/A --------------------						
0 - 1	17	21	28	22	25	23	24	21	25
1 - 2	18	12	14	11	15	12	10	11	11
2 - 3	17	11	10	8	10	11	8	11	8
3 - 4	12	14	8	9	7	9	7	9	5
4 - 5	14	23	12	11	7	10	10	10	5
5 - 6	18	25	13	11	8	12	8	9	7
6 - 7	16	17	12	10	9	12	10	8	9
7 - 8	15	20	14	11	11	14	9	9	9
Total in									
0 - 5' profile	79	81	72	61	64	65	59	62	54
0 - 8' profile	129	143	111	93	92	103	86	88	79

NITROGEN FERTILIZATION OF ESTABLISHED REED CANARYGRASS

G. W. Randall, J. A. Vetsch, 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 3-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. Forage yields in 1994 were 1.2 T DM/A less than in previous years and yield was optimized at 200 lb N/A compared to 250 to 300 lb N/A in 1992 and 1993, respectively. Single applications of N were as effective as split applications for forage yield. Increasing fertilizer N rate significantly increased total N and NO_3-N concentrations in the forage. Forage NO_3-N concentration reached toxic levels with fertilizer rates greater than 350 lb N/A for the second harvest and 500 lb N/A for the third harvest. Apparent N recovery declined sharply when fertilizer N rate exceeded 200 lb N/A. The effects of split application on N recovery were inconsistent. Recoveries were less than previous years. Residual soil NO_3-N (RSN) in November accumulated in the top 2 ft with rates less than or equal to 300 lb N/A, while at rates greater than 400 lb N/A RSN was found below 3 ft. The residual effects of nitrogen application to reed canarygrass were measured from last year's site. Nitrogen treatments, applied in 1993, significantly affected forage yield, total N, plant NO_3-N, and N uptake in 1994. Nearly 20% of 600 lb N/A applied in 1993 was recovered in forage in 1994. This suggests that not all residual N will be lost to ground and surface water when optimum N rates are exceeded.

EXPERIMENTAL PROCEDURES

Twenty plots, measuring 20 ft by 40 ft, were laid out on established reed canarygrass (variety Palaton) in April 1994 on a Webster clay loam soil. Plots were fertilized with varying rates of N as ammonium nitrate on April 11. After the first cutting the main plots were split into subplots and again were fertilized with varying rates of N as ammonium nitrate on June 20 (Table 1). A randomized complete block design with four replicates was used in the analysis of the first harvest (June 2). An unbalanced split-plot design was used for the second (July 18) and third (Sept. 14) harvests. Yields were taken by harvesting a 3 ft by 38 ft swath (first cut) and a 3 ft by 19 ft swath (second and third cuts) from each plot. Forage subsamples were taken and analyzed for moisture content, total Kjeldahl N, and plant NO_3-N concentration. The total N analyses were conducted by the Research Analytical Laboratory (RAL) and the NO_3-N analyses 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 on November 9. All soil samples were immediately forced-air dried at 125° F, then ground and analyzed for NO_3-N by the RAL.

Yields were taken from selected plots (0, 200, 300, 400, 600 lb N/A) from the 1993 research area to determine residual N effects. The harvest methods, harvest dates, and sample procedures were the same as those used in the 1994 study.

RESULTS AND DISCUSSION

Yield

First harvest dry matter yields increased significantly from the early (April 11) application of N fertilizer compared to the control (zero N plots). Yields were not increased by rates > 150 lb N/A (Table 1). Second and third harvest yields were not affected solely by the April application of N. Second and third harvest yields increased significantly up to 100 lb N/A for the June application. A significant (April x June) interaction was found for both the second and third harvest. This interaction is explained by a 0.71 and 0.60 T DM/A yield increase for the second and third harvests, respectively, when 150 lb N/A was applied in June and no N was applied in April compared to a 0.20 T DM/A yield decrease for both second and third harvests with the same June rate applied to plots receiving 200 lb N/A in April. Moreover, the highest second cut yield (1.48 T DM/A) occurred with the 0 + 150 lb N/A (April + June) application rate, compared to 1.19 T DM/A when 150 lb N/A was applied in both April and June. The 0 + 150 (April + June), 50 + 150, and 100 + 150 lb N/A treatments produced equally high yields for the third harvest.

Total dry matter yield was optimized with a total of 200 lb N/A. An April application of 200 lb N/A produced yields equal to the split application of 100 + 100 and 50 + 150 lb N/A. The significant interaction for total dry matter yield is shown by the 1.31 T DM/A yield increase when 150 lb N/A was applied in June to plots that received no N in April, compared to only a 0.61 T DM/A increase when the same June rate was applied to plots receiving 150 lb N/A in April. Also, yield decreased when 200 lb N/A was applied in June to plots receiving 200 lb N/A in April. Less fertilizer N (200 lb N/A compared to 250 lb N/A in 1992 and 300 lb N/A in 1993) was required to obtain optimum yield of reed canarygrass in 1994. Total dry matter yields were significantly less (1.2 T DM/A), compared to 1992 and 1993. Decreased fertilizer N needs for 1994 were attributed partly to the lower yields.

N Concentration

Total N concentration in the forage increased significantly with N application (both April and June) for all three harvests (Table 2). In the first harvest forage N concentration increased significantly with April rates up through 200 lb N/A. Also, nitrogen concentration in the forage from second and third harvests increased significantly with June rates up to 200 lb N/A. Nitrogen concentration in the forage from the second harvest was very high for the 0 + 150 lb N/A application, suggesting rapid uptake of N in the 28-day period between application and harvest. Generally, June N affected N concentration more than April N for the second and third harvests. The treatment effects on N concentration are consistent with the observed significant yield interaction between April and June applications.

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Table 1. Dry matter yield of Reed Canarygrass as influenced by N fertilization at Waseca in 1994.

Rate/Time of Application		Harvest Number and (Date)			
April 11	June 20	1st (June 2)	2nd (July 18)	3rd (Sept. 14)	Total
------ lb N/A ------		--------------- TDM/A ---------------			
0	0	1.09	0.77	0.43	2.30
0	50		1.26	0.74	3.09
0	100		1.41	0.94	3.43
0	150		1.48	1.03	3.61
50	0	1.46	0.84	0.50	2.80
50	50		1.23	0.73	3.42
50	100		1.30	0.93	3.69
50	150		1.34	1.07	3.87
100	0	1.46	0.90	0.64	2.94
100	50		1.17	0.74	3.31
100	100		1.42	0.94	3.77
100	150		1.30	1.08	3.78
150	0	1.60	0.86	0.63	3.05
150	50		1.15	0.76	3.51
150	100		1.15	0.83	3.57
150	150		1.19	0.88	3.66
200	0	1.81	1.13	0.99	3.92
200	50		1.04	0.88	3.74
200	150		0.93	0.79	3.52
200	200		1.03	0.64	3.48
300	0	1.83	1.04	0.89	3.75
300	150		0.96	0.70	3.49
300	200		0.90	0.77	3.51
300	300		1.07	0.72	3.61
Individual Factors					
April N Rate					
0		1.09	1.23	0.78	3.11
50		1.46	1.18	0.80	3.45
100		1.46	1.19	0.85	3.51
150		1.60	1.09	0.77	3.46
200		1.80	1.03	0.82	3.66
300		1.80	0.99	0.77	3.59
Significance level (%):		99	85	39	99
BLSD (0.05):		0.32			0.26
June N Rate					
0			0.92	0.68	3.14
50			1.17	0.77	3.42
100			1.32	0.91	3.63
150			1.20	0.92	3.67
200			0.97	0.70	3.49
300			1.07	0.72	3.61
Significance level (%):			99	99	99
BLSD (0.05):			0.11	0.11	0.17
Interaction 'April x June'					
Significance level (%):			99	99	99
C.V. (%):		7.4	12.0	17.0	6.1

NO_3-N Concentration

Fertilizer nitrogen application significantly affected plant NO_3-N concentration (Table 2). Nitrate concentration in the forage increased with increasing N rate for all harvests at all rates for both April and June applications. A significant interaction was found for both the second and third harvests. This interaction is shown by a 1400% increase in NO_3-N concentration for the 150 + 150 lb N/A plots compared to 150 + 0 lb N/A plots and only a 60% increase for the 300 + 150 lb N/A plots compared to the 300 + 0 lb N/A plots (second harvest). Forage NO_3-N reached toxic levels (> 3500 ppm) when total N applied was ≥ 400 (second harvest) and = 600 lb N/A (third harvest).

Table 2. Total N and NO_3-N concentration in and N uptake by Reed Canarygrass as influenced by N fertilization in 1994.

Rate/Time of N Application		Total N Concentration			NO_3-N Concentration			Total N Uptake		
April 11	June 20	1st cut	2nd cut	3rd cut	1st cut	2nd cut	3rd cut	1st cut	2nd cut	3rd cut
------ lb N/A ------		------- % -------			------ ppm ------			------ lb N/A ------		
0	0	1.94	1.61	1.94	194	86	83	42.6	24.8	16.9
0	50		2.27	2.00		497	81		57.3	29.7
0	100		2.78	2.32		1617	256		78.3	43.8
0	150		3.36	2.75		2338	704		98.3	56.4
50	0	2.26	1.76	1.81	232	151	76	66.4	29.4	17.9
50	50		2.31	2.12		636	99		56.5	31.0
50	100		2.79	2.54		1489	438		72.0	46.6
50	150		3.24	2.71		2537	811		86.3	57.3
100	0	2.23	1.75	2.14	356	214	97	65.4	31.1	27.3
100	50		2.53	2.32		791	98		59.1	33.9
100	100		2.79	2.24		1544	145		78.8	42.4
100	150		3.06	2.66		2208	553		79.2	56.9
150	0	2.39	1.97	2.07	539	199	97	76.1	33.9	26.1
150	50		2.62	2.22		1184	333		60.1	34.1
150	100		3.30	2.63		2056	442		75.3	43.7
150	150		3.54	3.22		3055	1354		83.9	56.4
200	0	2.81	2.64	2.31	1954	1296	225	101.8	58.5	45.8
200	50		3.03	2.92		2388	837		62.4	50.9
200	150		3.56	3.94		3150	2707		66.3	62.0
200	200		3.84	4.00		4024	3191		78.2	50.2
300	0	2.98	3.39	3.02	2496	2417	1078	109.1	69.2	53.2
300	150		4.02	4.00		3795	2980		77.2	55.7
300	200		3.93	3.91		3868	3185		70.9	60.6
300	300		3.77	3.99		4230	3891		80.0	56.7
Individual Factors										
April N Rate										
0		1.94	2.51	2.25	194	1134	281	42.6	64.7	36.7
50		2.26	2.52	2.29	232	1203	356	66.4	61.1	38.2
100		2.23	2.54	2.34	356	1189	223	65.4	62.0	40.1
150		2.39	2.86	2.54	539	1624	557	76.2	63.3	40.0
200		2.81	3.27	3.29	1954	2714	1740	101.8	66.4	52.2
300		2.96	3.78	3.73	2496	3577	2784	106.3	74.3	56.6
Significance level (%):		99	99	99	99	99	99	99	98	99
BLSD (0.05):		0.26	0.24	0.09	305	427	288	17.7	6.5	9.1
June N Rate										
0			2.19	2.21		727	276		41.2	31.2
50			2.56	2.32		1099	290		59.1	35.9
100			2.92	2.43		1676	320		76.1	44.1
150			3.46	3.21		2847	1518		81.9	57.4
200			3.89	3.95		3946	3188		74.6	55.4
300			3.77	3.99		4230	3891		80.0	56.6
Significance level (%):			99	99		99	99		99	99
BLSD (0.05):			0.26	0.19		314	294		6.9	6.3
Interaction 'April x June'										
Significance level (%):			93	99		99	99		99	99
C.V. (%):		7.4	11.2	8.8	23.0	21.2	38.1	16.2	13.6	18.1

Total N Uptake

April and June N application significantly affected total N uptake in the forage (Table 2). Nitrogen applied in April significantly increased N uptake up to 200 (first and third harvest) and 300 lb N/A (second harvest). While June rates of 100 and 150 lb N/A produced equally high total N uptake for the second and third harvests, respectively. The significant interactions for N uptake are consistent with the interactions for dry matter yield and N concentration.

Annual Uptake of Total N and NO_3-N and Apparent N Recovery

Generally, annual (sum of three harvests) total N uptake and annual NO_3-N uptake increased with increasing total N rate up to 300 to 350 lb N/A (Table 3). Annual total N and NO_3-N uptake was highest with the 300 lb N/A rate for both April and June applications (statistical analysis not shown). Nitrogen applied in June increased annual total N, NO_3-N uptake, and N recovery more than N applied in April. Apparent N recovery in 1994 was substantially less than in previous years. Much of this was due to the higher yield and N concentration in the first harvest in the control plots compared to past years. As a result, recovery of N applied in April above that in the control ranged from only 35 to 59% when no additional N was applied in June. On the other hand, recovery of N ranged from 75 to 91% when no N was applied in April. This interaction between application dates led to very inconsistent effects of split application of N on apparent N recovery. When averaged over both application dates, recovery of N exceeded 50% at total N rates ≤ 200 lb N/A and ranged from 48 to 27% at rates above 200 lb N/A.

Table 3. Annual uptake of total N and NO_3-N, and recovery of fertilizer N by Reed Canarygrass as affected by N treatment.

Rate/Time of N Application				
April 11	June 20	Annual Total N Uptake	Annual NO_3-N Uptake	Apparent N Recovery[1/]
------ lb N/A ------		-- lb N/A --	-- lb NO_3-N/A --	-- percent --
0	0	84.3	0.6	—
0	50	129.6	1.8	91
0	100	164.6	5.5	80
0	150	197.3	8.6	75
50	0	113.7	1.0	59
50	50	153.9	2.4	70
50	100	185.0	5.2	67
50	150	210.1	9.2	63
100	0	123.8	1.6	39
100	50	158.4	3.1	49
100	100	186.6	5.8	51
100	150	201.6	8.0	47
150	0	136.1	2.2	35
150	50	170.3	5.0	43
150	100	195.1	7.1	44
150	150	216.3	11.2	44
200	0	206.1	10.4	61
200	50	215.1	13.4	52
200	150	230.1	17.2	42
200	200	230.2	19.3	36
300	0	231.6	15.8	49
300	150	242.0	20.5	35
300	200	240.7	21.0	31
300	300	245.7	23.7	27

[1/] (Total N uptake - N uptake from control) ÷ Total N applied

Soil Nitrate-N

Soil samples were taken in November to determine if substantial quantities of RSN remained in the 0-5 ft profile and if the fertilizer N had moved down through the soil profile. Residual soil NO_3-N in November accumulated in the top 2 ft with rates ≤ 300 lb N/A, while at rates > 400 lb N/A, RSN was found below 3 ft (Table 4). Movement of soil NO_3-N to depths below 3 ft suggests the potential for leaching losses to ground and surface drainage waters.

Table 4. Nitrate-N remaining in the 0-5 ft profile on November 9 as influenced by N rates applied to Reed Canarygrass.

Rate/Time of N Application		Soil Profile Depth					
April 11	June 20	0 - 1'	1 - 2'	2 - 3'	3 - 4'	4 - 5'	0 - 5'
------ lb N/A ------		lb NO_3-N/A					
0	0	3	3	2	2	3	13
100	100	7	4	2	3	3	19
100	150	7	5	4	4	6	26
150	150	18	10	4	3	4	40
200	150	21	21	16	8	5	70
200	200	57	41	28	8	5	140
300	200	43	46	39	30	8	168
300	300	107	108	70	26	13	323

Residual Effects from 1993 Reed Canarygrass N Study

Yield data, obtained in 1994 from selected treatments of the 1993 study, were taken to address the potential for plant recovery of residual N. Nitrogen fertilizer applied in 1993 significantly affected dry matter yields, total N, plant NO_3-N concentration, total N uptake, and plant NO_3-N uptake in 1994 (Table 5). First harvest yields were increased significantly above the control by 1993 rates > 200 lb N/A. Only the 600 lb N/A rate resulted in a yield increase above the control in the second and third harvests. Total N and NO_3-N concentration were significantly increased by 1993 N rates, but only in the first cutting and only by the 600 lb N/A rate. Total N and NO_3-N uptake in the forage were consistent with the response in the first harvest. Nitrogen recovered in the 1994 forage from plots that received 600 lb N/A in 1993 totaled 117 lb N/A. Soil samples, taken in November to a depth of 5 ft, contained < 15 lb NO_3-N/A among all 1993 N rates (data not shown). This suggests that excess nitrogen applied to reed canarygrass may not be lost to the environment, but can be recovered in subsequent cropping years. The residual effects of the 1994 study will be studied in 1995 to provide support to this hypothesis.

Table 5. Residual effects of N applied in 1993 on dry matter yield, total N and NO_3-N concentration, and total N uptake of Reed Canarygrass in 1994.

	Dry Matter Yield				Total N Concentration			NO_3-N Concentration			Annual Uptake	
1993 N Rate	1st cut	2nd cut	3rd cut	Total	1st cut	2nd cut	3rd cut	1st cut	2nd cut	3rd cut	Total N	NO_3-N
lb N/A	----- TDM/A -----				----- % -----			----- ppm -----			lb N/A	lb NO_3-N/A
0	0.48	0.64	0.57	1.68	1.93	1.64	1.85	135	121	93	60.4	0.4
200	0.67	0.67	0.45	1.79	1.96	1.62	1.89	182	117	86	65.7	0.5
300	0.96	0.88	0.56	2.40	1.93	1.76	1.86	247	152	90	90.9	1.0
400	1.28	0.84	0.54	2.65	1.93	1.64	1.83	186	109	89	96.6	0.8
600	1.47	1.59	0.94	4.00	2.61	1.90	2.06	953	300	192	177.3	4.2
Stat. Analysis												
Signif. level (%):	99	99	99	99	99	85	58	99	84	60	99	99
BLSD (0.05):	0.32	0.34	0.24	0.74	0.29			283			39.4	1.5
C.V. (%):	22	25	25	20	9	10	9	56	72	80	27	72

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

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

1994

ABSTRACT: A 3-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. Three-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 both fertilizer N and manure. 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 while NO_3-N concentrations in the soil water at 7.5' were markedly higher compared to the annual applications. 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) 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 and 1994 and by hand-harvesting in 1993.

Soil water samples were obtained periodically throughout the season (May - Nov.) 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 but were quite respectable in 1994. Optimum yield each year and the greatest economic return to the fertilizer 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 3-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 yields and about $5/A less profit 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.

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). Three annual applications averaging 4400 gal/A (145 lb total N/A/yr) (trt. no. 9) produced 3-year average corn yields which were similar to those from the 90-lb fertilizer N rate. Similar to 1992, the large every-other-year treatment (trt. no. 10) produced a yield in 1994 that was 23 bu/A higher than the annual rate of manure. This yield of 167 bu/A was similar to that obtained with the 120-lb fertilizer N rate, but silage production was 0.7 tons dry matter/A higher with the heavy manure treatment (data not shown).

[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 and 1994.

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

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

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
1992-93 Total	9	8200	292	150	124	183
	10	8650	389	157	123	183
1992-94 Total	9	13200	434	230	184	334
	10	18650	673	317	243	485

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

Treatment No.	N rate	Time of Application	Year 1992	1993	1994	Three-Yr Avg.	Return[1] to fert.
	lb/A		Yield (bu/A)				$/A
1	0	Spr. preplant (PP)	33	58	63	51	-
2	60	"	82	95	139	105	110
3	90	"	103	96	147	115	128
4	120	"	113	106	165	128	152
5	150	"	112	108	157	126	143
6	60 + 30	Spr. PP + SD (8-leaf)	100	105	153	119	134
7	60 + 60	"	105	105	155	122	136
8	90	SD (8-leaf)	89	100	150	113	123
9[2]	liquid dairy manure, annually	Spring injected	113	99	144	119	-
10[2]	liquid dairy manure, every other year	Spring injected	136	80	167	128	-

[1] Economics based on the following prices: Corn = $2.25/bu, N = $0.15/lb, and $3.00/acre/application.
[2] See Table 2.

Residual Soil Nitrate

Residual soil nitrate-N (RSN) in the soil profile in November, 1994 was greatly impacted by the N treatments (Fig. 1). RSN ranged from 32 lb/A in the 0-8' profile with the 0-lb N rate to 176 lb/A with the 150-lb treatment. Much of this increase was due to NO_3-N that was found below 5 feet with the 150-lb rate. Accumulation of NO_3 below this depth is significant because of the higher potential for leaching to 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 not excessive and did not result in high levels of NO_3-N in the profile at the end of three years (Fig. 1). Significantly more NO_3 was found in the 0-1' and 1-2' layers with the high every-other-year treatment (no. 10) compared to the annual treatment (no. 9). An intent of this research is to determine whether this "extra" residual NO_3 will carry over and be available for the 1995 crop or whether it will leach downward out of the root zone prior to crop uptake.

Nitrate-N in the Soil Water

Soil water extracted from the 5' and 7.5' depths on Sept. 8, 1994 also showed a significant effect of N rate, source and time of application on the NO_3-N in the water (Fig.'s 2, 3 and 4). Nitrate-N concentration increased at both the 5' and 7.5' depths with increasing fertilizer N rate. At the optimum fertilizer N rate (120 lb/A) soil water contained 14 and 16 mg NO_3-N/L at the 5' and 7.5' depths, respectively (Fig. 2). Reducing the N rate to 90 lb/A resulted in NO_3-N concentrations of 13 and 12 mg/L at the 5 and 7.5' depths, respectively.

Split and sidedress applications of N gave somewhat inconsistent results (Fig. 3). Split applications at the 90- and 120-lb N rates gave similar NO_3-N concentrations as preplant applications at these rates. Surprisingly, the 90-lb sidedress treatment resulted in significantly lower NO_3-N concentrations compared to the preplant application. This is not consistent with previous studies in SE Minnesota.

Nitrate-N concentrations at the 5' depth in the manure treatments were less than from the 60-lb fertilizer N treatment at the end of three years (Fig. 4). The every-other-year treatment applied in 1992 did result in higher NO_3-N concentrations at the 7.5' depth compared to the annual manure treatment. It is very doubtful that the April, 1994 treatment would have contributed to NO_3 at this depth by early September. This suggests that high rates applied every-other-year have a higher potential for NO_3 leaching in years of above-normal rainfall compared to lower rates applied annually.

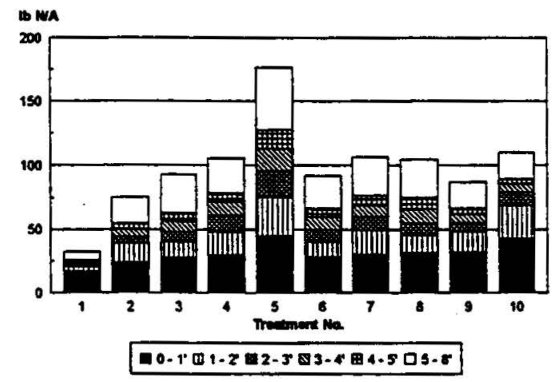

Fig. 1. Soil NO_3-N content as influenced by three years of fertilizer and manure treatments.

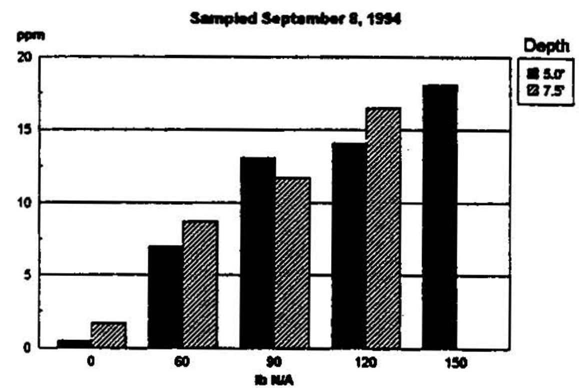

Fig. 2. Nitrate-N concentration in the soil water as influenced by fertilizer N rate.

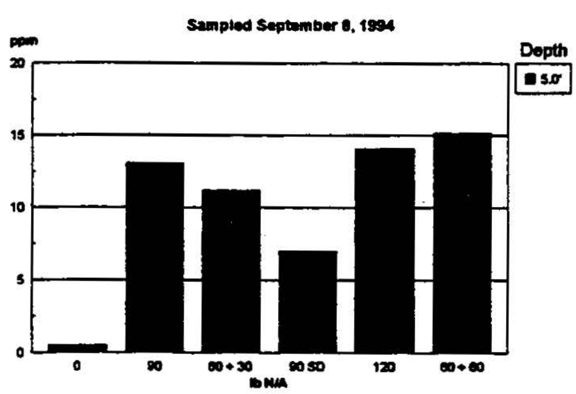

Fig. 3. Nitrate-N concentration in the soil water as influenced by rate and time of fertilizer N application.

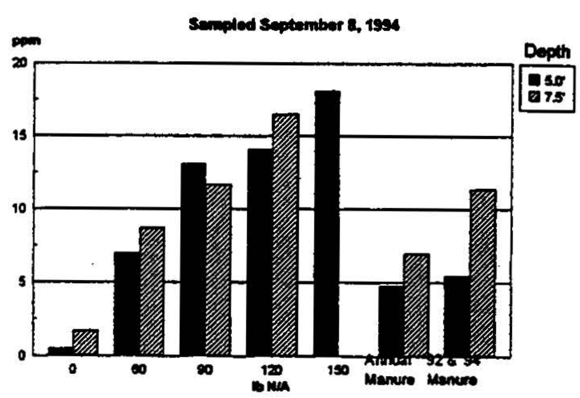

Fig. 4 Nitrate-N concentration in the soil water as influenced by rate and source of N.

NITROGEN AND MANURE MANAGEMENT FOR CORN AFTER ALFALFA IN WINONA COUNTY

G. W. Randall and J. A. Vetsch

1994

ABSTRACT: Semi-solid dairy manure was applied at rates of 0, 10, 20 and 30 T/A (wet basis) to a 3-yr old stand of alfalfa in late October and chisel plowed in. Corn was planted on this Seaton silt loam soil and a sidedress N treatment of 75 lb N/A was applied at the V5 stage. Grain, stover and silage yields and grain N concentration were not affected by the manure or fertilizer treatments. However, N removal by the grain, stover and whole plant (silage) was increased by the manure treatments. Nitrate-N concentration in the soil water at the 5' depth was increased markedly by the manure treatments by July and by both the manure and fertilizer treatments by September. Nitrate-N concentrations in the soil at the V1 and V4 stages, especially the top foot, were increased by the manure treatments. Increased plant uptake lowered the NO_3-N concentrations by the V9 and VT stages, but there was still a slight effect of the manure and fertilizer treatments. These data show no advantage to applying manure or fertilizer N for first year corn after alfalfa.

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. Surveys of private wells within the county document that nitrate-N concentrations are frequently found to exceed the maximum contaminant level (MCL) for drinking water.

The purposes of this study were to determine: (1) the effect of dairy manure and fertilizer N applied 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 (Pioneer 3861) was planted on May 6 after field cultivation. Weeds were controlled well with herbicides. No mechanical cultivation was practiced. Urea was knifed in 4" deep midway between the rows at a rate of 75 lb N/A on June 14 to four additional plots. The corn was about 12" tall (V5 stage). 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 Sept. 20.

RESULTS AND DISCUSSION

Grain yield, grain N content, and silage yield were not significantly different ($P \leq 10\%$ level) among the five treatments (Table 1). As a group, however, yields and N removal tended to be slightly higher with the manure treatments compared to the fertilizer treatment.

The negative impact of these manure and fertilizer N treatments can readily be seen in Table 2. Nitrate-N concentrations in the soil solution water at a 5' depth in July were increased by all three manure treatments with no effect of the June-applied fertilizer treatment. By September, nitrate-N concentrations were 2X to 3X higher with all of the fertilizer and manure treatments compared to the control.

Nitrate-N concentrations in the 0-2' layer of all plots were considerably higher than in October '93 prior to chisel plowing and reflected mineralization which occurred from the alfalfa system (Table 3). Concentrations of NO_3-N were slightly higher for the manure treatments than for the control throughout the season. At the V1 stage, NO_3-N concentration did not exceed 15 ppm, which is below the sufficiency level of 19 ppm where no yield response is expected according to Minnesota's new soil N test. Because no yield response was obtained, these data suggest that plant available N released from the alfalfa and manure is not being adequately identified and interpreted by the new soil nitrate test at this early sampling time. Under these conditions a 0-1' sample taken at the V4 stage using 21 ppm as the sufficiency level would have been a better test.

SUMMARY

- Although trends toward higher corn yields (<4% grain yield increase) were evident when dairy manure was applied for first year corn after alfalfa, the negative consequences of the manure were readily shown with NO_3-N concentrations in the soil water 2X to 3X above that found in the control.
- Sidedress applying 75 lb N/A to first year corn after alfalfa did not increase corn production but did increase NO_3-N concentration in the soil water by over 3-fold three months after application.
- Based on these data, applying fertilizer or manure for first year corn after good alfalfa is not a recommended BMP.

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 for corn following alfalfa.

Treatments		Yield			N Concentration		N Removal		
Manure	Fert N.	Grain	Stover	Silage	Grain	Stover	Grain	Stover	Silage
T/A (wet)	lb/A	bu/A	TDM/A	TDM/A	---- % ------		------- lb N/A -------		
0	0	178.6-	3.972	8.197	1.04	0.53	87.9	42.2	130.0
10	0	185.8	3.941	8.338	1.13	0.69	99.4	54.0	153.4
20	0	183.5	4.235	8.577	1.15	0.67	99.8	56.4	156.2
30	0	187.2	4.382	8.811	1.10	0.70	97.6	61.2	158.8
0	75	176.9	3.988	8.173	1.08	0.67	90.0	53.0	143.0
Treatment Statistical Analysis									
Sign. level (%):		56	82	83	81	97	99	91	99
LSD (0.05):						0.11	7.3		15.4
LSD (0.10):						0.09	6.0	8.8	12.6
C.V. (%):		4.9	7.9	5.3	5.8	10.7	8.9	7.3	6.8
Contrasts 'manure vs fertilizer'									
Sign. level (%):		88	69	85	80	31	85	95	96

Table 2. Nitrate-N concentrations in the soil water at 5' in July and September, 1994 as affected by manure and fertilizer N applied for corn after alfalfa.

Treatments		Nitrate-N Conc. in Soil Water at 5'	
Manure	Fert N.	July	Sept.
T/A (wet)	lb/A	-------- mg/L --------	
0	0	5	4
10	0	9	8
20	0	12	8
30	0	13	11
0	75	7	13

Table 3. Nitrate-N concentrations in the soil as affected by manure and fertilizer N applied for corn after alfalfa.

Treatment			Growth Stage			
Manure	Fert N	Depth	V1	V4	V9	VT
T/A (wet)	lb/A	ft	---------------- ppm ----------------			
0	0	0-1	13.7	22.3	5.3	3.5
		1-2	7.1	6.8	4.5	1.8
		0-2	10.4	14.6	4.9	2.6
10	0	0-1	16.9	25.6	7.0	3.6
		1-2	8.2	8.7	5.1	2.2
		0-2	12.6	17.2	6.0	2.9
20	0	0-1	20.4	23.8	6.4	5.2
		1-2	8.7	9.7	5.6	3.1
		0-2	14.6	16.8	6.0	4.2
30	0	0-1	19.9	23.9	8.2	6.8
		1-2	9.7	10.3	7.0	5.8
		0-2	14.8	17.1	7.6	6.3
0	75	0-1	-	-	-	8.2
		1-2	-	-	-	5.4
		0-2	-	-	-	6.8

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

Gyles Randall, Michael Schmitt, and Jeffrey 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 0, 0, 60 and 120 lb N/A at the four sites and were related to the residual soil NO_3-N (RSN) indicated by the new preplant soil N test. Using the test reduced N recommendations at three of the sites to more economical and environmentally-sound rates of N. Fertilizer N was not under-recommended at any site by the new 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

Four sites were selected for this study in 1994 (Table 1). Two were on fine-textured glacial till soils in south-central Minnesota and two were on medium-textured loess soils in southeastern Minnesota. Three sites had a history of dairy manure and one had hog manure. Manure was not applied after the fall of 1992 at any of the sites. The previous cropping history is also given in Table 1.

Table 1. Cooperator, field history, soil type, and parent material at each of the 1994 sites.

	Site (County)			
	Waseca	Nicollet	Olmsted	Olmsted
Cooperator:	SES, U of M	Leonard Pork Farms	Elmer Borst & Sons	Dan Griffin
History:				
Crop	Corn - 1993 & 1992 Alfalfa - 1989-91	Corn - 1991 & 1993 Soybean - 1992	Continuous Corn	Continuous corn
Manure[1/]	10000 gal/A of liquid dairy manure in Oct. '91 & Oct. '92	9100 gal/A of liquid hog manure in Oct. '92	Dairy manure applied annually	Dairy manure applied annually
Soil type:	Webster cl	LeSueur cl	Mt. Carroll sil	Port Byron sil
Parent Material:	Glacial till	Glacial till	Loess	Loess

[1/] No manure applied after Fall, 1992.

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 two glacial till sites, 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" 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 3751 was planted and thinned to uniform populations at all sites. Weeds were controlled very well with a combination of herbicides and cultivation.

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

[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 Science, St. Paul; and Assistant Scientist, Southern Experiment Station, Waseca.

Grain yields were taken by combine harvesting 114' of row from each plot at the Waseca and Nicollet Co. sites and hand-harvesting 60' of row from each plot at the Olmsted Co. sites. Silage yields were determined from 20' of row in each plot at all sites.

RESULTS AND DISCUSSION

Corn yields were excellent at all sites (Table 2). Statistical analysis showed no significant difference among the yields at both Olmsted Co. sites but a highly significant response to N at the Waseca and Nicollet Co. sites. Yields were optimized at the 120 and 60-lb N rates at these two sites, respectively.

Table 2. Corn yields as influenced by N applied to fields with a manure history in 1994.[1/]

N Treatment		Site			
Preplant	Sidedress	Waseca Co. SES	Nicollet Co. Leonard	Olmsted Co. Borst	Olmsted Co. Griffin
lb N/A		Grain Yield (bu/A)			
0	0	116	161	196	175
30	0	135	177	201	179
60	0	154	187	207	183
90	0	159	179	208	185
120	0	166	181	205	180
150	0	169	182	203	179
180	0	160	184	211	181
30	30	159	190	-	-
30	60	159	178	-	-
30	90	162	178	-	-
Statistical Signif. (%):		99	99	57	57
LSD (.05):		11	13	-	-
CV (%):		4.8	4.9	4.8	3.3

[1/] No manure applied after Fall, 1992.

Soil NO_3-N analyses from samples taken early in the season show virtually no residual soil NO_3 (RSN) at the Waseca Co. site regardless of sampling time (Table 3). At the Nicollet Co. site, modest amounts of RSN were found at all sampling times, especially at the 2 to 3' depth. Modest amounts of RSN were also found at the Borst site in Olmsted Co. with little difference among times or depths of sampling. At the Griffin site in Olmsted Co., somewhat more soil NO_3-N was found, especially in the emergence (V1) and 12" corn (V4 to V5) stages and in the surface 1-foot layer. Rapid mineralization of organic N from prior manure applications with subsequent nitrification occurred at this site when the soil temperatures warmed.

Table 3. Soil NO_3-N as influenced by time and depth of sampling in fields with a manure history in 1994.

Sampling		Site			
Time	Depth (ft)	Waseca SES	Nicollet Leonard	Olmsted Borst	Olmsted Griffin
		ppm			
Preplant[1/]	0-1	4.6	10.7	10.6	12.7
"	1-2	4.7	10.9	10.4	11.1
"	2-3	3.4	14.0	9.8	12.4
"	**0-2**	**4.6**	**10.8**	**10.5**	**11.9**
V1 (emergence)	0-1	4.5	10.4	10.3	21.1
"	1-2	4.3	12.8	9.9	14.0
"	2-3	3.8	16.4	8.2	10.7
"	**0-2**	**4.4**	**11.6**	**10.1**	**17.6**
V4-5 (12" corn)	0-1	4.6	10.8	12.0	28.4
"	1-2	5.3	12.8	11.7	17.2
"	2-3	4.8	17.8	9.1	8.6
"	**0-2**	**5.0**	**11.8**	**11.8**	**22.8**

[1/] Soil NO_3-N in the 0-4' profile totaled 65, 198, 161, and 214 lb/A for the four sites, respectively.

Soil N credits determined by Minnesota's new preplant soil N test indicate a credit of 0, 65, 65, and 65 lb N/A for the Waseca, Nicollet, Olmsted, and Olmsted Co. sites, respectively. Subtracting this credit from our present recommendation of 150 lb N/A for a yield goal of 170 bu/A at these four sites provides N recommendations of 150, 85, 85, and 85 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. Even though N recommendations at three of these sites were reduced to more economical rates by our present N test, it appears that further refinement of the test may be needed in cropping systems with long-term manure histories.

Residual soil NO_3-N in the 0-4' profile after harvest was greatly different among the four sites (Table 4). At the Waseca site, where grain yield responded to the 120-lb N rate, RSN did not accumulate above that in the control until the applied N rate clearly exceeded the optimum N rate. In Nicollet Co., where 9100 gal of liquid hog manure had been applied in 1992 and where grain yields only responded to the 60-lb N rate, substantial amounts of RSN were found in all treatments. This was especially true for the 180-lb N rate and in the 3 to 4' depth. Apparently RSN had leached to this depth in the 24 months since application of the manure and much of it had not been taken up by the plants. Some accumulation of excess RSN occurred at the Borst site, especially at the 180-lb N rate. Excess RSN was also found at the Griffin site, where no yield response to N fertilizer was found. These data clearly show how high levels of RSN can accumulate in soils when N from previous manure applications becomes available and fertilizer N is applied, even when very high yields are produced.

Table 4. Residual soil NO_3-N (RSN) after harvest at the four sites.

N rate	Depth	Site			
		Waseca	Nicollet	Borst	Griffin
lb/A	ft	- - - - - - - - - - - - - - - - - - lb NO_3-N/A - - - - - - - - - - - - - - - - - -			
0	0-1	16	57	32	38
	1-2	14	46	18	27
	2-3	10	34	15	22
	3-4	11	61	22	26
	0-4	**51**	**198**	**87**	**113**
90	0-1	16	49	36	50
	1-2	14	60	22	46
	2-3	11	57	20	36
	3-4	12	86	28	35
	0-4	**53**	**252**	**106**	**167**
180	0-1	51	98	44	45
	1-2	38	106	50	66
	2-3	27	88	47	66
	3-4	20	83	42	48
	0-4	**136**	**375**	**183**	**225**

SUMMARY

- The response to fertilizer N by continuous corn was related to the RSN indicated by the new preplant soil N test in these fields with a long-term manure history.
- The present soil N test recommended a 65-lb credit (reduction in fertilizer N rate) at three of the sites, which was much closer to the optimum economic rate than if one had not used the test in these fields. 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 soil N test research appears to be necessary to more accurately predict the N availability in fields with a long-term manure history.

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/]

1994

ABSTRACT: Four single crop production components (ridge tillage; 3-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 (Nitro alfalfa or hairy vetch). Each corn strip following wheat and soybeans was fertilized at four N rates (0, 40, 80, and 120 lb N/A) to determine N contribution of legumes. Results from the last 4 years 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. While corn yields were enhanced (1 and 9% in E-W and N-S row orientation, respectively) and soybean yields decreased slightly (5% in both E-W and N-S rows), wheat yields were unaffected in the narrow strips compared to conventional systems. Wheat introduced into the traditional corn-soybean strip system reduced the negative border effects of corn on soybeans. Results from this study suggest that these 3-crop systems be planted in N-S orientation to optimize production.

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 2-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 3-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). Nitrogen as ammonium nitrate was broadcast-applied by hand at rates of 0, 40, 80, and 120 lb N/A to plots measuring 6 rows wide x 30' long in each strip. Weeds were controlled with a 15" band-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 (Sturdy) was planted at a rate of 9 to 10 beans/foot of row in 30" rows. Weeds were controlled with a preemergence, 15" band-application of Lasso (3 lb ai/A), and postemergence, 15" band-application of Pursuit (4 oz ai/A), and by ridge cultivation. Each individual row was harvested with a plot combine.

Spring wheat (Grandin) was planted at a rate of 94 lb/A with a minimum-till drill in 8" rows. Broadleaf weeds, when present, were controlled with a broadcast-application of Bromoxynil. Nitrogen as ammonium nitrate was preplant-applied at 50 lb N/A.

RESULTS

The yield advantage of the narrow strips for corn in the 3-crop (wheat-corn-soybean) rotation was 2.0 bu/A (1%) in the E-W system and 12.2 bu/A (9%) in the N-S row orientation compared to the whole-field averages when averaged across the 4 yr period (Table 1). In the E-W rows, the north row (next to wheat) and the south row (next to soybeans) yielded 4 and 15% higher, respectively, compared to the average of the center two rows, which were assumed to represent whole field production. The reason for the south row yielding more than the north is it receives more direct sunlight than the north row.

[1/] Funding provided by USDA-LISA and Minnesota Department of Agriculture.

[2/] Post-doctoral Research Associate and Professor, respectively, Univ. of Minnesota.

When the rows were oriented N-S, both outside corn rows benefitted due to similar amounts of sunlight reaching these outside rows. The yield advantage was 24 and 28% for the east and west outside rows, respectively, compared to the center two rows. Dandelions were a major problem throughout southern Minnesota in the spring of 1994, especially in fields with either no-tillage or reduced tillage. Weed pressure, especially dandelions coupled with previous year's wheat residue posed problems in establishing an uniformly emerging stand of corn and the outside rows showed no yield advantage compared to the center two rows. As a result, the 4 yr average yield advantage for the strips was less than that of the first 3 yr (see Field Research in Soil Science, 1994).

Grain moisture of the strip was 0.2 points greater than the center two rows in E-W rows (Table 2) because of higher moisture content in the north outside row. This is probably due to less sunlight reaching this row than the other rows. On the other hand, grain moisture was lowest in the south row since it receives direct sunlight. In N-S rows, the strip was drier by 0.6 points compared to the center two rows. The west outside row had the lowest grain moisture since it receives more sunlight late in the afternoon when temperatures are high resulting in a faster dry down in this row.

Soybean yields were depressed 7 bu/A (18%) for the north row (next to corn) and 4 bu/A (10%) for the south row next to wheat compared to the center two rows in the E-W row orientation (Table 3). In N-S rows, row 6 (next to wheat) yielded only 1.5 bu/A (4%) less compared to the center two rows while the row bordering corn (row 1) suffered 7.7 bu/A (22%) yield loss. This suggests that including wheat resulted in reduced competition with the adjacent soybean row than the corn row. 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 were decreased much more severely in narrow strips alternated with corn (Table 4). Outside rows (rows 1 & 6) bordering corn yielded 23% less (9 bu/A) than the center two rows in the E-W system and 22% less (7.7 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 34 and 22% less, respectively, than the center two rows. Seed yields for the 6-row alternate strips were decreased by 3.5 bu/A in the E-W rows and 3.6 bu/A in the N-S rows compared to the whole-field averages. Averaged across the 4-yr period, wheat yields were not affected greatly either by the corn or soybean borders (Table 5).

Surface residue coverage before planting was ideal for all crops (Table 6). After planting, residue coverage was still > 30% following corn and wheat. Residue coverage after soybean was only 21%, but this was offset by mid-May with a well-established stand of wheat (soybean is followed by wheat in the 3-crop rotation) 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	Row/Position					Yield Adv.of
Direction	1	2	3&4	5	6	6-row strip[‡]
	bu/A					
E-W Rows	154.3	139.9	148.8	142.0	170.8	2.0
N-S Rows	168.8	140.0	136.3	135.4	174.1	12.2

[†] 4-yr (1991-1994) averages at the 120-lb N/A rate.
[‡] 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	Row/Position 1	2	3&4	5	6	Moisture Adv.of 6-row strip[‡]
	%					
E-W Rows	33.7	32.5	31.5	31.5	29.5	-0.2
N-S Rows	23.4	23.5	24.2	23.5	22.7	0.6

[†] 4-yr (1991-1994) averages at the 120-lb N/A rate.
[‡] 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	Row/Position 1	2	3&4	5	6	Yield Adv.of 6-row strip[‡]
	bu/A					
E-W Rows	32.1	36.4	39.1	40.0	35.1	-2.1
N-S Rows	27.7	34.5	35.4	35.5	33.9	-1.7

[†] 4-yr (1991-1994) averages
[‡] 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	Row/Position 1	2	3&4	5	6	Yield Adv.of 6-row strip[‡]
	bu/A					
E-W Rows	35.2	38.5	39.8	38.0	26.3	-3.5
N-S Rows	27.5	32.2	35.5	32.7	28.0	-3.6

[†] 4-yr (1991-1994) averages
[‡] 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	43.6	42.1	41.1	0.2
North-South	42.1	38.6	35.9	0.3

[†] 4-yr (1991-1994) averages
[‡] 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 (3-year average)[†] as influenced by previous crop at Freeborn Co.

Previous crop	Before planting	After planting
	---------%	---------
Corn	63	37
Soybean	51	21
Wheat	83	35
Wheat + Alf.	88	56
Wheat + Vetch	90	48

[†] 1992-1994 averages

CONCLUSIONS

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

2. Corn benefitted more in N-S strips than in E-W strips due to greater yield advantage for the strip and less grain moisture at harvest compared to the whole-field averages.

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

4. 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.

NITROGEN SOURCE, ROW CLEANER, AND STARTER FERTILIZER EFFECTS IN NO-TILL CORN PRODUCTION ON A WEBSTER CLAY LOAM SOIL.[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, and starter fertilizer on corn production in continuous corn and a corn-soybean rotation. Only data from the corn setup area will be presented in this initial year. Anhydrous ammonia (AA) increased grain yield by 4.3 bu/A as compared to urea ammonium-nitrate (UAN) applied with a point-injector. Row cleaner treatments encouraged early plant growth and provided a 3.7 bu/A yield advantage as compared to non row cleaner plots. Starter fertilizer increased early plant growth but resulted in a 5.1 bu/A yield reduction as compared to non starter plots.

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 and a corn-soybean rotation.

EXPERIMENTAL PROCEDURES

A research site was established in the spring of 1994 at the Southern Experiment Station on a Webster clay loam soil. 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, contnuous no-till corn. The second was no-till drilled to soybean in 1994 and will be planted to corn in 1995 to establish a corn-soybean rotation. A third section was planted to corn in 1994 and will be planted to soybean in 1995.

Treatments were based on current "on farm" management options for no-till. Individual plots were 10 ft wide by 115 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 cleaner (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 an early-season, broadcast application of UAN to a point-injector banded application at the V1 stage. Anhydrous ammonia was injected 15 in. from the row and 7 in. deep with a 5-knife applicator. UAN was injected 3 in. from the row to a depth of 4 in. with a 4-wheel point-injector. Both AA and UAN treatments were applied at V1. Dawn® row cleaners were used on a John Deere Maxi-merge 7100 planter for the RC treatments. Ten gallons 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 150 lb N/A to the corn plots. A 10-lb N/A credit was given to plots that received SF, thus, only 140 lb N/A were applied to SF plots.

Corn (Pioneer 3578) was planted on May 16. Weeds were controlled with a pre-emergence application (May 18) of Lasso (3.0 qt. /A) and Bladex (2.5 qt. /A). The early-season broadcast application of UAN was applied on May 13. The AA and UAN point-injector treatments were applied on June 3. Plant emergence counts were taken on RC and non RC treatments by counting plants emerged in 50 ft of row. Plant heights were measured by taking extended leaf heights of 10 consecutive plants in each plot on June 20. Corn grain was combine harvested from two rows each 112 ft in length on October 26. 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 (UMRAL).

Soil samples were taken in the spring of 1994 to characterize the P and K fertility of the plot area. Nine soil cores (8 in. deep) were taken and composited from each replication. The samples were analyzed for pH, Bray P, and exchangeable K by the UMRAL. Soil tests for P and K were high to very high in all replications. The continuous corn area for 1994 averaged 28 and 190 ppm for Bray P and K, respectively, and had a pH of 6.7.

RESULTS AND DISCUSSION

Nitrogen source significantly affected grain yield, grain moisture, grain N removal, and final plant population. Grain moisture at harvest was 0.6 percent higher with AA (Table 1). Anhydrous ammonia treatments resulted in 4.3 bu/A greater corn grain yields and 4.9 lb more N in the grain compared to UAN treatments. Slight N deficiencies were evident during the growing season in some UAN plots. Greater N efficiency or less loss of AA could explain the yield advantage to AA.

Row cleaners significantly affected early plant growth and grain yield. Plant emergence reached 80% of total one day earlier in RC plots (Table 2). Plant heights, measured 35 days after planting, averaged 32.1 and 29.6 in. for the RC and non RC plots, respectively (Table 1). Row cleaners produced 3.7 bu/A greater yield as compared to non RC plots. As observed by other researchers in earlier studies, row cleaners hasten emergence and increase early plant growth and grain yield on cool wet soils.

1/ Funding provided by the University of Minnesota, Southern Experiment Station.
2/ Assistant Scientist and Professor, respectively, University of Minnesota, Southern Experiment Station.

Table 1. The effect of N source, method of application, row cleaner, and starter fertilizer on grain yield, grain moisture, grain N concentration, grain N removal, final plant population and early plant growth.

Treatments			Grain				Final	Plant
N-source	Row Cl.	Starter	H_2O	Yield	N Conc.	N removal	Plant Pop.	Height
			%	bu/A	%	lb N/A	ppAx1000	inch
UAN	No	No	24.1	146.2	1.28	90.9	32.5	27.8
AA	No	No	25.2	150.0	1.32	95.8	32.3	26.5
UAN	No	Yes	24.3	139.7	1.32	90.0	32.6	33.2
AA	No	Yes	24.2	144.8	1.36	94.5	31.7	31.3
UAN	Yes	No	24.3	147.3	1.29	93.0	32.3	31.0
AA	Yes	No	24.8	154.8	1.30	99.0	31.7	29.6
UAN	Yes	Yes	23.4	146.4	1.30	93.6	32.8	34.2
AA	Yes	Yes	24.0	147.2	1.37	98.2	32.1	33.9
UAN Bdct	Yes	No	24.2	146.8	1.26	90.6	32.1	34.2
Statistical analysis of main effects for 2^3 factorial design (8 treatments).								
N source								
AA			24.6	149.2	1.34	96.8	31.9	30.3
UAN			24.0	144.9	1.30	91.9	32.5	31.5
N source Sign. level (%)			99	99	90	95	98	87
Row cleaner								
Yes			24.2	148.9	1.31	96.0	32.2	32.1
No			24.4	145.2	1.32	92.8	32.3	29.6
Row cleaner Sign. level (%)			89	99	26	81	22	99
Starter fertilizer								
Yes			24.0	144.5	1.34	94.1	32.3	33.1
No			24.6	149.6	1.30	94.7	32.2	28.7
Starter Fertilizer Sign. level (%)			99	99	87	20	26	99
Statistical analysis of interaction effects for 2^3 factorial design (8 treatments).								
N-source x Row cl. (%)			15	9	10	9	13	36
N-source x Starter (%)			85	64	44	15	62	13
Row cl. x Starter (%)			78	45	6	17	85	60
N-source x Row cl.*Starter (%)			93	84	54	8	49	40
C.V. (%)			2.6	3.8	5.2	7.0	3.0	7.1
Statistical analysis of treatment effect for randomized complete block design (9 treatments).								
Sign. level (%)			99	99	63	48	67	99
LSD (0.05)			0.6	5.4				3.1
C.V. (%)			2.6	3.7	5.3	7.2	3.0	6.9

Starter fertilizer significantly affected early plant growth (plant height), grain moisture, and grain yield. Plots that received SF averaged 33.1 in. tall 35 days after planting as compared to 28.7 in. for plots without SF (Table 1). Starter fertilizer plots had lower grain moisture but produced 5.1 bu/A less grain than plots without SF.

Table 2. The effect of row cleaners on plant emergence in continuous no-till corn.

Row cl.	Date Measured							
	23-May	24-May	25-May	26-May	27-May	28-May	31-May	3-June
	percent emerged							
No	1	5	26	44	62	79	97	100
Yes	1	13	44	65	78	86	98	100

There were no statistically significant interaction terms among the main effects at the 95% level (Table 1). Analysis of all 9 treatments in a randomized complete block design showed no significant difference between an injected application of UAN at the V1 stage as compared to an early-season broadcast application of UAN.

Impact of Turkey Manure Application on Corn Production and Potential Water Quality Concerns Westport MN 1994.[1]

G.L. Malzer, and T. Graff[2]

Abstract

A field study was continued at Westport, MN (begun in 1991) to study the impact of turkey manure application on irrigated corn and soybean production and nitrate-N movement below an Estherville sandy loam. Treatments included two rates of commercial fertilizer (70 and 140 lb N/a), and two rates of turkey manure (4 and 8 tons/A--wet weight basis) and an untreated check. Manure rates were computed to provide an estimated equivalent amount of available N per acre as fertilizer treatments. Treatments were planted to corn in 1994 following a previous crop of corn. Plant samples were collected at 8 leaf, silking, and physiological maturity. Plant samples obtained at physiological maturity were separated into grain and stover. Total dry matter production, N concentration and total N uptake were determined for each sampling. Water percolation, and movement of nitrate-N below the root zone was monitored utilizing 30 closed bottom non-weighing drainage lysimeters. Excess percolation was to be removed from the bottom of each lysimeter after each leaching event. Lysimeters were drained prior to planting, but since there were no large rainfall events in 1994 at Westport there was no excess water to collect during the growing season. Soil samples were collected from the soil profile prior to planting and at harvest time and analyzed for nitrate and ammonium N. Grain yields were excellent in 1994. Grain yields and N uptake were significantly higher with the higher rate of turkey manure application than with the highest rate of fertilizer. Grain yields and N uptake were increased substantially due to previously applied manure.

Introduction

Turkey production in Minnesota is ranked second in the nation (Minnesota Statistics, 1990). In 1990, Minnesota's turkey farmers boosted their output to a new record of 43.6 million turkeys. A large portion of the turkey production is concentrated in the West Central and Northwest regions of the state, where many turkey producers have limited land areas available to them for manure disposal. As production increases improved manure management skills will be required to meet the agronomic need and minimize groundwater contamination.

Increased emphasis on protection of surface water and ground water, and the farmers desire to reduce fertilizer cost have increased the need to evaluate the use of turkey manure. Turkey manure is rich in several nutrients. A survey conducted by Moncrief et al.(1991 unpublished data at the University of Minnesota) revealed that the nutrient composition of poultry manure on a dry weight basis is 5.1% N, 2.2% P and 2.3% K respectively. The 860,000 tons (dry wt.) of turkey manure produced per year in Minnesota could supply approximately 87.7, 86.7 and 47.5 million pounds of N, P_2O_5 and K_2O respectively for crop production.

The objective of this field study was to compare two rates of turkey manure (4 and 8 T/A on wet weight basis) and two rates of fertilizer N (70 and 140 lb N/A) on dry matter production, N uptake, grain yields, and leaching losses of NO_3-N within a corn-corn-soybean rotation.

Materials and Methods

In 1975, 30 non-weighing lysimeters were installed on the Rosholt farm near Westport, Minnesota. Each lysimeter was 5.75 ft in diameter,and 4 feet deep and constructed of 12-gauge galvanized steel coated with coal tar epoxy enamel. At the bottom of each lysimeter a sintered stainless filter candle was installed and connected to the soil surface by polyethylene tubing. Each lysimeter was placed in the center of 30' x 30' plots. Soil at the experimental site was an Estherville sandy loam (Typic Hapludoll) and the lysimeters were backfilled with that soil by depth. Selected chemical and physical properties of the soil are presented in Table 1.

Prior to 1991 this site did not have a history of manure application. Cropping history was corn following corn in a corn-corn-soybean rotation, and in 1990 corn was grown at this site without any fertilizers. This study was initiated in 1991 and corn was grown with urea fertilizer and manure treatments. In 1992 soybeans were grown with manure treatments only and in 1993 and 1994 corn again was planted into the experimental area with both fertilizer and manure treatments.

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1. Appreciation is expressed to the University of Minnesota Experiment Station, Wes-Min RCD, Pope Co. SWCD, and Pioneer Hi-Bred International for supplying seed.
2. Professor, and Assistant Scientist respectively, Dept. of Soil Science, University of Minnesota.

Table 1. Some chemical and physical properties of the Estherville sandy loam.

Soil Depth	Gravel	Sand	Silt	Clay	Organic Matter	pH
inches			%			
0-6	0.8	57.9	23.8	18.3	4.8	5.7
6-15	8.0	69.0	16.8	14.1	1.1	5.8
15-30	5.4	66.8	16.1	17.1	0.7	6.2

Irrigation was provided to all plots through a drip-type irrigation system. Drippers were 30 inches apart on a 0.5 inch plastic irrigation line. An irrigation line was placed along each row of corn. Water was pumped through the irrigation system at 13.8 kPa pressure. The emission rate for each dripper was 0.35 gal/hr. Each lysimeter contained 4 drippers. Irrigation water was applied when less than 2 inches of water was available in the soil profile. Irrigation water was metered through 3 main irrigation lines.

The experimental design included three replications of nine treatments in a randomized complete block design. Treatments in 1994 consisted of a zero N control, two rates of turkey manure (4 and 8 T/A, wet weight basis) and two rates of commercial fertilizer N (70 and 140 lb N/A as urea) which were applied to the same plots as in 1991 and 1993 (the five original 1991 treatments), two rates of manure (4 and 8 T/A) were added to the 1992 plots, which were residual manure in 1993, and two residual treatments which had manure in 1993. Turkey manure treatments were incorporated, immediately after application. The nutrient composition of the turkey manure is presented in table 2. Estimate of manure N availability was based on the assumption that 80% of the inorganic N and 30% of the organic N will be available during the first year of application. The manure rates applied were expected to provide approximately 70 and 140 lb. of available N/A. The entire study area had a broadcast application of 60 #/A of P_2O_5 and 160 #/A K_2O incorporated with the turkey manure. The area was planted to corn (Pioneer 3751 - 100 day R.M.) on May 3rd at a seeding rate of 29,600 seeds/A. Lorsban at (8 #/A) was banded in the row at planting for insect control. A tank mix of Lasso (1.75 #/A) + Bladex DF (1.5 #/A) was applied on May 20th for weed control.

Table 2.Turkey Manure Composition

Nutrients	lb/T
Total N	49
Inorg. NH_4^+-N	19
NO_3^--N	---
Organic N	30
P_2O	---
K_2O	---
Moisture %	50

+ Nutrient composition presented in wet basis.
--- not available at this time

Dry Matter production and N uptake were determined June 30th (8-leaf), July 25th (silking) and October 4th. Grain yields were determined by harvesting two 20 foot rows. Corn grain yields were reported at 15.5% moisture.

Soil water percolate was collected prior to planting in 1994. There were no major leaching events in 1994 and hence no water was removed during the 1994 growing season. The amount percolated and the NO_3^--N in the leachate was measured to quantitate concentration, flow rate and total N lost by leaching.

Soil samples collected prior to planting and at harvest (0-6, 6-12 and 12-18 inches), were analyzed for nitrate and ammonium N.

Results and Discussion

The 1994 growing season was excellent and grain yields associated with treatment applications ranged from 75 to 227 bu/a (table 4). Turkey manure applications produced higher yields and resulted in higher N uptake by the crop (more available N) than the anticipated comparable urea fertilizer treatment. Both turkey manure and urea application increased yields up to the highest rate applied. The low rates of turkey manure, however, provided N availability and crop responses similar to the highest rate of urea application. Most of the benefits associated with manure application were associated with the growing season following application. The residual benefits associated with manure application were, however, substantial. The grain yield obtained in 1994 when the high rate of manure was applied in 1993 produced yields comparable to 70 lbs N/A as urea applied in 1994.

The only water drained from the lysimeters in 1994 took place prior to planting. The results presented in Table 5, therefore, would not reflect the impact of 1994 treatments, but rather a reflection of what was present at the end of the 1993 growing season. No treatment effects were detected regarding the amount of water, nitrate concentration, and total loss of nitrate-N in the percolate water. All concentrations of nitrate-N in the percolate water (including the check) exceeded the EPA drinking water standard of 10 mg/L. Nitrate-N concentrations in the soil at planting time indicated that high turkey manure applications made in 1993 resulted in elevated concentrations of residual nitrate-N in the soil profile. This nitrate N could be leached to the shallow surface aquifer if the precipitation is excessive enough to cause leaching.

Table 3. Dry matter production, and N utilization as influenced by turkey manure, fertilizer and residual manure treatments - 1994.

Treatments	Dry Matter 8-leaf	Dry Matter silking	N-Concentration 8-leaf	N-Concentration silking	N Uptake 8-leaf	N Uptake silking
	--------T/A--------		------ % N --------		----lb/A-----	
Control	0.64	2.33	2.05	0.79	26	37
70 lb N/A in '91,'93,'94	1.07	4.60	3.03	1.08	65	99
140 lb N/A in '91,'93,'94	1.02	4.41	3.48	1.72	71	151
TM 4 T/A in'91,'93,'94	1.17	4.76	2.96	1.29	69	122
TM 8 T/A in'91, '93,'94	1.45	5.71	3.27	1.50	94	170
TM 4 T/A TM'92,'94	1.07	4.66	2.88	1.18	61	109
TM 8 T/A TM'92,'94	1.42	5.36	3.07	1.52	87	162
TM 4 T/A in '93,none '94	0.76	3.36	2.05	0.90	31	61
TM 8 T/A in '93,none'94	0.97	3.53	1.99	0.98	38	69
Statistical Analysis						
N-Rate X Management						
N-Rate						
Low Fertility	1.01	4.34	2.73	1.11	56	98
High Fertility	1.21	4.75	2.95	1.43	72	138
P-Valve	99	99	99	99	99	99
Management						
Fertilizer Annually	1.04	4.50	3.25	1.40	67	125
Manure Annually	1.31	5.23	3.11	1.39	82	146
Manure Biannual	1.24	5.01	2.97	1.34	74	136
Manure Residual	0.86	3.44	2.02	0.94	35	65
P-Valve	99	99	99	99	99	99
LSD (0.05)	0.12	0.33	0.16	0.09	5	8
Rate X Management	98	98	96	99	99	99

* TM is turkey manure.

Table 4. Grain and stover yields as influenced by turkey manure, fertilizer and residual manure treatments - 1994.

Treatments	Grain yield	N-Concentration Stover	N-Concentration Grain	Dry Matter Production Stover	Dry Matter Production Grain	Dry Matter Production Total	N-Removal Stover	N-Removal Grain	N-Removal Total
	bu/a	------%------		-------T/A-------			--------lb/a---------		
Control	75	0.45	1.08	4.98	1.78	7.89	55	38	93
70 lb N/A in '91,'93,94	142	0.44	1.21	4.78	3.37	9.30	52	81	133
140 lb N/A in '91,'93,94	174	0.58	1.51	5.43	4.12	10.70	76	124	200
TM 4 T/A in'91,'93,'94	167	0.57	1.28	4.88	3.96	9.97	68	102	170
TM 8 T/A in'91,'93,'94	227	0.93	1.51	4.84	5.38	11.35	111	162	273
TM 4 T/A TM'92,'94	154	0.54	1.11	4.89	3.65	9.69	65	81	146
TM 8 T/A TM'92,'94	206	0.65	1.58	4.98	4.88	11.01	80	154	234
TM 4 T/A in '93 none'94	108	0.41	1.06	4.97	2.56	8.66	51	54	105
TM 8 T/A in '93 none'94	137	0.43	1.06	5.42	3.26	9.80	63	69	132
Statistical Analysis									
N-Rate X Management									
N-Rate									
Low Fertility	143	0.48	1.16	6.02	3.38	9.40	59	80	138
High Fertility	186	0.66	1.41	6.30	4.40	10.72	82	128	210
P-Valve	99	99	99	87	99	99	99	99	99
Management									
Fertilizer Annually	158	0.50	1.36	6.25	3.74	10.00	64	103	167
Manure Annually	197	0.74	1.40	5.99	4.67	10.67	89	132	221
Manure Biannual	180	0.59	1.34	6.08	4.27	10.35	72	117	189
Manure Residual	123	0.44	1.06	6.32	2.91	9.23	56	62	118
P-Valve	99	99	99	43	99	99	99	99	99
LSD (0.05)	12	0.07	0.12		0.27	0.65	12	14	22
Rate X Management	95	99	99	48	95	3	91	99	98

* TM is Turkey Manure

Table 5. Water percolation amount, concentration of NO_3^--N and Nitrate-N leached as influenced by manure, fertilizer and residual manure treatments in 1994.

Planting 1994

Treatments	Inches of H_2O	ppm NO_3^--N	lb/A NO_3^--N
Control	2.8	27.2	12.2
70 lb N/A in '91,'93,'94	3.6	12.8	11.7
140 lb N/A in '91,'93,'94	3.9	18.5	15.9
TM 4 T/A in'91,'93,'94	2.5	24.9	14.5
TM 8 T/A in'91,'93,'94	4.3	16.7	11.5
TM 4 T/A TM'92, '94	2.8	32.8	19.5
TM 8 T/A TM'92, '94	3.8	16.6	13.0
TM 4 T/A in '93 none '94	2.4	28.7	13.4
TM 8 T/A in '93 none '94	3.2	18.2	13.5
P-Value	25	32	18
LSD (0.05)			

* TM is Turkey manure.

Table 6. Soil N levels sampled before planting and at harvest 1994.

Treatments	Depth	Ammonium Planting	Ammonium Harvest	Nitrate Planting	Nitrate Harvest	Total Inorg. Planting	Total Inorg. Harvest
		------ppm------		-----ppm------		------ppm------	
Control	1	3.2	2.5	7.1	5.0	10.3	7.5
	2	2.2	2.7	3.6	2.9	5.8	5.6
	3	0.8	2.7	2.9	2.7	3.7	5.4
70 lb N/A in '91,'93,'94	1	2.3	3.0	11.1	5.9	13.4	8.9
	2	2.7	1.7	5.3	3.7	8.0	9.7
	3	2.3	2.3	2.6	3.2	4.9	7.2
140 lb N/A in '91,'93,'94	1	3.2	3.0	9.2	6.5	12.4	9.5
	2	1.7	1.2	4.2	4.2	5.9	5.4
	3	1.7	1.3	5.0	5.1	6.7	6.4
TM 4 T/A in'91,'93,'94	1	2.5	2.0	10.4	7.6	12.9	9.6
	2	1.7	2.2	5.2	5.2	6.9	8.8
	3	1.4	1.5	4.6	2.3	5.9	3.8
TM 8 T/A in'91,'93,'94	1	3.1	3.6	28.5	12.8	31.6	16.4
	2	2.5	1.4	14.9	6.8	17.3	18.7
	3	2.8	3.5	12.6	7.4	15.4	10.9
TM 4 T/A TM'92,'94	1	1.8	2.5	10.1	4.5	11.8	7.0
	2	1.2	1.8	4.2	2.4	5.5	4.2
	3	1.1	1.5	3.1	1.0	4.2	2.5
TM 8 T/A TM'92,'94	1	2.6	3.3	12.4	4.5	15.0	7.8
	2	1.9	1.0	6.0	3.3	7.9	4.3
	3	2.5	2.9	3.3	3.4	5.8	6.3
TM 4 T/A in '93,none'94	1	3.1	6.8	12.2	1.8	15.3	8.6
	2	2.5	2.8	5.2	8.7	7.7	11.5
	3	2.3	1.8	5.4	2.9	7.7	4.7
TM 8 T/A in '93,none'94	1	2.5	6.3	22.7	7.0	25.2	13.3
	2	2.3	2.3	13.5	2.1	15.8	4.4
	3	2.1	1.6	9.4	1.0	11.5	2.6

* TM is turkey manure. Depth 1 ,2 and 3 (0-6), (6-12), and (12-18) inches.

LAND SPREADING OF YARD WASTE - 1994[1]

Carl Rosen, Thomas Halbach, Dave Birong, and Jennifer Weiszel[2]

ABSTRACT: The third 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 1994, 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 year of the study, 1993, increases in growth and yield were greater with increasing yard waste application rates than with applied fertilizer N. Results in 1994 were similar to those in 1993. About 2 lbs of N per dry ton were supplied by the yard waste. Highest yields were obtained with the yard waste applications plus 200 lb N/A. Nitrate leaching tended to increase with fertilizer N application than with yard waste application. Residual soil nitrate-N increased with increasing yard waste application but not 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 and third year after application. This study needs to be continued to determine nitrogen release rates from residual yard waste in subsequent years.

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 third 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 210 lbs/A 0-0-60 were broadcast and incorporated prior to planting. Pioneer hybrid 3751 (100 day maturity) was planted on May 9, 1994 at a population of 32,000 seeds/A (2.5 ft. 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 25 and the remainder on June 17, 1994. 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
[2]Extension Soil Scientist, Extension Waste Management Specialist, Assistant Scientist, and Senior Research Plot Technician respectively, Department of Soil, Water and Climate.

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 22 after all fertilizer N was applied. Ear leaf samples were collected on July 20 at 50% silking. Two, 20 foot rows were harvested for grain and stover yield from each plot on September 29 and October 6, 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 (Table 1). The addition of nitrogen also increased initial growth. At the 8 - 12 leaf stage, the greatest growth was found in treatments with the highest yard waste rates and highest nitrogen rates. The addition of yard waste also increased total yield indicating a significant release of nutrients during the second year after incorporation. Corn growth and yield displayed a greater response to yard waste application when nitrogen fertilizer was not applied; although 200 lb N/A plus 40 or 80 T/A yard waste resulted in the highest yields. At all N rates, addition of yard waste significantly increased grain yield. 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 did not create a significant difference in tissue nitrogen concentration (Table 2). By the silking stage, yard waste amendment increased ear leaf N concentrations with greatest increases occurring at the 0 and 100 lb N/A treatments. Nitrogen uptake increased with increased rates of yard waste. Yard waste application supplied approximately 2 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. Differences in tissue N concentration were observed 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 had minimal effects on residual nitrate-N content in the soil. 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. In all treatments, peak nitrate-N concentrations at the four foot depth occurred at about 7 - 8 weeks after planting. 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 less nitrate leaching than no yard waste applied with 200 lb N/A. Nitrate leaching in the treatments receiving yard waste and 200 lb N/A was similar to that in the 200 lb N/A treatment without yard waste. Although residual nitrate-N in the soil was higher with increasing yard waste application, overall nitrate movement was not greatly affected by yard waste application as measured with suction tubes. This lack of movement may have been due to the fact that 1994 was a relatively low leaching year.

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	7.5	32343	50	36
20	0	13.8	32452	90	33
40	0	20.8	31581	117	34
80	0	23.8	31254	159	29
0	100	16.6	31908	129	32
20	100	20.9	31799	166	31
40	100	26.8	32452	187	31
80	100	23.9	31037	208	29
0	200	16.8	31690	182	32
20	200	22.0	31037	220	29
40	200	25.2	31799	233	30
80	200	25.9	31254	238	29
Significance		**	NS	**	**
BLSD (5%)		4.0	--	22	3
Main effects					
	Yard Waste Rate				
	0	13.6	31980	120	34
	20	18.9	31763	159	31
	40	24.3	31944	179	32
	80	24.5	31182	202	29
	Significance	**	NS	**	**
	BLSD (5%)	2.3	--	13	2
	Linear	**	NS	**	**
	Quadratic	**	NS	**	NS
	Nitrogen Application				
	0	16.5	31908	104	33
	100	22.0	31799	172	31
	200	22.5	31445	218	30
	Significance	**	NS	**	**
	BLSD (5%)	2.0	--	11	1
Interaction					
	Yard Waste x Nitrogen	++	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			Dry Mass				Nitrogen Content			
				Cob	Stover	Grain	Cob	Stover	Grain	Total	Cob	Stover	Grain	Total
-tons/A-	--lbs/A--	-------- % Nitrogen --------		--- % Nitrogen ---			--------- Ton/A ---------				-------- lb N/A --------			
0	0	2.20	1.10	0.71	0.44	0.89	0.14	1.33	1.40	2.87	2.0	11.9	24.9	38.8
20	0	2.07	1.19	0.57	0.41	0.91	0.23	1.92	2.52	4.67	2.5	15.8	46.0	64.3
40	0	2.20	1.41	0.55	0.40	0.90	0.31	2.36	3.28	5.95	3.4	18.8	59.4	81.6
80	0	2.36	1.69	0.48	0.45	0.98	0.38	3.24	4.46	8.08	3.6	30.4	87.5	121.5
0	100	3.17	1.83	0.56	0.34	0.88	0.39	2.79	3.61	6.79	4.3	19.0	64.1	87.4
20	100	3.20	2.14	0.47	0.44	0.95	0.45	3.73	4.65	8.83	4.2	32.6	89.3	126.1
40	100	3.00	2.27	0.43	0.45	0.99	0.54	3.97	5.22	9.73	4.7	36.1	103.7	144.5
80	100	3.09	2.47	0.44	0.61	1.12	0.59	3.68	5.82	10.09	5.1	44.4	130.5	180.0
0	200	3.62	2.62	0.39	0.46	1.09	0.54	3.26	5.09	8.89	4.2	30.2	111.3	145.7
20	200	3.32	2.75	0.39	0.55	1.18	0.62	3.89	6.17	10.68	4.9	42.7	145.5	193.1
40	200	3.40	2.76	0.38	0.60	1.20	0.65	4.36	6.54	11.55	5.0	52.1	157.6	214.7
80	200	3.38	2.73	0.40	0.69	1.32	0.72	3.76	6.67	11.15	5.7	52.4	176.2	234.3
Significance		**	**	**	**	**	**	**	**	**	**	**	**	**
BLSD (5%)		0.22	0.21	0.09	0.10	0.06	0.06	0.52	0.61	1.00	0.8	10.6	15.5	21.4
Main effects														
Yard Waste Rate														
0		2.99	1.85	0.56	0.41	0.95	0.36	2.46	3.37	6.19	3.5	20.4	66.8	90.7
20		2.87	2.03	0.48	0.47	1.01	0.44	3.18	4.44	8.06	3.9	30.3	93.6	127.8
40		2.86	2.15	0.46	0.48	1.03	0.50	3.56	5.01	9.07	4.3	35.7	106.9	146.9
80		2.94	2.30	0.44	0.58	1.14	0.56	3.56	5.65	9.77	4.8	42.4	131.4	178.6
Significance		NS	**	**	**	**	**	**	**	**	**	**	**	**
BLSD (5%)		--	0.13	0.05	0.06	0.03	0.04	0.30	0.35	0.58	0.4	6.1	9.0	12.3
Linear		NS	**	**	**	**	**	**	**	**	**	**	**	**
Quadratic		*	NS	*	NS	NS	*	**	**	**	NS	++	*	*
Nitrogen Application														
0		2.21	1.35	0.58	0.43	0.92	0.26	2.21	2.92	5.39	2.9	19.2	54.5	76.6
100		3.12	2.18	0.48	0.46	0.99	0.49	3.54	4.83	8.86	4.6	33.0	96.9	134.5
200		3.43	2.71	0.39	0.57	1.20	0.63	3.81	6.12	10.56	4.9	44.4	147.7	197.0
Significance		**	**	**	**	**	**	**	**	**	**	**	**	**
BLSD (5%)		0.11	0.11	0.04	0.05	0.03	0.03	0.26	0.30	0.49	0.4	5.1	7.7	10.6
Interaction														
Yard Waste x Nitrogen		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	1.54	3.28	3.18	0.97	8.97
20	0	2.29	3.59	4.23	1.50	11.61
40	0	3.34	5.00	5.81	2.49	16.64
80	0	5.71	6.53	5.87	1.90	20.01
0	100	1.68	2.73	3.41	0.87	8.69
20	100	3.01	4.57	3.02	0.97	11.57
40	100	3.64	4.53	3.22	0.95	12.34
80	100	7.22	8.34	5.01	1.33	21.90
0	200	2.63	3.89	2.95	0.71	10.18
20	200	2.78	5.06	3.93	1.10	12.87
40	200	4.21	5.84	3.59	1.12	14.76
80	200	7.24	8.88	4.92	2.23	23.27
Significance		**	**	++	*	**
BLSD (5%)		2.43	3.55	3.05	1.37	7.54
Main effects						
Yard Waste Rate						
0		1.95	3.30	3.18	0.85	9.28
20		2.69	4.41	3.73	1.19	12.02
40		3.73	5.12	4.20	1.52	14.57
80		6.72	7.92	5.27	1.81	21.72
Significance		**	**	*	*	**
BLSD (5%)		1.29	1.73	1.39	0.68	3.83
Linear		**	**	**	**	**
Quadratic		NS	NS	NS	NS	NS
Nitrogen Application						
	0	3.22	4.60	4.77	1.71	14.30
	100	3.89	5.04	3.66	1.03	13.62
	200	4.21	5.92	3.85	1.29	15.27
Significance		NS	NS	NS	++	NS
BLSD (5%)		--	--	--	0.59	--
Interaction						
Yard Waste x Nitrogen		NS	NS	NS	NS	NS

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

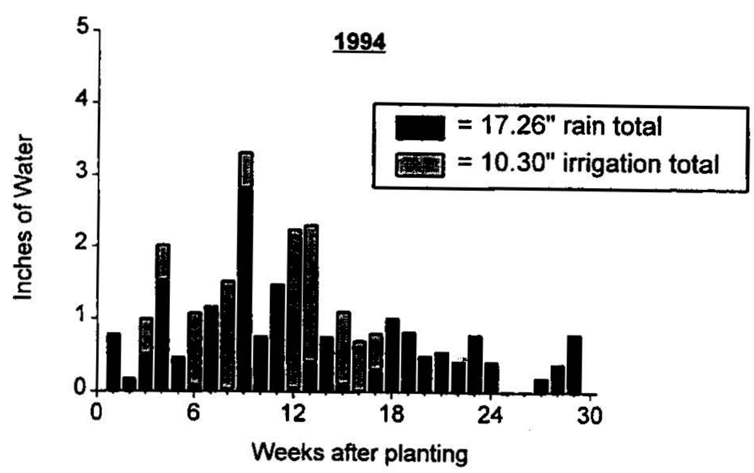

Figure 1. Rainfall and irrigation during the 1994 growing season.

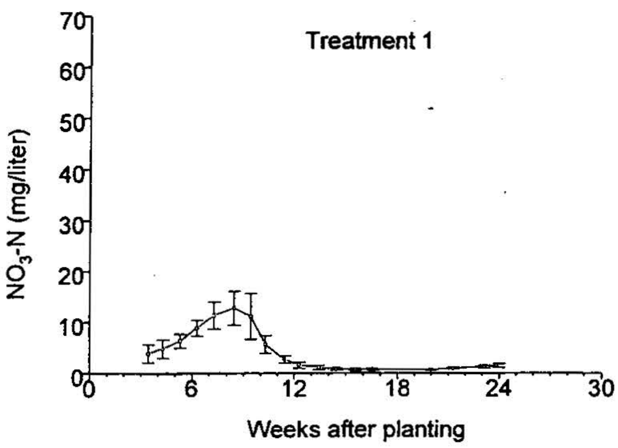

Figure 2. Nitrate - N concentration in soil water sampled at the 4 ft. depth over the 1994 growing season. Treatment 1: no leaves, no nitrogen applied. Error bars represent SE of the mean.

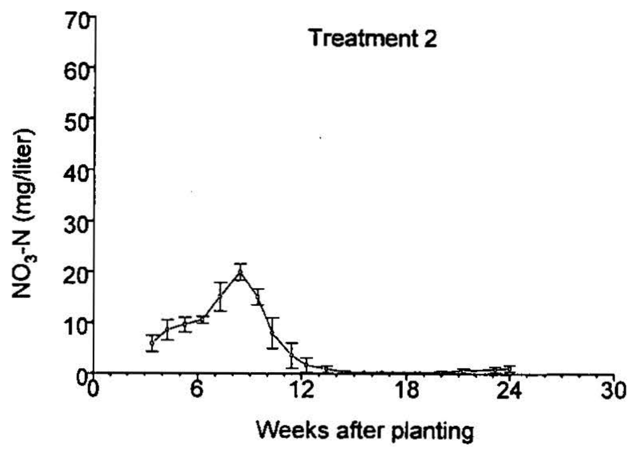

Figure 3. Nitrate - N concentration in soil water sampled at the 4 ft. depth over the 1994 growing season. Treatment 2: 20 tons/A leaves, no nitrogen applied. Error bars represent SE of the mean.

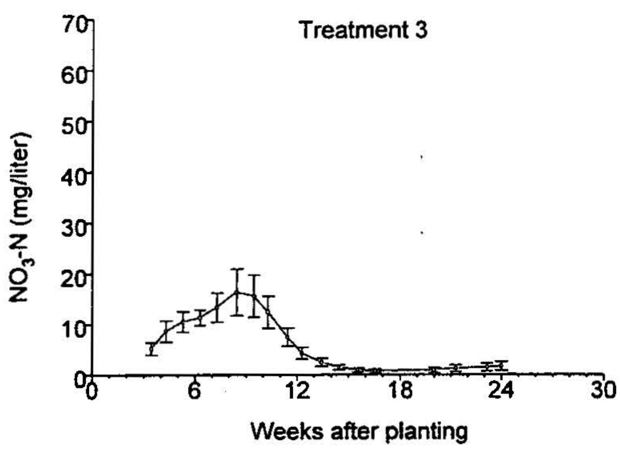

Figure 4. Nitrate - N concentration in soil water sampled at the 4 ft. depth over the 1994 growing season. Treatment 3: 40 tons/A leaves, no nitrogen applied. Error bars represent SE of the mean.

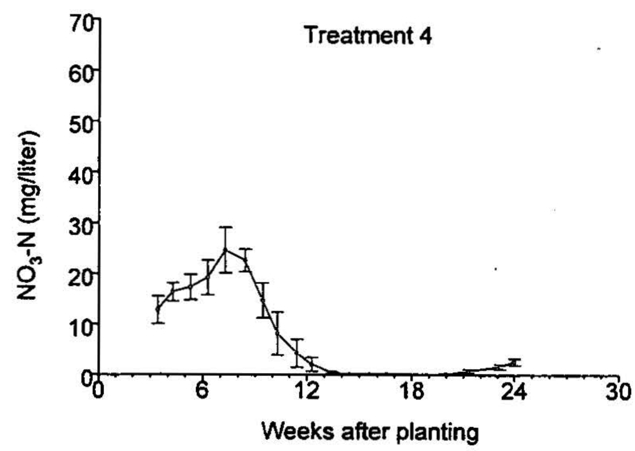

Figure 5. Nitrate - N concentration in soil water sampled at the 4 ft. depth over the 1994 growing season. Treatment 4: 80 tons/A leaves, no nitrogen applied. Error bars represent SE of the mean.

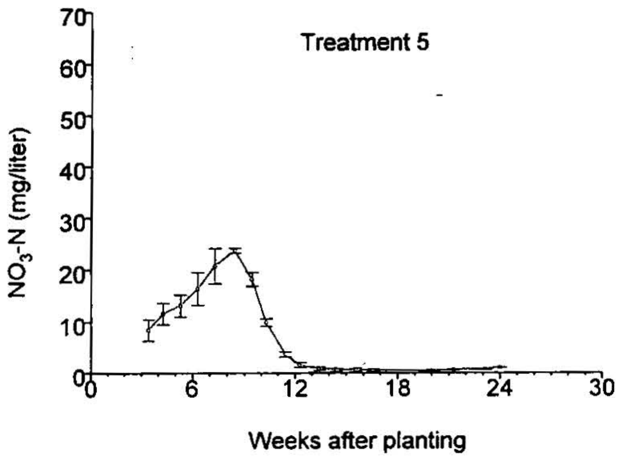

Figure 6. Nitrate - N concentration in soil water sampled at the 4 ft. depth over the 1994 growing season. Treatment 5: no leaves, 100 lbs/A nitrogen applied during the growing season. Error bars represent SE of the mean.

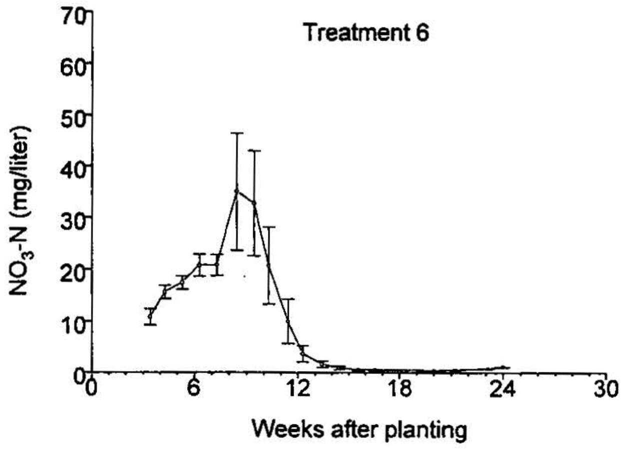

Figure 7. Nitrate - N concentration in soil water sampled at the 4 ft. depth over the 1994 growing season. Treatment 6: 20 tons/A leaves, 100 lbs/A nitrogen applied during the growing season. Error bars represent SE of the mean.

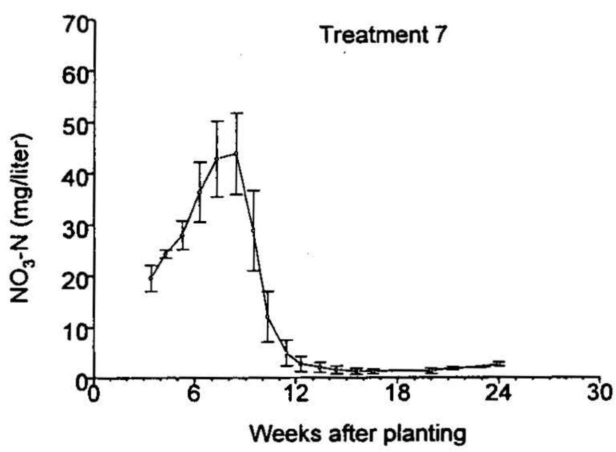

Figure 8. Nitrate - N concentration in soil water sampled at the 4 ft. depth over the 1994 growing season. Treatment 7: 40 tons/A leaves, 100 lbs/A nitrogen applied during the growing season. Error bars represent SE of the mean.

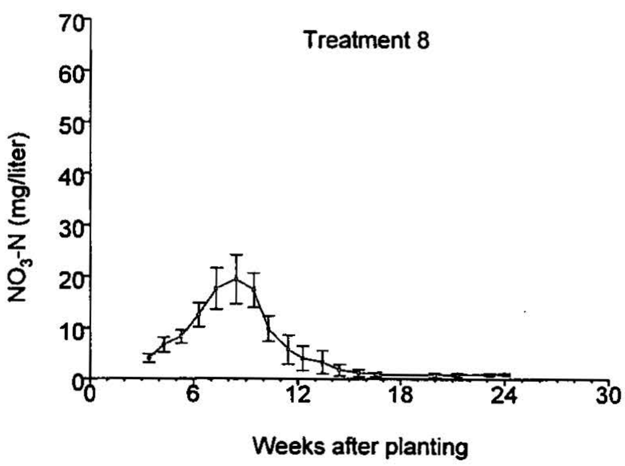

Figure 9. Nitrate - N concentration in soil water sampled at the 4 ft. depth over the 1994 growing season. Treatment 8: 80 tons/A leaves, 100 lbs/A nitrogen applied during the growing season. Error bars represent SE of the mean.

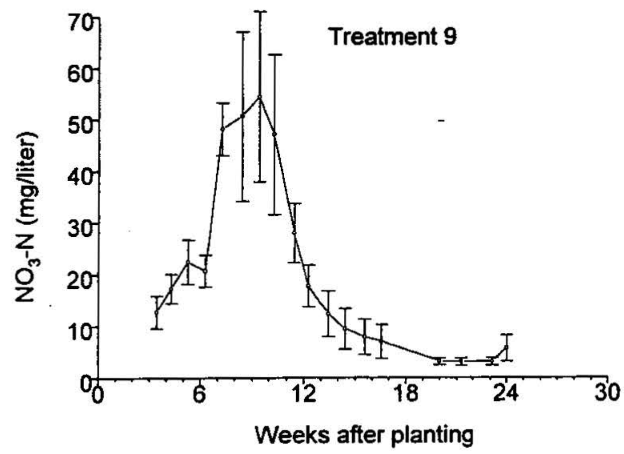

Figure 10. Nitrate - N concentration in soil water sampled at the 4 ft. depth over the 1994 growing season. Treatment 9: no leaves, 200 lbs/A nitrogen applied during the growing season. Error bars represent SE of the mean.

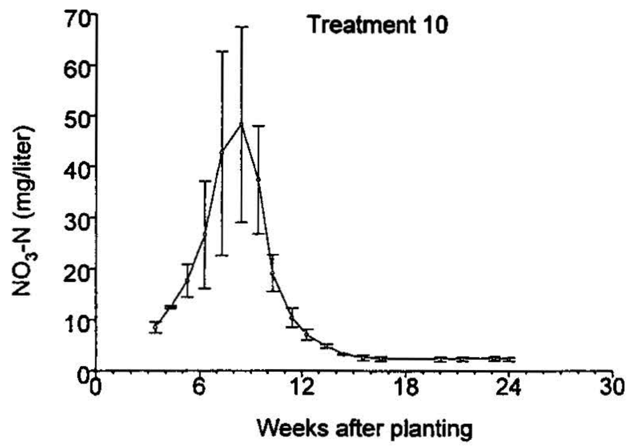

Figure 11. Nitrate - N concentration in soil water sampled at the 4 ft. depth over the 1994 growing season. Treatment 10: 20 tons/A leaves, 200 lbs/A nitrogen applied during the growing season. Error bars represent SE of the mean.

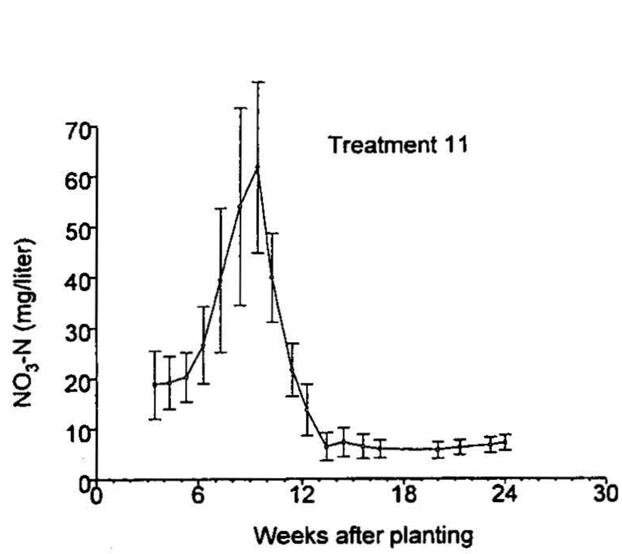

Figure 12. Nitrate - N concentration in soil water sampled at the 4 ft. depth over the 1994 growing season. Treatment 11: 40 tons/A leaves, 200 lbs/A nitrogen applied during the growing season. Error bars represent SE of the mean.

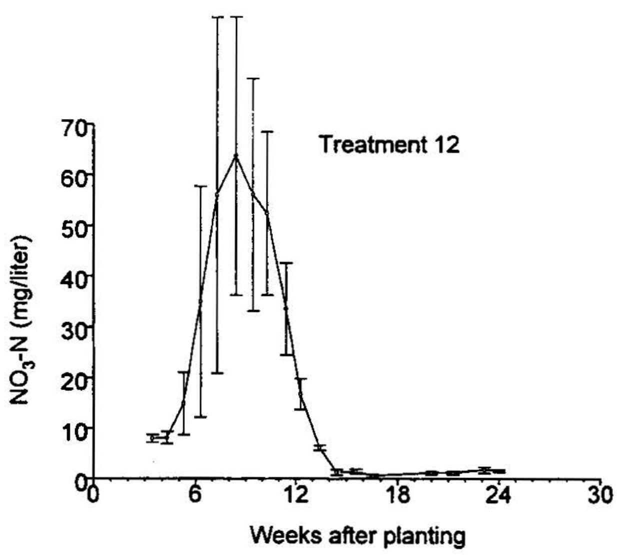

Figure 13. Nitrate - N concentration in soil water sampled at the 4 ft. depth over the 1994 growing season. Treatment 12: 80 tons/A leaves, 200 lbs/A nitrogen applied during the growing season. Error bars represent SE of the mean.

AGRICULTURAL UTILIZATION OF NUTRALIME: RESIDUAL EFFECTS ON ALFALFA PRODUCTION[1]

Carl Rosen, Dave Birong, and Jennifer Weiszel[2]

ABSTRACT: The fourth year of a NutraLime demonstration was conducted in Isanti county. NutraLime (spent lime and sewage sludge incinerator ash) was applied in 1991. Residual effects were monitored in 1994 on a second year alfalfa crop. Spent lime without ash was applied on half the control plots in 1993 to determine effects of raising pH without the elements in the ash. Alfalfa yields increased substantially with NutraLime application and to a lesser extent with spent lime application compared to the nonammended treatment. Elevated concentrations of Mo in alfalfa tissue (up to 7 ppm Mo) were associated with NutraLime application. The Cu/Mo ratios (<2) in alfalfa tissue from NutraLime plots were below those considered safe for chronic ingestion by ruminants. If fed to ruminants, close monitoring of the Cu/Mo ratio in feed rations is recommended. Mixing rations with low Mo forage or supplementing rations with Cu would be two methods to overcome the high Mo problem. Higher Mo was also found in alfalfa grown on limed plots, but levels were about 3 to 4 time lower than with NutraLime. Application of NutraLime increased soil water sulfur concentrations at the 2.5 ft depth. Trace metals in soil water were generally below detection limits at the 2.5 ft depth. In cases where NutraLime increased trace elements in soil water (Zn for example), the levels detected were all well below limits set for drinking water. Soil pH and plant available P increased with increasing NutraLime application. DTPA extractable Cd, Pb, Mo, and Cu increased with NutraLime in the top 6 inches, whereas DTPA extractable Fe, Ni, and Mn decreased. NutraLime had no effect on DTPA extractable Zn or Cr. Nitric acid extractable elements increased in the top 6 inches with NutraLime application.

NutraLime is a product made from two waste materials: sewage sludge incinerator ash from the Metropolitan Waste Control Commission in St. Paul and spent lime from municipal water treatment plants. Land application of these waste products has been studied individually in previous research. The sewage sludge ash was found to supply phosphorus and micronutrients for crop production. At realistic application rates, heavy metals were not found to be taken up by plants nor did the metals move significantly in the soil. Spent lime was found to an effective liming amendment. By combining these two waste products, both nutrients and lime could be recycled onto cropland, alleviating the need to rely on landfills for disposal. The objectives of this demonstration plot were to inform growers and the public about NutraLime, monitor alfalfa growth at various rates of applied NutraLime, monitor plant uptake of elements supplied by NutraLime, and follow movement of elements supplied by NutraLime in soil. All results reported here are based on residual effects of NutraLime following a one time application in 1991.

PROCEDURES

One field site, used for commercial crop production, was selected for the demonstration plot. The site was located in Isanti county on a Hayden silt loam. The site had an initial pH of 5.5, Bray P1 of 40 ppm, and ammonium acetate extractable K of 170 ppm. Treatments were applied in 1991 and consisted of a control and three rates (5.1, 10.2 and 20.4 dry tons/A) of NutraLime, replicated three times in strips. The strips were 25 feet wide and 300 feet in length. Prior to NutraLime application, 14" suction tubes were buried so that the ceramic tip was about 2.5' deep. These suction tubes were intended to be used for the duration of the demonstration without having to reinstall them each year. Plastic line from the suction tubes was laid along a 5' trench, so that soil above the suction tube would not be disturbed when water samples were collected, and the line was buried to allow for tillage operations. The NutraLime was applied as a slurry using a terragator set at the 0.5X rate. To obtain the 1X and 2X rate, the terragator travelled 2 and 4 times, respectively, over the plots at the same speed. Preweighed plastic trays (3ft x 2ft) were placed in the middle of each 0.5X strip to catch the applied material. The trays were weighed again after application and a subsample was collected in plastic bottles for moisture determination and elemental content. Elemental content of the NutraLime was determined on concentrated nitric acid/perchloric acid digests and has been presented previously. In addition to the NutraLime applied in 1991, spent lime (without the ash) was applied on half of the control plots at a rate of 20 dry tons/acre on April 24, 1993. Potassium was applied as KCl at the rate of 600 lb K_2O/A. The lime and potassium were disked in to a depth of 6" and the alfalfa (Agate) was planted on April 25, 1993. The site was nonirrigated.

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[1]Funding for this project was provided by the Metropolitan Waste Control Commission.
[2]Extension Soil Scientist, Assistant Scientist, and Senior Research Plot Technician, respectively, Department of Soil, Water and Climate.

Soil water samples were collected two times during the growing season at each site. Multiple elements were determined in water samples using ICP procedures. Alfalfa was harvested four times in 1994: June 3, July 13, August 24 and October 17. Harvested area included 6 square feet per replication. Samples were dried at 60 C, and then the samples were ground to pass through a 30 mesh screen. Samples were ashed, dissolved in 1 N HCl and then analyzed for elemental content using ICP procedures. Tissue nitrogen concentrations were determined following Kjeldahl digestion using conductimetric procedures. Soil samples were collected in the spring and fall; within each replication, eight subsamples were combined down to a depth of 6 inches. Samples were air dried and then ground. Multiple elements were determined on 1N nitric acid extracts. Other analyses included soil pH and soluble salts (1:1 soil:water), ammonium acetate extractable cations, and DTPA extractable metals.

RESULTS

Plant growth and yield. Effects of NutraLime on alfalfa growth are presented in Table 1. Except for the first cutting where no differences among treatments were recorded, NutraLime increased alfalfa yield substantially compared to the nonlimed control. Yield with NutraLime also tended to be greater than yield with the limed control. This comparison is somewhat biased toward the NutraLime treatment since the lime application was recently applied and only disked in prior to planting. The yield data from 1994 indicate that when applied at realistic rates, NutraLime can have a beneficial effect on plant growth.

Elemental Concentrations in Soil Water. Concentrations of Al, B, Cd, Cr, Cu, Fe, K, Mo, Ni, P, and Pb in soil water at the 2.5 ft depth were generally below detection limits (Table 2). Concentrations of Ca, Mg, Mn, Na, and Zn were not consistently affected by NutraLime application. Concentrations of S increased with increasing NutraLime at both sampling dates.

Elemental Concentrations in Soil. Soluble salts, soil pH, Bray and Olsen P, ammonium acetate extractable cations and DTPA extractable metals in the spring and fall of 1994 are presented in Tables 3 and 4, respectively. In general, few changes occurred between the spring and fall sampling dates. Soil pH was substantially higher (1 - 2 units) in the top 6 inches with NutraLime application compared to the control. Lime application resulted in similar pH changes as the NutraLime. Soluble salts in the top 6 inches generally increased with NutraLime application rate; however, none of the soluble salt levels were in a range considered to be high enough to cause salt toxicity. Lime application resulted in higher salt levels than the control and similar to those for NutraLime. Bray and Olsen P increased with NutraLime application in the top 6 inches. Lime application resulted in similar extractable P levels as the control. Extractable K decreased with NutraLime application rate. Extractable Ca and Mg increased with NutraLime application in the top 6 inches. DTPA extractable Fe, Mn, and Ni decreased with NutraLime application in the top 6 inches. DTPA extractable Cd, Cu, Pb, and Mo increased in the top 6 inches. DTPA extractable Zn in the top 6 inches was not affected by NutraLime application. DTPA extractable Cr was not affected by NutraLime application, with most concentrations below detection limits of the spectrophotometer. Lime treatment generally decreased availability of Mn, Pb, Ni, Cu and Cd in the top 6".

Nitric acid extractable soil elements are presented in Tables 5 and 6. All elements tested, except K increased with NutraLime application in the top 6 inches. The lime treatment resulted in higher levels of nitric acid extractable Al, B, Ca, Fe, Mg, Mn, and S in the 0-6" depth relative to the nonlimed treatment and lower levels of all elements except for Ca, Mg, Fe, K, and S relative to the NutraLime treatments.

Elemental Concentrations in Plant Tissue. Elemental concentrations in alfalfa tissue at the four harvests are presented in Tables 7-10. In the first harvest, concentrations of N, P, Ca, Mg, Na, Al, Cu, and Mo increased and Mn, Zn, and Ni decreased with increasing NutraLime. Spent lime applications increased Mo compared to the nonlimed treatment. In the other harvests, the most consistent trend was increased levels of P and Mo with NutraLime application. Alfalfa tissue concentrations of Mo relative to tissue Cu in NutraLime amended plots were at a level where molybdenosis could be a problem. The Cu/Mo ratio should be greater than 2 to ensure that molybdenosis does not occur. The Cu/Mo ratios in tissue from the 1X and 2X NutraLime plots were less than 2 at all harvest dates. In contrast to 1993, concentrations of Mo in the alfalfa tissue actually increased over the season. As discussed in previous years when soybean was grown, legumes have a high demand for Mo and seem to accumulate this element in foliage and grain. The amount of Mo applied with the 10 dry ton NutraLime rate was 0.5 lb/A. Based on the yields obtained in this study, the alfalfa crop removes about 0.065 lb Mo per year which means that about 7 to 8 years would be required to remove the Mo applied with NutraLime from alfalfa production. Although the lime treatment also increased Mo concentrations, the level was below that considered a problem for ruminants. For all harvests, Cd, Cr, and Pb were either not affected by NutraLime treatment or were below detection limits.

GENERAL SUMMARY

NutraLime application significantly increased alfalfa yield, but tissue Mo increased to levels where molybdenosis could be a problem if the forage was chronically ingested. The implication for using NutraLime for alfalfa is that plant tissue Mo content needs to be monitored so that rations can be supplemented with copper or mixed with forage that is much lower in Mo. Improved P and Mo nutrition appeared to be involved with increases in alfalfa yield. Concentrations of Cd, Cr, Ni and Pb in plant tissues were below the levels where animal health problems would be a concern. NutraLime effectively increased soil pH and plant available P. Trace elements detected in soil water at the 2.5 foot depth were below limits set for drinking water. If legumes are grown on NutraLime amended soil, monitoring of the NutraLime and forage for Mo content is recommended to prevent molybdenosis problems.

Table 1. Effect of NutraLime on alfalfa whole plant dry weight at the 1 to 10 percent bloom stage - Isanti County.

NutraLime Treatment	Plant dry weight first cutting	Plant dry weight second cutting	Plant dry weight third cutting	Plant dry weight fourth cutting	Plant dry weight year total
	-tons/A-	-tons/A-	-tons/A-	-tons/A-	-tons/A-
0	1.82	1.31	1.05	0.66	4.84
Lime	2.09	1.61	1.24	0.82	5.76
0.5x	2.17	2.03	1.42	0.71	6.33
1.0x	2.34	1.82	1.29	0.99	6.44
2.0x	2.33	1.65	1.55	0.88	6.41
Significance	NS	*	**	*	*
BLSD (5%)	--	0.37	0.22	0.20	1.20
Linear	NS	NS	**	*	*
Quadratic	NS	**	NS	*	*
Lime vs 2.0x	NS	NS	*	NS	NS

NS = not significant, * = significant at 5%, ** = significant at 1%.

Table 2. Effect of NutraLime on elemental composition of soil water collected from suction tubes - Isanti County.

Date	Trmt	Al	B	Ca	Cd	Cr	Cu	Fe	K	Mg	Mn	Mo	Na	Ni	P	Pb	S	Zn
April 21, 1994										ppm								
	0	<0.18	<0.02	28	<0.006	<0.01	<0.03	<0.02	<0.7	11	<0.01	<0.01	10	<0.03	<0.04	<0.08	5	0.05
	0.5x	<0.38	<0.02	77	<0.006	<0.01	<0.03	<0.02	<0.7	26	0.05	<0.01	14	0.04	<0.04	<0.08	16	0.06
	1.0x	<0.18	<0.02	46	<0.006	<0.01	<0.03	<0.02	<0.7	16	0.04	<0.01	10	<0.03	<0.04	<0.08	20	0.11
	2.0x	<0.23	<0.02	52	<0.006	<0.01	<0.03	<0.02	<0.7	18	0.05	<0.01	9	<0.04	<0.04	<0.08	34	0.08
Significance		--	--	NS	--	--	--	--	--	NS	--	--	NS	--	--	--	*	NS
BLSD (5%)		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	19	--
Contrasts																		
Linear		--	--	NS	--	--	--	--	--	NS	--	--	NS	--	--	--	**	NS
Quadratic		--	--	NS	--	--	--	--	--	NS	--	--	NS	--	--	--	NS	NS
May 24, 1994																		
	0	<0.18	<0.02	26	<0.006	<0.01	<0.03	<0.02	<0.7	11	<0.01	<0.01	11	<0.02	<0.04	<0.08	3	0.02
	0.5x	<0.20	<0.02	79	<0.006	<0.01	<0.03	<0.02	<0.7	27	0.06	<0.01	14	0.04	<0.04	<0.08	15	0.04
	1.0x	<0.19	<0.02	41	<0.006	<0.01	<0.03	<0.02	<0.8	15	0.03	<0.01	9	<0.03	<0.04	<0.08	18	0.04
	2.0x	<0.28	<0.02	79	<0.006	<0.01	<0.03	<0.02	<0.7	28	0.08	<0.01	13	0.06	<0.04	<0.08	44	0.04
Significance		--	--	NS	--	--	--	--	--	NS	--	--	NS	--	--	--	**	NS
BLSD (5%)		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	12	--
Contrasts																		
Linear		--	--	NS	--	--	--	--	--	NS	--	--	NS	--	--	--	**	NS
Quadratic		--	--	NS	--	--	--	--	--	NS	--	--	NS	--	--	--	NS	NS

NS = not significant, * = significant at 5%, ** = significant at 1%.

Table 3. Effect of NutraLime on soil pH, soluble salts, Bray P, Olsen P, ammonium acetate extractable cations and DTPA extractable metals - April 21, 1994

						NH_4OAc Extractable				DTPA Extractable								
Depth	Trmt	pH	Soluble Salts	Bray P	Olsen P	K	Ca	Mg	Na	Fe	Mn	Zn	Cu	Pb	Ni	Cd	Cr	Mo
			mmhos/cm	----------	----------	----------	----------	----------	----------	ppm	----------	----------	----------	----------	----------	----------	----------	----------
0-6"	0	6.9	0.10	26	11	240	751	70	4.1	61	28.9	1.3	0.5	0.8	0.8	0.06	<0.03	<0.02
	Lime	7.9	0.37	24	15	209	3472	225	5.0	44	14.4	1.0	0.6	0.7	0.6	0.06	<0.03	<0.02
	0.5x	8.1	0.20	106	31	212	1856	114	5.0	29	10.1	1.2	2.7	0.9	0.5	0.11	<0.03	0.03
	1.0x	8.2	0.20	127	33	213	2171	125	4.9	28	9.4	1.2	3.1	0.9	0.5	0.11	<0.03	0.04
	2.0x	8.2	0.20	143	37	186	2491	136	5.3	28	9.1	1.3	3.7	1.0	0.5	0.12	<0.03	0.04
Significance		**	**	**	**	NS	**	*	NS	**	**	NS	**	**	*	**	--	*
BLSD (5%)		0.2	0.10	29	8	--	860	92	--	13	5.7	--	0.9	0.1	0.2	0.02	--	0.01
Contrasts																		
Linear		**	NS	**	**	*	**	NS	*	**	**	NS	**	**	*	**	--	**
Quadratic		**	NS	**	**	NS	NS	NS	NS	**	**	NS	**	NS	*	**	--	NS
Lime vs 2.0x		NS	**	**	**	NS	*	*	NS	*	NS	NS	**	**	NS	**	--	**

NS = not significant, * = significant at 5%, ** = significant at 1%.

Table 4. Effect of NutraLime on soil pH, soluble salts, Bray P1, Olsen P, ammonium acetate extractable cations, and DTPA extractable metals - October 17, 1994

						NH_4OAc Extractable				DTPA Extractable							
Depth	Trmt	pH	Soluble Salts	Bray P	Olsen P	K	Ca	Mg	Na	Fe	Mn	Zn	Cu	Pb	Ni	Cd	Cr
			mmhos/cm	----------	----------	----------	----------	----------	----------	ppm	----------	----------	----------	----------	----------	----------	----------
0 - 6"	0	6.1	0.10	23	9	155	731	66	4.2	66	17.1	1.1	0.5	0.7	0.7	0.05	0.03
	Lime	8.1	0.27	17	12	144	4112	230	5.2	37	6.9	0.8	0.5	0.4	0.4	0.04	0.03
	0.5x	8.0	0.20	112	29	117	1774	98	5.0	24	5.1	1.1	2.7	0.7	0.6	0.11	0.03
	1.0x	8.1	0.17	135	34	108	2377	110	5.2	23	4.3	1.1	3.3	0.8	0.3	0.12	0.03
	2.0x	8.0	0.17	152	39	106	2603	126	5.5	25	4.2	1.3	3.7	1.0	0.7	0.11	0.03
Significance		**	*	**	**	*	**	**	*	**	**	NS	**	**	NS	**	NS
BLSD (5%)		0.2	0.09	30	7	40	607	34	0.8	16	3.4	--	0.8	0.2	--	0.02	--
Contrasts																	
Linear		**	NS	**	**	*	**	**	**	**	**	NS	**	*	NS	**	NS
Quadratic		**	NS	**	**	NS	*	NS	NS	**	**	NS	**	NS	*	*	NS
Lime vs 2.0x		NS	*	**	**	*	**	**	NS	NS	NS	*	**	**	*	**	NS

NS = not significant, * = significant at 5%, ** = significant at 1%.

Table 5. Effect of NutraLime on nitric acid extractable elements - April 21, 1994

DEPTH	Treatment	Al	B	Cd	Ca	Cr	Cu	Fe	Pb	Mg	Mn	Mo	Ni	P	K	Na	S	Zn
		1 N Nitric Acid Extractable																
		ppm																
0 - 6 inches	0	617	0.4	0.2	1018	0.5	2	567	4	109	104	0.20	1.6	62	295	7	8	4
	Lime	802	0.7	0.2	8743	0.8	3	833	5	410	167	0.22	1.7	103	286	10	22	4
	0.5x	892	0.8	0.6	3148	1.9	18	848	8	238	175	0.31	2.1	472	280	15	13	9
	1.0x	981	0.9	0.7	3705	2.3	22	907	9	278	191	0.35	2.3	576	279	17	15	11
	2.0x	1081	1.0	0.8	4451	2.8	28	954	10	331	203	0.39	2.4	711	263	20	16	12
Significance		**	**	**	*	**	**	**	**	NS	**	**	**	**	NS	**	*	**
BLSD (5%)		104	0.2	0.2	488	0.7	8	125	2	--	27	0.04	0.4	194	--	4	8	3
Contrasts																		
Linear		**	**	**	NS	**	**	**	**	*	**	**	**	**	NS	**	*	**
Quadratic		**	*	**	NS	**	*	**	**	NS	**	**	*	*	NS	*	NS	*
Lime vs 2.0x		**	*	**	NS	**	**	NS	**	NS	*	**	**	**	NS	**	NS	**

NS = not significant; * = significant at 5%, ** = significant at 1%.

Table 6. Effect of NutraLime on nitric acid extractable elements - Isanti County. October 21, 1994

DEPTH	Treatment	Al	B	Cd	Ca	Cr	Cu	Fe	Pb	Mg	Mn	Mo	Ni	P	K	Na	S	Zn
		1 N Nitric Acid Extractable																
		ppm																
0 - 6 inches	0	599	0.3	0.2	972	0.5	2	510	4	103	81	0.18	1.6	54	232	6	7	3
	Lime	790	0.9	0.3	8513	0.8	3	782	7	382	152	0.28	1.8	94	221	9	18	4
	0.5x	855	0.8	0.7	3088	2.0	20	727	8	228	156	0.32	2.5	475	207	14	11	9
	1.0x	990	0.9	0.9	4240	2.8	28	775	10	295	171	0.37	2.3	691	192	18	14	11
	2.0x	1054	1.0	0.9	4573	3.0	30	853	11	326	178	0.40	3.2	744	190	19	14	12
Significance		**	**	**	**	**	**	*	**	**	**	**	**	**	NS	**	**	**
BLSD (5%)		178	0.2	0.2	2470	0.9	10	178	2	109	31	0.07	0.6	251	--	5	4	3
Contrasts																		
Linear		**	**	**	*	**	**	**	**	**	**	**	**	**	NS	**	**	**
Quadratic		*	**	**	NS	**	**	NS	**	NS	**	**	NS	**	NS	*	NS	*
Lime vs 2.0x		**	NS	**	**	**	**	NS	**	NS	NS	**	**	**	NS	**	NS	**

NS = not significant, * = significant at 5%, ** = significant at 1%.

Table 7. Effect of NutraLime on the elemental composition of alfalfa samples, June 3, 1994 - Isanti county.

Treatment	N	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	Mo
	%					ppm											
0	2.45	0.21	3.25	1.03	0.17	25	54	53	44	22.4	6.5	17.9	<1.68	1.91	<0.30	<0.12	<0.26
Lime	2.71	0.22	3.39	1.16	0.17	26	58	67	32	20.2	6.8	16.3	<1.68	2.12	<0.30	<0.12	0.78
0.5x	2.85	0.25	3.36	1.25	0.18	32	63	86	23	17.9	7.3	16.2	<1.68	1.75	0.32	<0.12	2.78
1.0x	2.93	0.27	3.49	1.30	0.19	37	68	102	24	18.1	7.3	17.4	<1.68	1.82	0.35	<0.12	4.01
2.0x	3.13	0.27	3.25	1.38	0.20	45	75	108	25	17.9	7.5	19.0	<1.68	1.41	<0.41	<0.12	4.29
Significance	**	**	NS	*	*	NS	NS	*	NS	**	*	NS	--	NS	--	--	**
BLSD (5%)	0.30	0.02	--	0.18	0.02	--	--	38	--	1.6	0.6	--	--	--	--	--	1.36
Contrasts																	
Linear	**	**	NS	**	**	*	*	**	NS	**	*	NS	--	NS	--	--	**
Quadratic	NS	**	NS	NS	NS	NS	NS	NS	*	**	NS	NS	--	NS	--	--	**
Lime vs 2.0x	*	**	NS	*	*	*	*	*	NS	**	*	NS	--	*	--	--	**

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

Table 8. Effect of NutraLime on the elemental composition of alfalfa samples, July 13, 1994 - Isanti county.

Treatment	N	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	Mo
	%					ppm											
0	3.08	0.26	2.91	1.10	0.18	36	80	77	54	24.6	9.8	21.0	<1.68	2.82	<0.32	<0.12	<0.22
Lime	2.65	0.26	2.86	1.05	0.16	28	73	74	41	21.5	9.6	15.3	<1.68	3.25	<0.30	<0.12	0.92
0.5x	2.89	0.30	2.76	1.21	0.17	38	77	124	40	19.7	8.9	16.5	<1.68	2.69	0.34	<0.12	3.26
1.0x	2.79	0.30	2.61	1.21	0.18	42	79	152	35	18.7	8.7	17.6	<1.68	2.40	0.35	<0.12	5.57
2.0x	2.80	0.30	2.47	1.19	0.19	45	78	184	32	18.3	8.9	16.9	<1.68	2.60	0.41	<0.12	6.38
Significance	NS	**	**	NS	NS	NS	NS	*	NS	**	**	**	--	NS	--	--	**
BLSD (5%)	--	0.02	0.22	--	--	--	--	84	--	2.5	0.6	2.0	--	--	--	--	1.79
Contrasts																	
Linear	NS	**	**	NS	NS	NS	NS	*	*	**	*	**	--	NS	--	NS	**
Quadratic	NS	**	NS	NS	NS	NS	NS	NS	NS	**	**	*	--	NS	--	NS	**
Lime vs 2.0x	NS	**	**	NS	NS	NS	NS	*	NS	*	*	NS	--	NS	--	NS	**

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

Table 9. Effect of NutraLime on the elemental composition of alfalfa samples, August 24, 1994 - Isanti county.

Treatment	N	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	Mo
	%					ppm											
0	3.48	0.25	2.87	1.48	0.20	93	155	115	71	26.1	10.0	22.9	<1.68	4.46	0.63	<0.20	0.27
Lime	3.30	0.28	2.90	1.36	0.19	158	192	121	67	23.8	9.9	19.8	<1.68	5.04	0.77	0.19	0.92
0.5x	3.54	0.32	2.84	1.56	0.20	117	159	156	55	22.3	10.0	18.2	<1.68	3.78	0.72	0.16	3.06
1.0x	3.46	0.32	2.74	1.62	0.21	78	126	157	55	21.6	10.0	20.0	<1.68	3.06	0.63	0.16	5.25
2.0x	3.45	0.32	3.36	1.54	0.21	83	125	229	50	21.2	10.0	25.0	<1.68	3.21	0.64	0.17	5.95
Significance	NS	**	NS	*	NS	NS	NS	NS	*	**	NS	*	--	**	NS	--	**
BLSD (5%)	--	0.01	--	0.16	--	--	--	--	16	2.4	--	2.9	--	0.79	--	--	2.05
<u>Contrasts</u>																	
Linear	NS	**	NS	NS	NS	NS	NS	*	*	**	NS	NS	--	**	NS	--	**
Quadratic	NS	**	NS	NS	NS	NS	NS	NS	NS	*	NS	*	--	*	NS	--	*
Lime vs 2.0x	NS	**	*	*	NS	NS	NS	*	*	*	NS	NS	--	**	NS	--	**

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

Table 10. Effect of NutraLime on the elemental composition of alfalfa samples, October 17, 1994 - Isanti county.

Treatment	N	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	Mo
	%					ppm											
0	3.71	0.26	2.93	1.41	0.20	338	339	138	96	24.9	9.1	27.4	<1.68	6.77	2.29	0.16	0.61
Lime	3.45	0.29	3.15	1.41	0.20	449	446	98	91	23.6	9.2	25.1	<1.82	6.34	2.41	0.18	1.60
0.5x	3.57	0.33	2.96	1.54	0.18	431	417	194	77	22.2	10.3	25.6	<1.88	6.00	3.14	0.17	4.60
1.0x	3.50	0.32	2.90	1.49	0.19	432	403	193	84	20.5	10.3	25.5	<2.00	4.41	2.48	0.16	5.97
2.0x	3.58	0.34	2.86	1.59	0.21	357	328	279	69	21.0	10.7	28.3	<1.82	5.04	2.22	0.17	7.12
Significance	NS	**	NS	NS	NS	NS	NS	NS	NS	**	**	NS	NS	NS	NS	NS	**
BLSD (5%)	--	0.03	--	--	--	--	--	--	--	2.0	0.9	--	--	--	--	--	1.57
<u>Contrasts</u>																	
Linear	NS	**	NS	NS	NS	NS	NS	*	NS	**	**	NS	--	NS	NS	NS	**
Quadratic	NS	*	NS	NS	NS	NS	NS	NS	NS	**	NS	NS	--	NS	NS	NS	**
Lime vs 2.0x	NS	**	NS	NS	NS	NS	NS	**	NS	*	**	NS	--	NS	NS	NS	**

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

EVALUATION OF WOOD ASH AS A LIMING SOURCE[1]

D. L. Rabas and R. D. Mathison[2]

Abstract

Research comparing wood ash from Blandin Paper Company in Grand Rapids to conventional agricultural limestone found the ash to be an effective liming material. An application rate of 10 dry tons/acre (DT/A) of wood ash produced the same increase in soil pH as 4 tons/acre of lime, and application rates above 20 DT/A did not result in further soil pH increases. Five years after treatment application, soil pH of the 10 DT/A ash and lime treatments were 5.7 and and 6.0, respectively (considered too low for alfalfa production), whereas soil pH of the 20, 30 and 40 DT/A ash treatments remained above 6.5. Alfalfa dry matter yield was highest for the 30 and 40 DT/A ash treatments, intermediate for the 10 DT/A ash and lime treatments, and lowest for the control. Ash application did not result in soil or plant tissue heavy metal concentrations higher than the control.

Introduction

Many wood-based industries, such as paper mills, burn waste wood to produce steam or electricity, and many institutions near adequate wood supplies burn wood to heat buildings in winter. The resultant ashes from these activities are high in pH and may have potential as a lime source to neutralize acidic soils for production of pH sensitive crops, such as alfalfa (Medicago sativa). Use of ashes as a lime source would benefit alfalfa producers by providing a low cost alternative to traditional liming materials and would benefit ash producers by providing a disposal alternative to the expensive and environmentally questionable practice of landfilling of large quantities of ash. The objective of this research was to evaluate the agronomic value and environmental aspects associated with farmland utilization of industrially produced wood ashes.

Materials and Methods

The experiment was conducted at Grand Rapids, MN. Soil was a coarse-loamy, mixed, nonacid, frigid Aeric Haplaquepts (Cowhorn very fine sand) with a pH of 5.7. Treatments were hand applied in fall 1986 to 10 x 20 ft plots in a randomized complete block design with four replicates, then immediately incorporated to a depth of 2 in. with a tractor-mounted Howard rotovator. All plots initially received 66, 306, and 54 lb/a of S, K, and MG, respectively and 240 and 4 lb/a of K and B annually to ensure plant responses were to soil pH, not other nutrients contained in the ash. In the spring following treatment application, carbofuran (2,3 dihydro-2, 2-dimethyl-7-benzifuranyl methylcarbamate) was applied at 2 lb a.i./a before alfalfa establishment for nematode control. 'Oneida' alfalfa was seeded at 15 lb/a on May 11, 1987.

Herbage yields were measured by cutting a 54 sq ft area within each plot to a 4 in stubble height. Wet forage yields were adjusted to dry weight by drying a 500 to 800 g subsample from each plot at 135° F to determine dry matter percentage. One harvest was taken during the seeding year, followed by a lenient 3 cut/year schedule in subsequent years to maximize forage yield and favor long-term stand persistence.

Soil samples were collected at the beginning of the study and annually after the second harvest at depths of 0 to 6 in. Samples were sent to the University of Minnesota Research Analytical Laboratory to be analyzed for pH, S, K, Ca, Mg, Na, Cu, B, Zn, Fe, Mn, Cr, Cd, Ni, and Pb according to Recommended Chemical Soil Test Procedures for the North Central Region (North Dakota State University Bulletin 499 [Revised], October, 1988), except that samples, excluding pH samples, were weighed rather than scooped. In the first and last production years of each experiment, all four replicates were sampled to allow statistical analysis of soil test data. In intermediate years, samples from the four individual plots of each treatment were bulked to form two samples to minimize analysis costs. Plant tissue samples consisting of the top one third of one tenth bloom alfalfa were hand cut at the second harvest to allow comparisons with soil test data and to monitor the possible accumulation of toxic compounds in harvested forage.

Results

Soil pH

Ash proved to be an effective liming material. Soil pH changes indicated that approximately 2.5 tons of ash were equivelant to 1 ton of the agricultural limestone used in this study, as the 10 DT/A ash rate produced the same change in soil pH as 4 t/a lime. After 5 years, soil pH of the lime and 10 DT/A ash had declined below 6.5, the level considered necessary for alfalfa production. Maximum soil pH increase was reached with application of 20 DT/A of ash; however the 30 and 40 DT/A application rates maintained the higher soil pH levels longer.

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[1] Support for this project was provided by the Blandin Foundation.

[2] D. L. Rabas is Head and R. D. Mathison is Agronomist, respectively, at the North Central Experiment Station, University of Minnesota, Grand Rapids.

Forage yield

Forage dry matter yield was increased with the addition of lime, as expected. Ash application also resulted in increased forage dry matter yield, with the 10 and 20 DT/A ash application rates resulting in dry matter yield increases similar to the ag lime treatment, and the 30 and 40 DT/A application rates yielding significantly more. The reason for the dry matter yield increase associated with the two higher ash rates is not readily apparent, as sufficient fertilizer was added annually as part of the experimental procedure to attempt to eliminate soil fertility as a variable in this study. Comparison of soil and plant tissue elemental analysis suggests differences in soil K levels may have been partially responsible for the observed yield differences because treatments with the highest dry matter yield had significantly higher soil and plant tissue K levels. Similarly, differences in S levels may have also been partially responsible for the observed differences in dry matter yield.

Table 1. Effect of treatment application on forage dry matter yield[3] and plant tissue elemental analysis[4]

Treatment	Yield	Plant Tissue							
		SO_4	K	Mg	B	Pb	Ni	Cd	Cr
	TDM/A	%	ppm						
Check	6.32	0.24	17,971	2660	89	<2.16	2.33	<0.32	<0.22
Ag lime, 4T/A	7.87	0.28	16,386	3174	78	<2.16	1.99	<0.33	<0.22
Ash,10 TDM/A	7.78	0.29	18,568	2546	86	<2.16	<2.09	<0.40	<0.24
Ash,20 TDM/A	8.36	0.31	20,207	2440	80	<2.16	<1.81	<0.39	<0.24
Ash,30 TDM/A	8.93	0.33	22,254	2298	81	<2.16	1.62	<0.32	<0.30
Ash,40 TDM/A	8.93	0.35	22,338	2283	89	<2.16	2.25	<0.28	<0.23
LSD (0.05)	0.74	0.04	2335	230	NS	NS	NS	NS	NS

Table 2. Effect of treatment application on soil pH and elemental analysis[5]

Treatment	pH		Soil							
	1987	1990	K	Mg	SO_4	B	Pb	Ni	Cd	Cr
			ppm							
Check	5.7	5.2	81	60	7	1.3	3.06	0.53	0.04	<0.02
Ag lime, 4 T/A	6.5	6.0	61	140	8	1.5	3.56	0.38	0.05	<0.03
Ash,10 TDM/A	6.5	5.7	73	63	6	2.1	3.15	0.43	0.07	<0.02
Ash,20 TDM/A	7.3	6.6	88	64	8	2.4	2.38	0.27	0.06	<0.02
Ash,30 TDM/A	7.3	7.1	112	73	9	2.5	2.95	0.33	0.04	<0.02
Ash,40 TDM/A	7.5	7.2	114	78	10	3.3	3.91	0.26	0.04	<0.02
LSD (0.05)	0.5	0.3	27	20	2	0.7	NS	0.13	NS	<0.004

[3]Total forage dry matter yield for 1988 through 1990.

[4]Top one third of earlhy bloom aflalfa taken at the second harvest.

[5]0 to 6 in. sampling depth, collected after the second harvest.

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

Field experiments were conducted at Staples and Becker to assess corn yield and nitrate leaching on soils amended with municipal solid waste (MSW) compost. The MSW composts (Truman, Swift, and St. Cloud) were applied in the spring of 1992. The Becker location received Truman and Swift composts, while Staples received Truman and St. Cloud. The compost rates were 0, 20,40, and 80 dry T/A with either 0, 220, or 440 lbsN/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 1994, nitrate leaching was high on compost amended soils compared to unamended soils. Nitrogen application on all compost types and rates increased NO_3-N leaching. In 1993, yield was relatively high on residual plots compared to the control. The 1993 established plot gave a reasonable yield at all compost rates with N application in 1994. Yield was lower at all compost rates when N was not applied.

INTRODUCTION

Increasing costs and environmental concerns associated with landfills and incineration have prompted interest in developing alternative methods for managing municipal wastes. Viable waste management alternatives should ideally be environmentally sound and should emphasize recycling of resources. Composting of municipal solid waste (MSW) has been given consideration during recent years as it becomes a practical alternative to landfilling. The number of composting facilities in the U.S. has consistently increased in number since 1988. This increase is due to limited storage capacity of landfills and their failure to meet regulatory guidelines and increasing costs. Minnesota leads the nation in MSW composting facilities with eight currently in operation. Thus, there is a need to determine environmentally safe and beneficial uses as well as establish potential markets for the compost.

The compost utilization project (CUP) was initiated in 1992 to evaluate the use of municipal solid waste (MSW) compost on crop production. Three compost studies were established in 1992 and 1993 at Becker and Staples, MN. Two of the experiments were established in 1992 at Becker and Staples to compare the effects of MSW compost and nitrogen (N) application rates on field corn production. A third experiment was established in 1993 to compare a one time compost application (120 T/A) with three annual compost application (40 T/A). The overall goals of the 1994 CUP 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 and 3) to monitor levels of nitrate in soil water 4) to assess if any water stress is induced by compost amendments on plants.

MATERIALS AND METHODS

1994 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. In 1994, the 440 lbs/A N rate was omitted.
- Corn variety 3921 Pioneer (85 day) was planted May 6, 1994 at a planting rate of 30,700 kernels per acre in 30" rows with starter fertilizer banded at 160 lbs/A (8-10-30).

[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, Associate Professor, Extension Specialist, and Associate Professor, respectively.

- Granular fertilizer urea 46-0-0 was split applied: one-half on 5/26/94 and the other half on 6/16/94. The urea was sidedressed with a Gandy on both sides of each row and irrigated in with 0.5-1" of water for incorporation.
- Four whole plant samples were taken from each plot for chemical analysis on 6/24/94.
- Two 20' rows of corn were harvested for grain and stover between 9/29/94 and 10/6/94.

1994 Staples Compost Utilization Project
(established in 1992)

- The treatments for the 1992 established experiment are listed in Table 2. MSW compost was applied only in the first year. Nitrogen fertilizer was applied every year. In 1994, the 440 lbs/A N rate was omitted.
- Corn variety 3921 Pioneer (85 day) was planted May 3, 1994 at a planting rate of 32,200 kernels per acre in 30" rows with starter fertilizer banded at 175 lbs/A (25-5-10-20).
- Granular fertilizer urea 46-0-0 was split: applied one-half on 5/31/94 and the other half on 6/13/94. The urea was sidedressed with a Gandy on both sides of each row and incorporated by cultivation.
- Four whole plant samples were taken from each plot for chemical analysis on 6/23/94.
- Two 20' rows of corn were harvested for grain and stover on 10/14/94.

1994 Becker Compost Utilization Project
(established in 1993)

- The treatments for the 1993 established experiment are listed in Table 3. MSW compost was applied either annually for two years or at one cumulative rate the first year. Nitrogen fertilizer was applied every year.
- Corn variety 3921 Pioneer (85 day) was planted May 6, 1994 at a planting rate of 32,200 kernels per acre in 30" rows with starter fertilizer banded at 160 lbs/A (8-10-30).
- Granular fertilizer urea 46-0-0 was split applied: one-half on 5/26/94 and the other half on 6/16/94. The urea was sidedressed with a Gandy on both sides of each row and irrigated with 0.5-1" of water for incorporation.
- Four whole plant samples were taken from each plot for chemical analysis on 6/24/94.
- Two 15' rows of corn were harvested for grain and stover between 9/30/94 and 10/17/94.

Table 1. Residual effect of compost type, compost rate, and nitrogen rate on grain yield, stover yield, and plant population, Becker, MN. 1994.

Compost type	N rate LBS/A- 1994	Compost rate T/A 1992	Grain Yield BU/A	Stover Yield T/A	Plant/A Population x 1000
Control	0	0	49.3	1.46	24.8
Control	220	0	153.9	2.88	26.0
Control§	440	0	68.5	1.76	24.7
Truman	0	20	84.3	2.04	27.2
Truman	220	20	155.0	3.05	26.2
Truman	0	40	98.4	2.17	24.5
Truman	220	40	162.7	3.04	25.7
Truman§	440	40	94.6	2.44	25.5
Truman	0	80	110.0	2.44	26.2
Truman	220	80	175.3	3.55	27.8
Swift	0	40	118.1	2.37	25.7
Swift	220	40	163.1	2.90	25.0
Significance			**	**	**
BLSD			12.9	0.72	1.8

§ The N rate at 440 lbs/A was applied only in 1992 and 1993. * Significant at 5% **Significant at 1% NS= Not significant

Table 2. Residual effect of compost type, compost rate, and nitrogen rate on grain yield, stover yield, and plant population, Staples, MN. 1994.

Compost type	N rate LBS/A 1994	Compost rate T/A 1992	Grain Yield BU/A	Stover Yield T/A	Plant/A Population x 1000
Control	0	0	84.3	1.61	28.5
Control	220	0	141.1	2.73	28.6
Truman	0	20	95.5	1.76	28.5
Truman	220	20	140.6	3.00	26.8
Truman	0	40	108.0	2.02	27.7
Truman	220	40	151.0	2.17	28.0
Truman§	440	40	104.3	1.63	28.6
Truman	0	80	112.5	1.56	28.4
Truman	220	80	140.5	2.73	28.4
St. Cloud	0	40	118.8	2.04	28.1
St. Cloud	220	40	142.1	2.43	27.4
St. Cloud§	440	40	110.7	1.85	29.8
Significance			**	**	NS
BLSD			19.9	0.47	---

§ The N rate at 440 lbs/A was applied only in 1992 and 1993.
* Significant at 5% **Significant at 1% NS= Not significant

Table 3. Effect of compost type, compost rate, and nitrogen rate on grain yield, stover yield, and plant population, Becker, MN. 1994.

Compost type	N rate LBS/A 1994	Compost rate T/A 1993-94	Grain Yield BU/A	Stover Yield T/A	Plant/A Population x 1000
Control	0	0	75.2	1.53	25.4
Control	110	0	160.1	2.53	26.4
Control	220	0	176.6	3.17	27.6
Truman	0	40+40†	119.0	1.80	24.8
Truman	110	40+40	166.9	1.85	26.4
Truman	220	40+40	185.9	3.24	27.4
Truman	0	120	153.6	2.65	25.0
Truman	110	120	175.8	3.47	26.0
Truman	220	120	190.1	3.55	27.6
Wright	0	40+40	145.2	2.55	26.4
Wright	110	40+40	184.2	3.22	26.6
Wright	220	40+40	182.7	3.25	27.2
Wright	0	120	121.8	2.20	25.0
Wright	110	120	178.6	3.21	25.7
Wright	220	120	192.0	4.17	27.3
Compost type			NS	*	NS
N rate			**	**	**
Compost rate			**	**	NS
Compost rate*N rate			**	NS	NS
Compost type*Compost rate			**	**	NS
N rate* Compost type			NS	NS	NS
Compost type*Compost rate*N rate			**	**	NS

* Significant at 5% **Significant at 1% NS= Not significant. †40 T/A applied in 1993, and second 40 T/A applied in 1994.

Table 4.Plant moisture stress measured during the 1994 growing season on the 1992 established experiment, Becker, MN.

Compost type	N rate LBS/A 1994	Compost rate T/A 1992	Leaf Water Potential† MPa Dates:7/29/94 and 7/1/94 Time 9:15-10:10 A.M.	1:30-2:30 P.M.
Control	220	0	0.49(0.28)	1.01(0.22)
Truman	220	40	0.56(0.46)	1.49(0.10)
Truman	220	80	0.53(0.23)	1.13(0.37)
Swift	220	40	0.52(0.31)	1.09(0.28)
Time			**	
Time*Compost			NS	
Date			**	
Time*Date			NS	
Compost*Date			NS	
Time*Compost*date			NS	

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

Table 5. Plant moisture stress measured during the 1994 growing season on the 1993 established experiment, Becker, MN.

Compost type	N rate LBS/A 1994	Compost rate T/A 1993-94	Leaf Water Potential† MPa Dates: 7/29/94 and 7/1/94‡ Time 8:15-10:10 A.M.	12:30-1:30 P.M.
Control	220	0	0.34(0.13)	0.91(0.30)
Truman	220	40+40	0.32(0.17)	1.04(0.36)
Truman	220	120	0.30(0.16)	0.89(0.23)
Wright	220	40+40	0.31(0.15)	0.97(0.24)
Wright	220	120	0.30(0.12)	0.67(0.25)
Time			**	
Time*Compost			NS	
Date			**	
Time*Date			NS	
Compost*Date			NS	
Time*Compost*date			NS	

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

SUMMARY OF RESULTS

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

YIELD
Compared to the control, grain yield was high at all compost rates with no N application (Tables 1 and 2). Yields at both sites were generally lower than 1993 when N was not applied. Nevertheless, trend of MSW compost residual effect still remains in 1994. Grain yield of residual compost with optimum N rate was generally higher than the control at the same N rate (Becker site).

SOIL WATER NITRATE
Becker (Figs. 1a, b, c, and d)- Soil water NO_3-N was generally high for the 20 T/A Truman compost with no N application. As expected, all compost rate at the 220 lbs N/A resulted in higher NO_3-N loss than the 0 lbs N/A. Compared to the control with N, the compost rates at 20, 40, and 80 T/A gave higher nitrate leaching losses.

Staples (Figs. 1a, b, c, and d)- Soil water NO_3-N was lower for no N compost rates compared to the 220 lbs N/A treatment. The Truman compost at 80 T/A and 220 lbs N/A resulted in much higher NO_3-N loss throughout the growing season compared to all other compost rates at the same N rate.

PLANT MOISTURE STRESS
Water stress measurements were made on two clear and warm days (air temperature: mid 80's). Unless of rain events, irrigation was not made before stress maesurements. The last irrigation event of one inch was made on 7/15/94 before leaf water potential measurements on 7/29/94 and 8/1/94. Morning leaf water potential were highly significantly lower than the afternoon. In the 1992 established experiment at Becker, compost treatment on plant moisture stress was not significant (Table 4).

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

YIELD

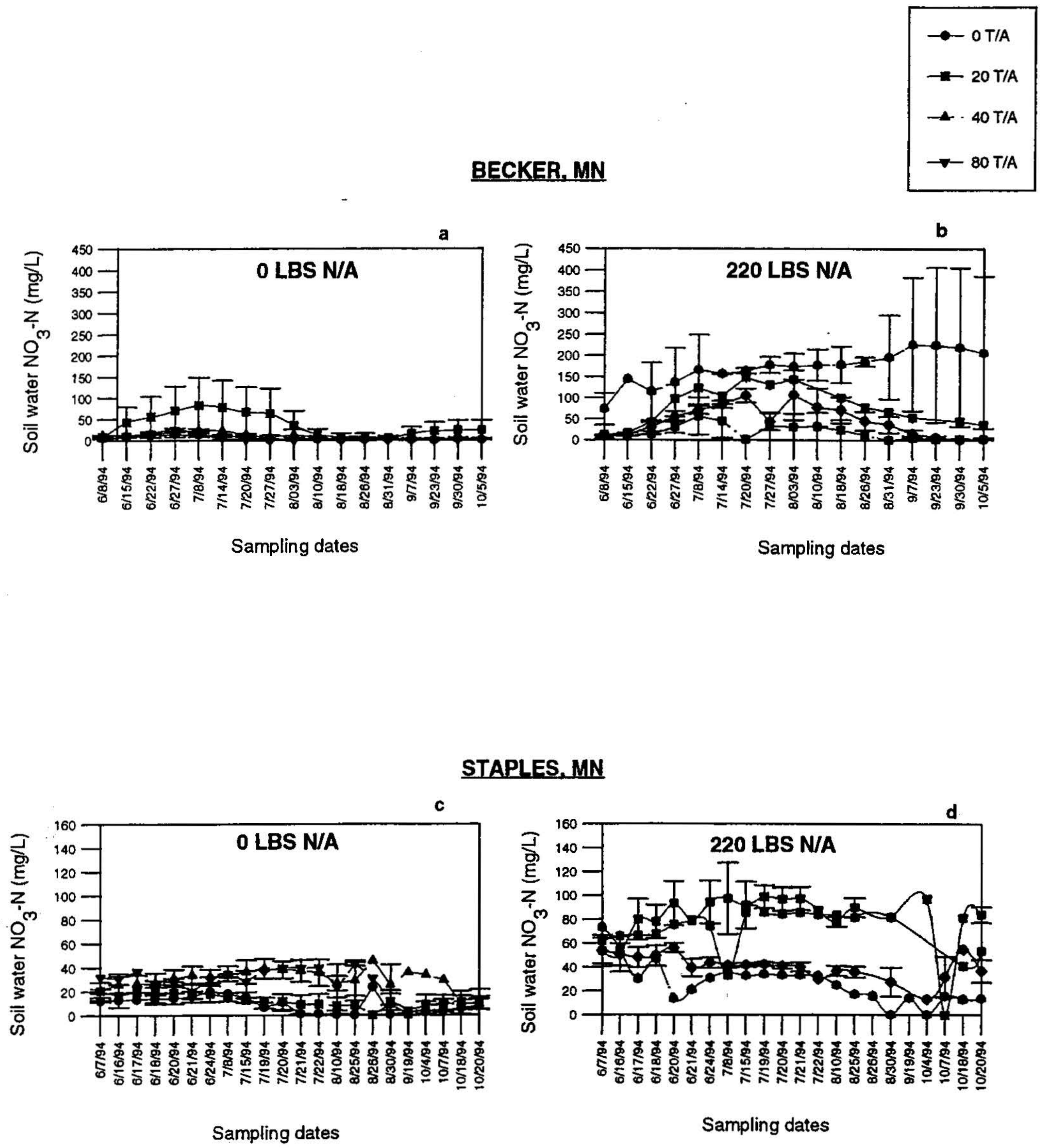
Grain and stover yields were much higher for all compost rates with no N application (Table 3). The higher grain and stover yield of the compost with no N suggests residual compost effect. Grain yield at a rate of 120 T/A compost with no N was higher for the Truman compost compared to the Swift compost, in which the latter gave much higher yield in 1993. In the year of application (1993), the Truman compost had a high C:N ratio (30:1). This high C:N of Truman in 1993 resulted in lower yield due to immobilization of applied N. The split application of MSW compost improved yield for both compost sources when N is added. The split application (40 T/A in 1993, and additional 40 T/A in 1994) of Truman compost with no Napplied resulted in lower grain yield compared to the 120 T/A one time application of Truman compost with no N application. This is suggestive of N immobilization by 40 T/A Truman compost (C:N> 20:1) applied in the second year (1994) and N mineralization one year after application of 120 T/A Truman compost (1993). The Wright compost split application (40 T/A in 1993, and additional 40 T/A in 1994) with no applied N gave higher yield compared to the Truman compost at the same compost and N rates as well as the 120 T/A Wright compost with no N (Table 3). Overall, The Wright compost had lower C:N ratio compared to the Truman compost both in 1993 and 1994. Thus, in the second year split application of Wright compost (40 T/A in 1993, and additional 40 T/A in 1994), there was less immobilization of the applied N, and hence resulted in higher yield compared to the Truman compost. Generally, the cumulative 80 T/A (40+40 T/A) rate still gave much higher grain yield for both sources compared to the control.

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 in 1993 generally gave higher NO_3-N losses compared to the annual rate of 40 T/A. This may be indicative of N mineralization from Truman compost a year after application, resulting in more N available for leaching. On the contrary, Wright compost amended in split at 40 T/A gave higher NO_3-N losses throughout most of the growing season compared to the Truman compost at the same rate. This is again associated with the low C:N of Wright compost All Wright compost rates at 220 lbs N/A had much higher NO_3-N loss compared to the control.

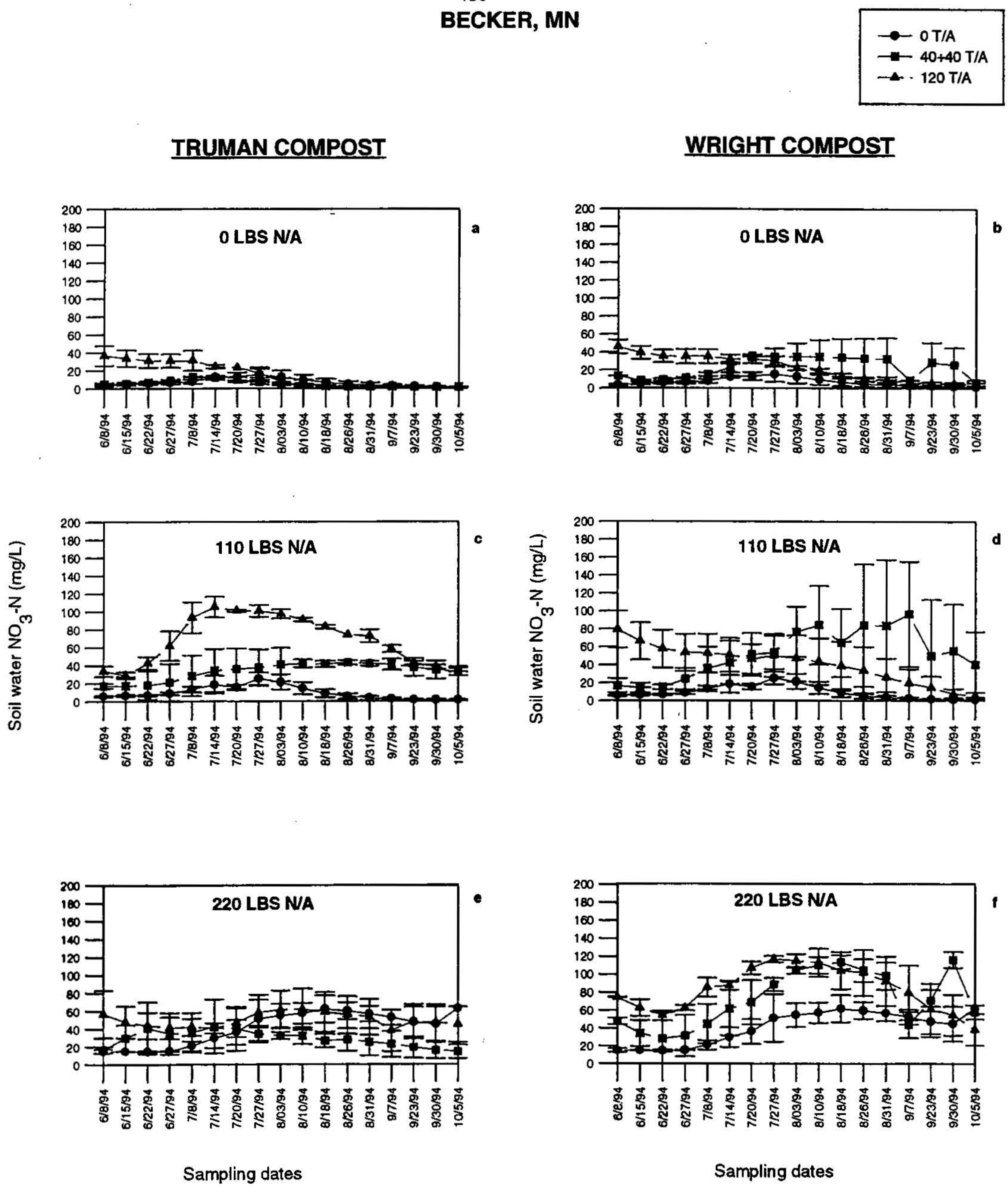
PLANT MOISTURE STRESS

Water stress measurements were made on two clear and warm days (air temperature: mid 80's). Unless of rain events, irrigation was not made before stress maesurements. The last irrigation event of one inch was made on 7/15/94 before leaf water potential measurements on 7/29/94 and 8/1/94.
In the 1993 established experiment, compost amendment, time, and date of measurement were significant. There were no treatment interactions. The mean comparison with compost as the main effect is presented in Table 5. Plants did not experience moisture stress in the early mornings. However, leaf water potential was highly significantly increased by the early afternoon compared to the morning. Afternoon plant moisture stress for the Wright compost at 120 T/A was significantly lower from the plots that received additional compost of 40 T/A in 1994. None of the compost treatments were significantly different from the control.



Figs. 1- SOIL WATER NITRATE-1994 GROWING SEASON
Compost utilization plots established in 1992

BECKER, MN



Figs. 2- SOIL WATER NITRATE- 1994 GROWING SEASON
Compost utilization plots established in 1993

TILLAGE COMPARISON AT ROSEMOUNT, 1994

T.L. Hansmeyer, D.R. Linden, K.L. Walters, R.H. Dowdy, R.R. Allmaras and C.E. Clapp[1]

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 plots planted to corn with no nitrogen applied to plots in soybeans. The objective of the study are to determine the long term effects of various cropping systems on herbicide movement, earthworm activity, grain yield, nutrient availability and nutrient uptake. Though it is too early in the study to examine the differences in many of the objectives, enough information has been gathered to study grain yield, surface residue, simple economic analysis, and earthworm populations.

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), corn/soybean (CS) [soybean 1994] and soybean/corn (SC) [corn 1994] rotations were planted into four tillage systems in a randomized complete block design with three replicates. 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 soybean. Corn is no-tilled 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 preformed only when soil or weed conditions require attention. Cultivation performed only when determined necessary.

EXPERIMENTAL PROCEDURE: Prepared seedbed by discing all Conventional and Conservation tillage which were to be planted to corn. Corn (Pioneer 3751) was planted in the CC and SC plots across all tillage systems on May 5. The seeds were planted at a population of 26,100 seeds/acre. Force insecticide was banded over the row at the rate of 8oz/1000 feet of row. Corn emergence was counted from two 20' sections of row in each plot periodically throughout the first five weeks of growth. Lasso (Alachlor) was broadcast at the rate of 2qt product/acre May 7 on all CC and SC treatments under Conservation and Minimized tillage and the SC treatment under Conventional tillage. Broadcast Roundup (glyphosate) at the rate of 6pt product/acre product on all the CS treatments under Minimized tillage, May 17. Applied Bladex (Cyanazine) on May 17 at the rate of 2 pounds product/acre on all plots planted to corn under all tillage systems. Planted soybean on all CS plots at the rate of 60 lbs/acre. Broadcast Pursuit (imazethapyr) on all CS plots at the rate of 4 oz product/acre, June 1. Broadcast Buctril (bromoxynil) on June 2 at the rate of 1 1/2 pt product/acre on both the CC and SC treatments under Conservation and Ridge till. The same was also applied to the SC treatments of Conventional and Minimum tillage. Cultivated all CC and SC plots to a depth of 3 inches applying 150 lbs N/acre during the cultivation. Broadcast Fusilade (Fluazifop) on June 21 to all CS plots at the rate of 20 oz product/acre. Accent (Nicosulfuron) was applied on June 21 at the rate of 2/3 oz product/acre. Ridged all CC, CS and SC treatments under the ridge tillage system. Harvested all soybean and corn plots under all tillage systems. Sampled earthworm populations in each plot under all tillage systems. Performed tillage as to tillage systems.

RESULTS

YIELD: Grain yields and moistures from all tillages and rotations are given in figures 1-3 and table 1.

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Within the continuous corn system, grain yields from the conventional till plots out-yielded all other tillages followed by conservation, ridge and minimized in that order. Statistically, conventional and conservation had significantly greater yields than minimized tillage (fig. 1). The Continuous corn yields averaged over the past three years rank the tillage systems differently. The three year average places conventional in front followed by ridge, conservation and minimized respectively. I will note that the combined year ranking has changed this year placing conventional ahead of ridge-till.

The 1994 corn yields in the soybean/corn rotation created the same yield rank as continuous corn when comparing the 4 tillage systems. Conventional tillage yielded the highest followed by conservation, ridge and minimized. Statistically, corn grain yields for the conventional system were significantly greater than the corn grain yield under minimized tillage (fig. 2). The 1994 soybean yields in the corn/soybean rotation were greatest under the ridge tillage system followed by minimized, conventional and conservation respectively. No statistical yield difference occurred between tillage systems (fig. 3). The three year average soybean yield ranked conventional first followed by conservation, minimized and ridge respectively. The complete difference in rank between the 1994 and three year average soybean yields points to unpredictability. Soybean yield changes more radically from year to year under the various tillage systems than do corn yields. One explanation is that the soybean yields are all within 2.2 bushels of each other enabling the tillage systems to change rank more easily.

The mean yield (which includes both crops) for each tillage system indicates that conventional tillage produced the highest yield followed by conservation, ridge and minimized respectively. The yield from the conventional system is significantly greater than both the ridge and minimized tillage systems. The conservation tillage system is significantly greater than the yield produced by the minimized tillage system. The only significant difference not yet described occurs between the ridge and minimized tillage systems. The mean corn grain yields in 1994 indicate the soybean/corn rotation outyielding the continuous corn rotation by 16.4 bushels/acre. The same rotation outyielded continuous corn in 1993, but only by 10 bushels/acre. It is uncertain whether the yield differences will become more pronounced in future years.

RESIDUE: Residue cover after planting is shown in table 2 . As expected both conservation and minimized tillage provide sufficient corn and soybean residue to qualify for the erosion control requirements, where residue must provide at least 30% surface coverage 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. Ridge-till provided sufficient residue to qualify under the continuous corn and corn/soybean systems. Ridge-till buried a majority of the soybean residue under the soybean/corn rotation leaving only 27% surface residue. A conventional tillage system did not provide enough surface residue to qualify for the residue requirements. Since the soybean plots in conventional tillage are chisel plowed in the fall, on might expect at least 30% residue cover. However, the fall chisel plowed soybean plots only produced 9% residue cover.

EMERGENCE: Corn seedling emergence varied in the cropping systems presumably due spring soil moistures and temperatures. Figure 5 depicts 4 types of corn emergence trends. Conventional (CC) and conventional (SC) sprouted quickly with 75-85% corn emergence 13 days after planting. Conservation (SC) and ridge (SC) tillage systems had about 55% emergence after 13 days. The third trend includes conservation (CC), ridge (CC) and minimized (SC) with 32-42% emergence after 13 days. The last trend was created by the minimized (CC) cropping system with 15% emergence after 13 days. The advantage of ridge-till was minimized during the 1994 growing season due to the warmer soil temperatures. During the 1993 growing season, ridge-till cropping systems were grouped in the first two trends. The same cropping systems dropped to the 2nd and 3rd trends during 1994. This could be connected to the advance of the conservation tillage corn yields over ridge-till corn yields which occurred in 1994. All cropping system corn seedling emergence began to merge at day 19 after planting (fig. 4).

ECONOMIC ANALYSIS: Table 3 presents a comparison in time (hrs) and costs ($). The information was gathered during the 1994 growing season. The corn crop comparison gives evidence that conventional is the most time and cost intensive cropping system. All corn systems are compared to the conventional (CC) system. Values greater than 1.00 indicates a system is more time or cost intensive than conventional (CC), whereas a value less than 1 indicates that the system in question is less intensive in time or costs. The soybean cropping system comparison is more varied. Ridge-till, overall, is the most time and cost intensive system.

EARTHWORM POPULATIONS: When comparing earthworms populations between the tillages, conventional tillage has the highest population at 50 earthworms/m^2. This was followed by the conservation tillage system with a population of 48/m^2, minimized tillage at 33/m^2 and ridge-till at 27/m^2. No statistical difference was found between the tillage systems. One might have expected the no-till and ridge-till systems to support a higher population of earthworms. An explanation for the low population in the ridge-till system might be that more earthworms might reside in the ridge, whereas the samples were taken from the inter-row. The cropping rotation CS (soybean 94) maintained the highest earthworm population with 56 earthworms/m^2 followed by SC (corn 94) and CC both with 32/m^2. Again, no statistical difference was found between rotations. The earthworm population consisted almost entirely of Apporectodea tuberculata and Aporectodea trapazoides.

Fig. 1

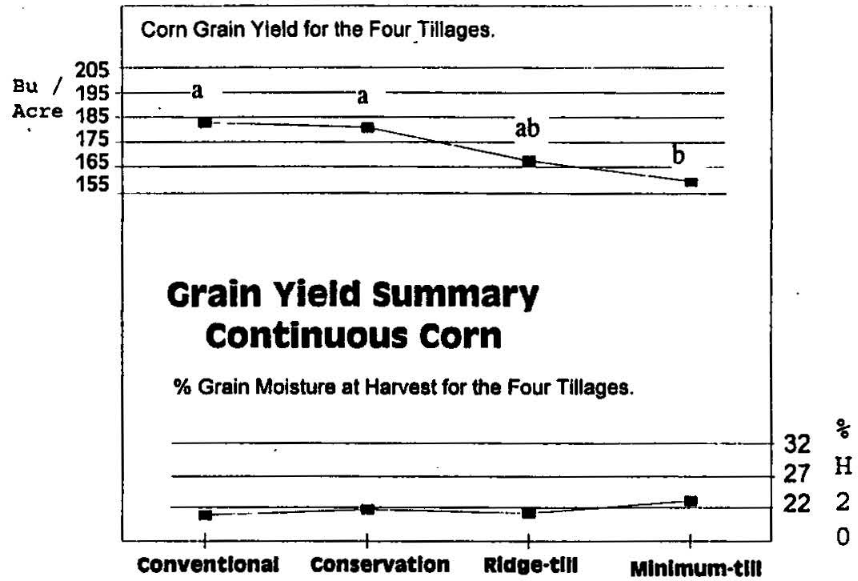

Fig. 2

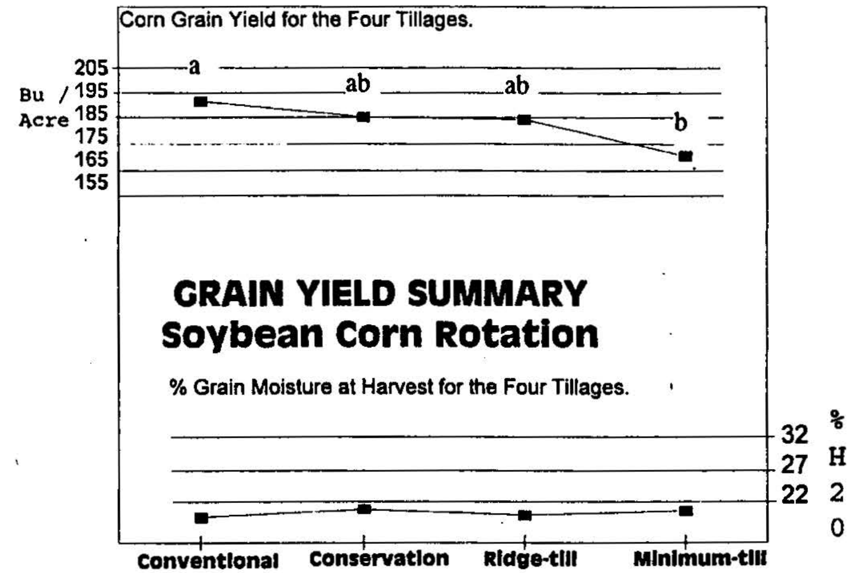

Fig. 3

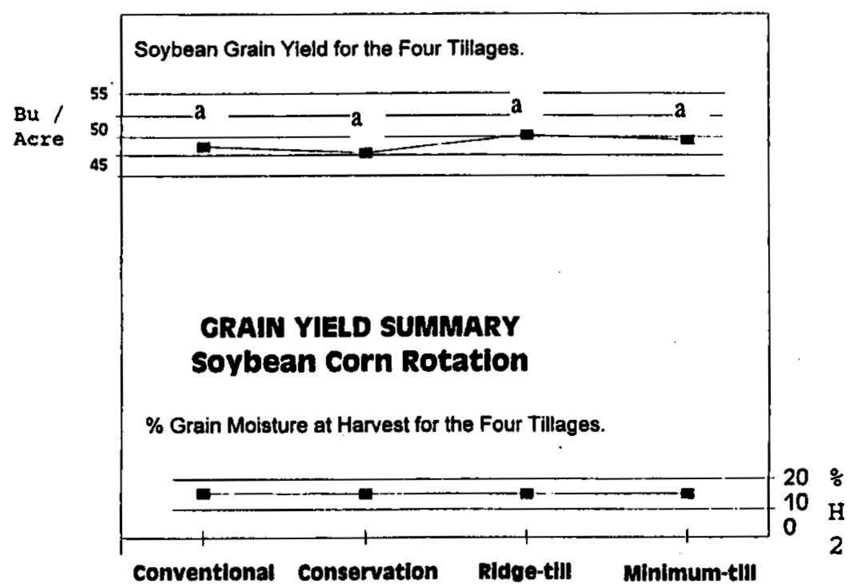

Fig. 4 **Corn Emergence**

days after planting

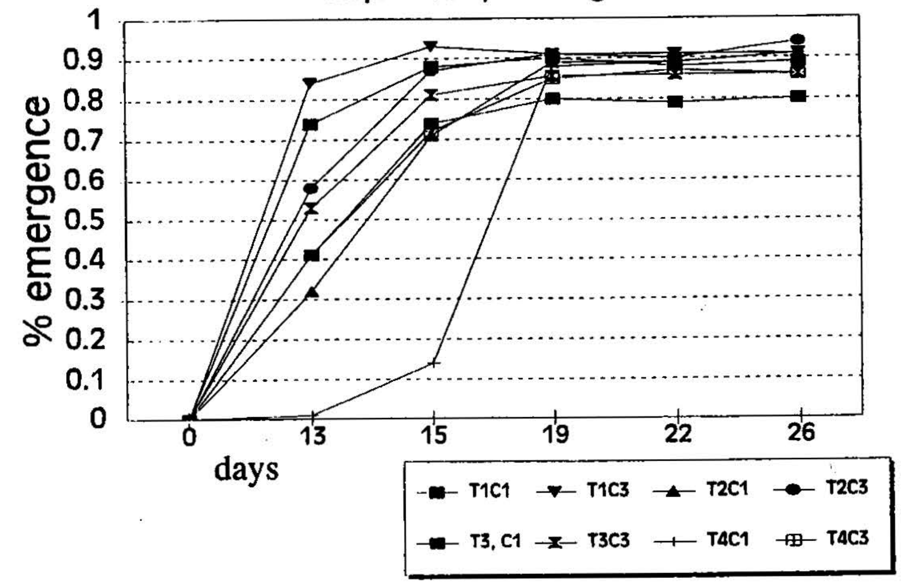

Table 1 Grain yields for the tillage study at Rosemount Study, 1994.

Treatment		Grain Yield			
Tillage	Rotation	1994 bu/ac	1994 mt/ha	92-94 avg. bu/ac	92-94 avg. mt/ha
Conventional (T1)	Cont.Corn	182.9	9.7	139.7	7.4
	Corn/Soy	48.6	2.8	43.2	2.5
	Soy/Corn	197.9	10.5	157.9	8.4
Conservation (T2)	Cont.Corn	181.0	9.6	128.7	6.8
	Corn/Soy	47.8	2.8	42.9	2.5
	Soy/Corn	191.8	10.2	145.9	7.7
Ridge-Till (T3)	Cont.Corn	167.9	8.9	136.6	7.2
	Corn/Soy	50.0	2.9	41.5	2.4
	Soy/Corn	190.8	10.1	155.2	8.2
Minimum-Till (T4)	Cont.Corn	159.9	8.5	115.3	6.1
	Corn/Soy	49.4	2.9	42.3	2.5
	Soy/Corn	176.8	9.4	138.3	7.6

Table 2

Treatment			% residue cover
Tillage	Rotation		
Conventional (T1)	Cont.Corn	(CC)	5.0
	Soy 94	(CS)	4.0
	Corn 94	(SC)	9.0
Conservation (T2)	Cont.Corn	(CC)	39.0
	Soy 94	(CS)	35.0
	Corn 94	(SC)	67.0
Ridge-Till (T3)	Cont.Corn	(CC)	36.0
	Soy 94	(CS)	64.0
	Corn 94	(SC)	27.0
Minimum-Till (T4)	Cont.Corn	(CC)	89.0
	Soy 94	(CS)	88.0
	Corn 94	(SC)	81.0

Table 3

Production time and cost comparisons for all cropping systems.

all systems use conventional tillage as the standard

Crop	Time only	Costs* without Pesticide	Costs* with Pesticide
(corn)			
Conventional (CC)	1.00	1.00	1.00
Conventional (SC)	1.00	1.00	1.00
Conservation (CC)	0.87	0.87	0.92
Conservation (SC)	0.78	0.80	0.85
Ridge-till (CC)	0.88	0.92	0.93
Ridge-till (SC)	0.88	0.92	0.85
Minimized (CC)	0.69	0.69	0.93
Minimized (SC)	0.69	0.70	0.93
Crop **(soybean)**			
Conventional (CS)	1.00	1.00	1.00
Conservation (CS)	0.82	0.79	0.88
Ridge-till (CS)	1.14	1.22	1.13
Minimized (CS)	0.80	0.75	1.14

**Costs include machinery costs only (no labor included)*

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EVALUATION OF RESIDUE MANAGEMENT SYSTEMS IN WEST CENTRAL MN FOR CORN, SOYBEANS, AND WHEAT, 1994[1]

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Abstract Crop residue cropping-systems were evaluated on five farms for soybeans, corn, and wheat. Yields were not influenced at one soybean, corn, and barley site. Yields were reduced at one soybean and wheat site with no till or paraplowing systems. The yield reduction with wheat appeared to be related to stand loss.

Introduction

This is the third and final year of a study evaluating residue management systems for corn, soybeans, and wheat. The crop sequence at all sites is corn-soybeans-wheat and back to corn. At each site there is only one crop each year. Treatments have varied somewhat in some respects over the course of the study but have consistency in others. Generally effectiveness of planter mounted tillage tools for planting corn in high residue environments has been looked at every year. Drill performance for soybean and small grain stand establishment in high residue environments has been a common treatment. In the fall of 1993 deep tillage treatments were established for evaluation in 1994 in response to the wet conditions and very dense soils that were encountered.

Results and Discussion

Tom Jennen Farm

At the Tom Jennen farm corn response following wheat to fall chisel and para plowing compared to no tillage was evaluated. A paraplow is a unique type of deep tillage tool. It has a vertical shank with a 45 degree bend. On the lower shank leg a small shatter plate is mounted. The angle of the plate can be changed with a cam located beneath it. This tool is specifically designed to maximize soil shattering while minimizing incorporation of surface residue. This treatment was used at the Tom and Dan Jennen farms in the fall of 1993.

Soil cover with residue is shown in table 1b. The "in row" (6" centered over the row) cover was higher than desired for corn in all the tillage systems evaluated (should be less than 10-15%). Cover was similar between the no till and paraplowing systems both in and between the row. Clearing tools were equally effective with these systems but did not reduce "in row" cover when chisel plowed followed by spring field cultivation.

The plant stand, early growth, grain moisture and yield are shown in table 1c. Stands were not affected by the tillage. Early growth and test weight were reduced with the paraplowing system. The absence of delayed early growth with the no till system is curious considering the 47 percent soil cover in the row with this system. Grain moisture trends followed early growth measurements (slowed early growth-higher grain moisture). Grain yields were not affected by tillage. This is curious since the soil was obviously very dense in the fall and tillage resulted in high draft. The lack of a response to fall 1993 tillage may have been due to a dry spring and timely rains in 1994.

There are no consistent trends in plant tissue levels due to tillage. Potassium levels are extremely low for all systems however.

Everett Gilbertson Farm

At this site fall chisel plowing was compared to a no till system using a Hiniker sweep type planter. A conventional planter (30" rows) was used on the chisel plowed plots. Soil cover was reduced from 95 to 60% with the Hiniker sweep seeder. There was no effect of the planter on soil cover with corn residue with the soybean planter on the chisel plowed plots.

Stands were good with both systems although much higher with the Hiniker unit. There was no statistical difference in yields due

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to tillage although the trend was for slightly lower yields with the no till system. This is surprising since a narrow row response (broadcast vs. 30" rows) often occurs with soybeans in MN.

There was no consistent trend in tissue levels of nutrients due to tillage (table 2c).

David Holt Farm

At this site a chisel plowing system was compared to a no till approach for soybeans following corn. The stands were adequate with both tillage systems. Residue levels were marginal with the chisel system. There was no difference in test weight but about an eight bushel per acre reduction in yield with the no till system. Differences in growth were apparent from early in the season. It may be possible that "in seed furrow" corn residue with the no till system delayed growth due to poor seed-soil contact and phytotoxicity. There is no consistent trend of tillage on tissue levels of trifoliate samples at 10% bloom.

Orland Ohe Farm

At this site a chisel plowing system was evaluated against a no till approach for barley production following wheat. The drill was equipped with smooth coulters to cut the wheat straw. Soil cover levels were relatively high with the chisel plowing system. There was no statistical difference in stand, test weight, protein, or yield due to tillage.

Dan Jennen Farm

Tillage influences on wheat following soybeans were evaluated at this site. The treatments were fall chisel or paraplowing compared to no tillage. Soil cover with soybean residue (table 6b) was similar for the chisel and paraplowing systems (53%) and much reduced with the chisel treatment (12%). Stands were reduced with the high residue systems.

Wheat yields were about 6 bushels per acre lower with the two high residue systems compared to the chisel plowing approach. The yield difference may have in part been due to the stand differences.

Table 1a. Cultural practices used at the corn tillage demonstration on the Tom Jennen farm, 1994.

Tillage Treatments

1. Chisel plow- 3" twisted shovels at 12" spacing going about 8-10" deep in the fall followed by a field cultivator in the spring (42'wide with 9" sweeps at 6" spacing)
2. Paraplow-in the fall with a five shank unit going about 14-16" deep. See text for description. No secondary tillage in the spring.
3. No tillage-planted with rolling finger clearing units.

Planting and harvest information

Crop	Hybrid	Planted	Seeding	Harvested
Corn	NK3907	5/7	29,500s/A	10/10

John Deere 7200 8-row planter

Crop history

1990-Wheat
1991-Corn
1992-Soybean
1993-Wheat
1994-Corn

Nutrients applied

		Actual applied lb//A		
Date	Analysis	N	P_2O_5	K_2O
5/7	24-60-40	24	60	40
6/10	82-0-0	120	0	0

Weed control

Date	Control	Rate lb ai/A
6/17	Primisulfuron (Beacon) +	0.02
	Nicosulfuron (Accent)	0.016
6/18	Dicamba (Banvel) (spot spray on thistle)	

Soil

Langhei loam (40%) (Typic Eutrochrept)
Fordum fine sandy loam (30%) (Mollic Fluvaquent)
Sandberg loamy sand (30%) (Udorthentic Haploboroll)

Table 1b. Effect of tillage on wheat residue in, between and across the rows at the Tom Jennen farm, May 17, 1994.

Tillage	Residue		
	In	Between	Across
	--------------%cover--------------		
Chisel plow	24.3cd[1]	26.0cd	21.7d
No-till	46.7bc	72.0a	62.0ab
Paraplow	44.0bcd	62.7ab	46.7bc
Chisel plow[2]	24.0b		
No-till	60.2a		
Paraplow	51.4a		
Row position	38.3b	53.9a	43.4b
Pr>F			
Tillage	0.063		
Row position	0.002		
Till.x Row pos.	0.086		

1. Data followed by the same letter in the same group are not significantly different at the 0.10 level, n=27.
2. Means averaged over row position.

Table 1c. Effect of tillage on corn population (5/17), leaf numbers (5/17), and harvest data at the Tom Jennen farm, 1994.

Tillage	Corn Population	Leaf Nos.	Test Weight	Grain Moisture	Corn Yield
	#/Ax1000	#/plant	lb/bu	%	bu/A
Chisel plow	24.5a[1]	6.8a	53.5a	24.1a	117a
No-till	25.0a	6.6a	53.3a	25.8a	105a
Paraplow	26.6a	6.2b	52.2b	25.2a	116a
Pr>F					
Tillage	0.535	0.026	0.023	0.290	0.336

1. Data followed by the same letter in the same column group are not significantly different at the 0.10 level, n=9.

Table 1d. Effect of tillage on ear leaf concentrations at the Tom Jennen site, 1994.

Tillage	P	K	Ca	Mg	Na	Al	Fe	Mn
	----------%----------		----------ppm----------					
Chisel	0.238a[1]	0.662a	8620a	6080a	4.05a	22.2a	89.8a	98.2a
No-till	0.280a	0.682a	9670a	7440a	3.66a	22.3a	115.9a	100.7a
Paraplow	0.235a	0.669a	9070a	6120a	4.44a	21.7a	88.8a	93.7a
Pr>F								
Tillage	0.693	0.988	0.509	0.540	0.616	0.982	0.108	0.849

1. Data followed by the same letter in the same column are not significantly different at the 0.10 level, n=9.

Table 1d. continued. Effect of tillage on ear leaf concentrations at the Jennen site, 1994.

Tillage	Zn	Cu	B	Pb	Ni	Cr	Cd
	----------ppm----------						
Chisel	11.9a	3.22a	5.80a	1.70a	0.483a	0.649a	0.121a
No-till	9.4a	5.07a	4.99b	1.68a	0.440b	0.520b	0.120a
Paraplow	12.3a	3.75a	5.35b	1.68a	0.459ab	0.512b	0.120a
Pr>F							
Tillage	0.654	0.280	0.044	0.444	0.074	0.056	0.444

1. Data followed by the same letter in the same column are not significantly different at the 0.10 level, n=9.

Table 2a. Cultural practices used at the soybean tillage demonstration on the Everett Gilbertson farm, 1994.

Tillage

1. Chisel plowed in the fall of 1993 followed by discing (4/30/94) 18.5' with 22" blades at 9" spacing and a field cultivator 22' with 7" sweeps at - 6" spacing on May 23, 1994
2. No till (planted with a Hiniker sweep unit)

Planting and harvest information

Crop	Variety	Plant	Pop.	Harvest
Soybean	P9091	5/26	200,000s/A	10/14
No-till plots	"		240,000s/A	"

IH CycloAir (8-30" rows) in chisel plots
Hiniker Air Seeder in no-till plots

Crop history 1991-Soybeans, 1992-Wheat, 1993-Corn, 1994-Soybeans

Soil Chappett loam 4% slope (Udic Agriboroll)

Nutrients applied

		Actual applied lb/A				
Date	Analysis	N	P_2O_5	K_2O	Fe	Mn
6/29	8-8-8-3-3	0.3	0.3	0.3	0.1	0.1
(1.5 qt/A)						

Weed control

Date	Control	Rate
No-till		lb ai/A
Pre-plant	Glyphosate (Roundup) +	0.38
"	2,4-D ester	0.25
5/20	Flumetsulam (Broadstrike)	
Chisel		
5/20	Flumetsulam (Broadstrike) & 2,4-D ester	0.25 lb ai/A
Spot spray of Bentazon (Basagran)		

Statistical Design
Randomized complete block with four replications.

Table 2b. Effect of tillage on corn residue before and after planting (5/26), soybean population (6/27), and harvest data (10/14) at the Gilbertson farm, 1994.

Tillage	Planting Before	Planting After	Soybean Population	Test Weight	Harvest Moisture	Soybean Yield
	------% cover-----		plts/Ax1000	lb/bu	%	bu/A
Chisel plow	15.9b[1]	15.9b	193b	54.0a	12.0a	41.0a
No-till	95.0a	60.1a	291a	54.0a	12.0a	38.0a
Pr>F						
Tillage	<0.001	0.001	<0.001	1.00	0.789	0.121

1. Data followed by the same letter in the same column are not significantly different at the 0.10 level, n=8.

Table 2c. Effect of tillage on soybean trifoliate concentrations contents at the Gilbertson site, 1994.

Tillage	P	K	Ca	Mg	Na	Al	Fe	Mn
	---------%-------		------------------ppm------------------					
Chisel	0.652a	2.58a	10,200a	3780a	7.06a	11.6a	72.8a	63.4a
No-till	0.655a	2.53a	9,860a	3830a	5.11a	8.7a	68.2a	49.9b
Pr>F								
Tillage	0.892	0.154	0.197	0.665	0.314	0.439	0.331	0.034

1. Data followed by the same letter in the same column are not significantly different at the 0.10 level, n=8.

Table 2c. continued. Effect of tillage on trifoliate concentrations at the Gilbertson site, 1994.

Tillage	Zn	Cu	B	Pb	Ni	Cr	Cd
	------------------ppm------------------						
Chisel	45.5a[1]	9.6a	34.3a	1.77a	8.49a	0.700a	0.221a
No-till	43.1a	9.0a	35.0a	1.68b	7.22b	0.550b	0.142a
Pr>F							
Tillage	0.198	0.127	0.608	0.070	0.023	0.070	0.368

1. Data followed by the same letter in the same column are not significantly different at the 0.10 level, n=8.

Table 3a. Cultural practices used at the soybean tillage demonstration on the David Holt farm, 1994.

Tillage
1. Disced and Chisel plowed (10/25/93) equipped with 4" twisted shovels at 1' spacing. Spring field cultivated (5/11/94) 7"-sweeps at 7" spacing.
2. No till planted with 750 no till drill.

Planting and harvest information

Crop	Variety	Plant	Pop.	Harvest
Soybean	P9091	5/17	200,000s/A	9/26

John Deere 7000 planter in chisel plots
John Deere 750 drill in no-till plots

Crop history
1991-Soybean
1992-Wheat
1993-Corn
1994-Soybean

Nutrients applied
None

Weed control

Date	Control	Rate (lb ai/A)
6/1	Fluazifop (Fusilade) +	0.14
	Imazethapyr (Pursuit)	0.047

Soil
Sandberg loam 4-9% slope
(Udorthentic Haploboroll)

Table 3b. Effect of tillage on soybean population (6/2), residue (5/17), test weight, harvest moisture content and yield (9/26) at the Holt farm, 1994.

Tillage	Soybean Population	Corn Residue	Test Weight	Harvest Moisture	Soybean Yield[1]
	plt/Ax1000	%cover	lb/bu	--%--	bu/A
Chisel plow	347a[2]	21.2b	56.7a	14.0a	32.3a
No-till	220b	84.7a	56.3a	12.7a	23.8b
Pr>F					
Tillage	0.005	0.004	0.423	0.424	0.027

1. Soybeans in the no-till plots were approx. 12" tall vs. 24" in the chisel plots; no-till plots also had significant ragweed and Canada thistle problems.
2. Data followed by the same letter in the same column are not significantly different at the 0.10 level, n=6.

Table 3c. Effect of tillage on soybean trifoliate concentrations at the Holt site, 1994.

Tillage	P	K	Ca	Mg	Na	Al	Fe	Mn
	--------%--------		---------------------------------ppm---------------------------------					
Chisel	0.604a[1]	2.16b	11,900a	4760a	7.12a	10.8b	74.4a	56.5a
No-till	0.578a	2.37a	13,100a	4740a	9.18a	12.9a	70.2a	60.8a
Pr>F								
Tillage	0.606	0.090	0.590	0.956	0.286	0.043	0.207	0.434

1. Data followed by the same letter in the same column are not significantly different at the 0.10 level, n=6.

Table 3c. continued. Effect of tillage on trifoliate concentrations at the Holt Farm.

Tillage	Zn	Cu	B	Pb	Ni	Cr	Cd
	---------------------------------ppm---------------------------------						
Chisel	41.2a[1]	8.74a	45.4a	1.71a	6.40a	0.679a	0.266a
No-till	39.0a	8.01a	44.8a	1.68a	4.40b	0.661a	0.209a
Pr>F							
Tillage	0.249	0.283	0.896	0.423	0.047	0.719	0.342

1. Data followed by the same letter in the same column are not significantly different at the 0.10 level, n=6.

Table 4a. Cultural practices used in the barley tillage demonstration on the Orland Ohe farm, 1994.

Tillage

1. Fall chisel plowing followed by field cultivation in the spring (4" sweep/harrow).
2. No tillage (Haybuster Drill with smooth coulters and double disc openers.

Planting and harvest information

Crop	Variety	Plant	Rate	Harvest
Barley	Robust	4/23	2 bu/A	8/19

Haybuster drill (7" rows)

Crop history 1991-Wheat, 1992-Soybeans, 1993-Wheat, 1994-Barley

Nutrients applied

		applied lb/A		
Date	Analysis	N	P_2O_5	K_2O
4/23	15-38-10	22	57	15
4/19	46-0-0	69	0	0

Weed control

Date	Control	Rate
		lb ai/A
Preplant	Glyphosate (Roundup)	0.75
6/5	Clopyralid (Stinger) + 2,4-D ester	0.59

Soil

Formdale-Buse clay loam complex 2-6% slope (60%)
(Udic Haploboroll & Typic Calciboroll)
Formdale-Langhei clay loam 6-12% slope (20%)
(Udic Haploboroll & Typic Eutrochrept)
Aazdahl clay loam 0-3% slope (20%)
(Aquic Haploboroll)

Table 4b. Effect of tillage on barley population (5/24), crop residue (5/10), and harvest data at the Ohe farm, 1994.

Tillage	Barley Population	Wheat Residue	Test Wt.	Protein	Plump Kernels	Grain Moisture	Barley Yield
	plt/Ax1000	%cover	lb/bu	%	%	%	bu/A
Chisel plow	641a[1]	40.4b	48.4a	13.9a	88.7a	14.1a	54.4a
No-till	572a	66.9a	47.8	13.3a	87.3a	14.1a	58.2a
Pr>F							
Tillage	0.157	0.029	0.122	0.230	0.529	0.940	0.227

1. Data followed by the same letter in the same column are not significantly different at the 0.10 level, n=6.

Table 5a. Effect of tillage on barley population (5/18/94) and residue (4/22/94) on the Sjostrom farm, 1994[1].

Tillage	Barley Population	Residue
	#/Ax1000	%cover
Chisel plow	732a[2]	16.0b
No-till	662a	45.2a
Pr>F		
Tillage	0.105	0.017

1. The barley crop was lost at this site and therefore are no yields to report.
2. Data followed by the same letter in the same column are not significantly different at the 0.10 level.

Table 6a. Cultural practices used in the wheat demonstration on the Dan Jennen farm, 1994.

Tillage Treatments

1. Chisel plow (11/3/93) 17' wide with 7" twisted shovels at 12" spacing; field cultivated (4/15/94) 27'wide with 7"sweeps at 7" spacing
2. No till
3. Paraplowed in the fall with no spring tillage.

Planting and harvest information

Crop	Variety	Plant	Rate	Harvest
Wheat	2375	4/22	2 bu/A	8/10

John Deere 9350 (6" row spacing, 30' width)

Crop history 1991-Wheat, 1992-Corn, 1993-Soybean, 1994-Wheat

Soil
Barnes-Langhi loam complex 6-12% slope (Udic Haploboroll & Typic Eutrochrept)

Nutrients applied

		Actual applied lb/A		
Date	Analysis	N	P_2O_5	K_2O
No-till				
4/22	9-23-30	9	23	30
4/20	82-0-0	100	0	0
Chisel				
11/1	28-20-9	81	60	26

Weed control

Date	Herbicide	Rate
		lb ai/A
5/26	Fenoxaprop + 2,4-D + MCPA (Tiller)	0.42
	Bromoxynil (Buctril)	0.25

Table 6b. Effect of tillage on wheat population (5/19), residue (5/11), and harvest data (8/10) on the Dan Jennen farm, 1994.

Tillage	Wheat Population	Residue	Test Weight	Protein	Grain Moisture	Wheat Yield
	#/Ax1000	%cover	lb/bu	%	%	bu/A
Chisel plow	963a[1]	11.8b	60.6a	13.6a	13.9a	51.4a
No-till	815b	52.3a	59.4b	13.8a	14.3a	44.5b
Paraplow	728c	53.6a	60.0ab	14.2a	14.0a	46.3b
Pr>F						
Tillage	0.007	<0.001	0.052	0.218	0.804	0.018

1. Data followed by the same letter in the same column are not significantly different at the 0.10 level, n=9.

EVALUATION OF TILLAGE AND NO TILL DRILLS FOR SOYBEANS IN NOBLES CO., MN 1994[1]

John F. Moncrief, Tom L. Ahlberg, Art R. Frame,
Jim B. Nesseth, Phyllis M. Bongard, and Brian J. Johnson [2]

Abstract: Evaluation of fall moldboard plowing, fall deep chiseling, and no till systems on soybean stand establishment, weeds present, and yields resulted in higher yields with a no till approach. Lower yields with moldboard and chisel plowing were correlated with increases in weeds present. Evaluation of no till drills for soybean production resulted in higher yields with single disc openers compared to sweep type units. Differences were not related to differences in stands or weeds present.

Introduction

There are two studies. One is designed to evaluate tillage systems and the other no till drills under no till conditions. The cultural practices are shown in table 1a. The soil is naturally poorly drained but well tiled. The seeds planted per acre (shown in table 1a) were determined by knowing the weight of seed in each drill before planting and weighing the residual after planting. Seeds per acre was determined by difference. The three drills planted slightly over 200,000 seeds per acre.

Results of Spring Tillage/Drill Study

Soil cover with corn residue after planting, stands, and yield for the tillage study are shown in table 1b. The three tillage treatments were planted with the John Deere no till drill. There was no difference in stand due to tillage and stands were adequate. Soil cover with corn residue was measured before and after spring discing, as well as after planting. There was very little soil cover with the fall deep tillage treatments. Yields were highest with the no till system and lowest with the DMI 530 subsoiler. Moldboard plowing resulted in intermediate yields.

The weeds were tallied at physiological maturity and are shown in table 1c. These data are visual estimates of the percent soil cover by weed species in each plot. The dominant weeds were cocklebur, pigweed, and smart weed. Full width, deep fall tillage increased these three weed species and may explain some of the yield reduction with these systems.

Results of No Till Drill Study

The results of study 2 looking at no till drills are summarized in tables 2a and 2b. The only weed species affected by drill type was thistle which was higher with the JD750 drill compared to the sweep type units. As expected the sweep type units resulted in lower levels of soil cover by corn residue. Both reduced soil cover by about 10% compared to no reduction with the JD750. Soybean stands were higher with the JD750 and DMI/Concord units compared to the Hiniker but stands were adequate with all drills. The sweep type units resulted in about a 6 bushel per acre lower yield than the single disc opener unit (JD750). This yield difference does not appear to be related to differences in weeds present or stand.

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[1] This project was supported by the Midwest Soybean Growers Association, Deere and Co., DMI, Gaylord, MN; Ramerth Ag. Service, Fulda, MN the Minnesota Extension Service, and the Natural Resource Conservation Service. Their support is greatly appreciated.

[2] John F. Moncrief is an Extension Soil Scientist, Soil Science Department, U of M; Tom Ahlberg is an independent crop consultant with Southwest Agronomics at Worthington, MN; Art R. Frame and Jim B. Nesseth are Extension Educators in Nobles and Jackson Counties respectively; Phyllis M. Bongard is an independent data analysis specialist, Faribault, MN; and Brian J. Johnson is an Assistant Scientist, Soil Science Department, U of MN, St. Paul.

Table 1a. Cultural practices used in the soybean tillage study on the Daryle Albersman farm at Worthington, Minnesota, 1994.

Tillage systems evaluated (study 1)

1. Fall DMI 530 Ecolo Tiger (parabolic shank subsoiler with wings, preceded by a gang of chisel shanks, preceded by a gang of discs) + spring disc
2. Fall Moldboard plow + spring disc
3. No-till

Drills Evaluated (study 2)

1. 15' John Deere 750 (7" rows)
2. Hiniker sweep 27" sweeps on 30" centers behind a coulter-gauge wheel
3. DMI/Concord 1100 sweep seeder 35' DMI (field cultivator) with 7" shovels at 6"spacing

Planting and harvest information
Soybean

Planter	Variety	Planted	seeds/a	Harvested
JD750	P9171	5/13	206,000s/A	9/30
DMI/Concord	"	5/15	226,000s/A	"
Hiniker	"	5/16	232,000s/A	"

Crop history
1993 - Corn

Nutrients applied none

Weed control

Date	Product	Rate
5/11	Roundup	.25 qt/a
	surfactant	2 qt/a
	ammonium sulfate	.7 lbs/a
	Dual+Broadstrike	2.75 pt/a

Soils Webster/Clarion/Nicollet 0-2% slope

Treatment	pH	O.M.	Olsen-P	Bray-P	K
No-till		%	-------ppm	----------	
JD750	7.8	4.3	65	74	132
Concord	7.8	4.2	65	82	118
Hiniker	7.8	4.1	60	78	121
DMI 530	7.9	4.1	60	76	137
Moldboard	7.7	4.0	65	80	123
Average	**7.8**	**4.1**	**63**	**78**	**126**

Statistical Design

Study 1. Randomized complete block with 5 replications.
Study 2. Split plot with 5 replications

Table 1b. Effect of tillage on soybean stand (6/10), corn residue before and after spring tillage and after planting, and yield and moisture (9/30) at Worthington, 1994.

Tillage	Soybean Population	Corn Residue 5/12[1]	5/13[2]	5/16?[3]	Harvest Moisture	Soybean Yield
	plt/Ax1000	--------%cover	---------		--%--	bu/A
No-till	184a[4]	52.0a	-	51.4a1	2.5a	61.7a
DMI Ecolo	162a	14.8b	12.6a	12.6b	13.3a	51.4b
Moldboard	184a	6.6b	2.6b	4.4c	12.8a	55.3c
Pr>F						
Tillage	0.289	<0.001	0.002	0.001	0.356	0.001

1. Residue measured before spring discing.
2. Residue measured after spring discing.
3. Residue measured after planting.
4. Data followed by the same letter in the same column are not significantly different at the 0.10 level, n=15.

Table 1c. Effect of tillage on weed cover at Worthington, September 9, 1994.

Tillage	Total cover	Weeds present[1] Ccklbur.	Pig-weed	Smart-weed	Com. lmsqtr.	Thistle	Foxtail sp.
	-------------	-------------	-------% cover	-------------	-------------	-------------	-------------
No-till	8.7b[2]	0.6a	2.3b	2.9b	1.7a	1.2a	0.0a
DMI Ecolo	32.1a	6.7a	9.9a	10.0a	3.1a	2.4a	0.0a
Moldboard	26.6a	8.2a	9.2a	5.1b	2.0a	1.6a	0.5a
Pr>F							
Tillage	0.023	0.168	0.084	0.007	0.264	0.181	0.143

1. Ccklbur=Cocklebur; Com. lmsqtr=Common lambsquarters.
2. Data followed by the same letter in the same column are not significantly different at the 0.10 level, n=15.

Table 2a. Effect of drill type on soil cover by weed species (no-till plots only) at Worthington, MN, September 9, 1994.

		Weeds present[1]					
Seeder	Total cover	Ccklbur.	Pig-weed	Smart-weed	Com. lmsqtr.	Thistle	Foxtail sp.
	---------------------------------% cover---------------------------------						
DMI/Concord	8.7a[2]	0.6a	4.0a	1.8a	1.7a	0.2b	0.4a
JD750	8.7a	0.6a	2.3a	2.9a	1.7a	1.2a	0.0a
Hiniker	6.5a	0.9a	2.5a	2.2a	0.4a	0.5b	0.0a
Pr>F							
Seeder	0.512	0.781	0.175	0.329	0.154	0.029	0.410

1. Ccklbur=Cocklebur; Com. lmsqtr=Common lambsquarters.
2. Data followed by the same letter in the same column are not significantly different at the 0.10 level, n=15.

Table 2b. Effect of seeder on soybean stand (6/10), stand establishment, corn residue before and after planting, and yield and moisture (9/30) in the no-till plots at the Worthington site, 1994.

Seeder	Seeding Pop.	Soybean Pop.	Stand Estab.	Corn Residue 5/12[1]	Corn Residue 5/16?[2]	Harvest Moisture	Soybean Yield
	plt/Ax1000		--%--	---%cover---		--%--	bu/A
Concord	226	167a[3]	74.1b	45.6a	33.8b	12.2a	54.7b
JD750	206	184a	89.6a	52.0a	51.4a	12.5a	61.7a
Hiniker	232	114b	49.2c	47.0a	37.6b	12.3a	55.4b
Pr>F							
Seeder		<0.001	<0.001	0.354	0.002	0.590	<0.001

1. Residue measured before planting.
2. Residue measured after planting.
3. Data followed by the same letter in the same column are not significantly different at the 0.10 level, n=15

EVALUATION OF TILLAGE AND NO TILL DRILLS FOR SOYBEANS IN YELLOW MEDICINE CO., MN, 1994[1]

Richard P. Kvols, Steve D. Lutes, John F. Moncrief
Phyllis M. Bongard, and Brian J. Johnson[2]

Abstract: Spring tillage and drill types were evaluated for soybeans following corn on a loam textured soil. Drill types that result in more tillage (sweep seeders and fluted coulters compared to single disc openers) reduced soil cover with corn residue and soybean stands (likely due to crusting from an intense rainfall shortly after planting). A yield reduction was associated with stand loss. Spring tillage approaches did not affect stands or yields.

Introduction

Two studies were initiated in the spring of 1994 in southwestern Minnesota, one to evaluate three spring tillage options and the other to evaluate three no till drills for soybeans following corn. The designs were a randomized complete block with split plots and split plot design for spring tillage and no till drill studies respecitively. The soil is a Ves loam (Udic Haplustol) with 0-2% slope. The cultural practices and treatment definitions are shown in table 1.

Results of Spring Tillage/Drill Study

The results of the spring tillage/drill comparison is shown in table 2. Spring tillage with discing or mulchmaster reduced soil cover with corn residue from 52 to about 36%. When averaged over tillage the John Deere 750 (JD750) drill reduced soil cover with corn residue from 45 to 39% compared to the Case-IH (CIH) drill equipped with a Yetter coulter cart. Although all the seeding equipment was set to deliver 200,000 seeds per acre stands were different between the two drills. The CIH drill resulted in about one half the stand of the JD750 (127 vs. 61 thousand plants per acre). The drill differences in stand were consistant across spring tillage treatments. There was a very intense rainfall following planting that had more of an effect on soil crusting over the row with the CIH compared to the JD750 unit due to lower soil cover in the row. This was the likely reason for stand differences. Spring tillage did not affect stands however and averaged about 100 thousand plants per acre.

The primary weeds were pig weed, yellow and giant foxtail, and lambsquarters. A visual estimate of broadleaves vs grass was made before post emergent herbicides were applied. There were no significant effects of drill type or tillage on weed type. Late season weed control was excellant although pressure was high before applying post emergent herbicides.

The grain yields varied from 45 to 52 bushels per acre over the three spring tillage treatments but was due to field variability and not tillage. There was a four bushel per acre reduction in yield with the CHI drill which was likely due to stand loss from the crusting rain discussed earlier. This is also supported by the trend for a tillage by drill interaction. The spring discing and mulch master tillage treatments resulted in a larger stand and yield reduction with the CHI drill than the no till system.

Results of Drill Study (no till only)

The comparision of the three no till drills evalauted (only under no till conditions) is shown in table 3. The DMI/Concord sweep seeder compared to the JD750 and CIH drills reduced soil cover by corn residue from 53 to 38%. Stands were reduced with the sweep and coulter cart units compared to the JD750. Grain yields were correlated with stands but not significantly different due to drill type.

Table 1. Cultural practices at Yellow Medicine County, 1994.

<u>Spring Tillage Treatments</u>

1. Spring discing-IH 470 with 16" discs at 9" spacing
2. Sweep seeder DMI/Concorde 1100-35' DMI (fld. cult) with 7" shovels at 6"spacing
3. John Deere Mulchmaster-24' wide with 24" low crown sweeps at 24" spacing followed by 1" heavey rotary hoe angled gangs on 18" diameter

<u>Crop history</u>

1993 - Corn

<u>Nutrients applied</u>

None

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[1] This project was supported by the Midwest Soybean Growers Association, Deere and Co., the Minnesota Extension Service, and the Natural Resource Conservation Service. Their support is greatly appreciated.

[2] Richard P. Kvols and Steve D. Lutes are Extension Educator and District Conservationist respectivley in Yellow Medicine County, MN; John F. Moncrief and Brian J. Johnson are Extension Soil Scientist and Assisstant Scientist in the Soil, Water, and Climate Department, U of M, St. Paul, MN; and Phyllis M. Bongard is an independent data analysis specialist, Faribault, MN.

Drills Evaluated

1. 15' John Deere 750 (7" rows)
2. 20' Case IH (10" rows) with Yetter coulter cart (1" fluted) & 2-bar tine drag
3. DMI/Concord 1100 sweep seeder 35' DMI (fld. cult) with 7" shovels at 6" spacing

Planting and harvest information

Crop	Variety	Planted	Seeding	Harvested
Soybean	DK532	5/22	200,000s/A	10/24

Rainfall

Date	Amt.(inches)
5/23	.9
5/24	1.1 Hard downpour.
5/26	A hot dry wind crusted topsoil.

Weed control

Date	Herbicide	Rate
5/12	Glyphosate +	0.2 lb ai/A
	2,4-D	0.25 lb ai/A
6/26	Bentazon + Acifluorfen+	0.7 lb ai/A
	Sethoxydim +	0.18 lb ai/A
	Thifensulfuron	0.002 lb ai/A

Soil	Soil Test O.M.	P	K
Ves loam (Udic Haplustoll)	3.4%	152 ppm	410 ppm

Experimental Design

1. Randomized Complete Block with split plots (tillage main plots and drill type subplots) and four replications (table 2).
2. Split plot with four replications (drill types with no tillage, table 3).

Table 2. Effect of tillage and drill type on corn residue, soybean population, stand establishment, weed composition, and yield at the Yellow Medicine County demonstration, 1994.

Tillage	Drill	Corn Residue	Soybean Population	Stand Estab.	Weed composition Grass	Broadleaves	Soybean Yield
		%cover	plt/Ax1000	%	--------%--------		bu/A
No-till	CIH[1]	52.7a[2]	72bc	45.8ab	68.8a	31.2a	48.7ab
	JD 750	52.2a	137a	57.4a	53.0a	47.0a	50.3ab
Spring disc	CIH	45.7b	45c	28.8b	43.3a	56.7a	48.7ab
	JD 750	34.0cd	135a	56.5ab	50.0a	50.0a	56.2a
Mulchmaster	CIH	37.0c	65bc	41.4ab	68.3a	31.7a	43.7b
	JD 750	30.7d	108ab	45.2ab	73.3a	26.7a	46.3b
No-till		52.4a	105a	51.6a	61.0a	39.1a	49.5a
Spring disc		39.8b	90a	42.6a	46.7a	53.3a	52.4a
Mulchmaster		33.8b	86a	43.3a	70.8a	29.2a	45.0a
	CIH	45.1a	61b	38.7b	60.2a	39.8a	47.0b
	JD 750	38.9b	127a	53.0a	58.8a	41.2a	51.0a
Pr>F							
Tillage		0.010	0.741	0.723	0.392	0.392	0.337
Drill type		0.053	0.001	0.038	0.876	0.876	0.013
Tillage*Drill		0.280	0.280	0.262	0.524	0.524	0.152

1. Case International Harvester drill with yetter coulter cart and tine drag (10" rows).
2. Data followed by the same letter in the same column group are not significantly different at the 0.10 level, n=18.

Table 2a. Effect of drill type on soil cover by weed speccies (no-till plots only) at Worthington, MN., September 9, 1994.

Seeder	Total cover	Weeds present[1] Cocklebur	Pigweed	Smart weed	Common Lambsqrtr	Thistle	Foxtail sp.
	%						
DMI/Concord	8.7a[2]	0.6a	4.0a	1.8a	1.7a	0.2b	0.4a
JD750	8.7a	0.6a	2.3a	2.9a	1.7a	1.2a	0.0a
Hiniker	6.5a	0.9a	2.5a	2.2a	0.4a	0.5b	0.0a
Pr>F							
Seeder	0.512	0.781	0.175	0.329	0.154	0.029	0.410

1. Data followed by the same column are not significantly different at the 0.10 level, n= 15.

Table 2b. Effect of seeder on soybean stand (6/10), stand establishment, corn residue before and after planting, and yield and moisture (9/30) in the no-till plots at the Worhtington site, 1994.

Seeder	Seeding Population	Soybean Population	Stand Estab.	Corn Residue 5/12[1]	Corn Residue 5/16[2]	Harvest Moisture	Soybean yield
	Plants/acre x 1000		--%--	%		----%----	bu/A
Concord	226	167a[3]	74.1b	45.6a	33.8b	12.2a	54.7b
JD750	206	184a	89.6a	52.0a	51.4a	12.5a	61.7a
Hiniker	232	114a	49.2c	47.0a	37.6b	12.3a	55.4b
Pr>r							
Seeder		<0.001	<0.001	0.354	0.002	0.590	<0.001

1. Residue measured before planting.
2. Residue measured after planting.
3 Data followed by the same letter in the same column are not significantly different at the 0.01 level, n=15.

Table 3. Effect of seeder type on corn residue, soybean population, stand establishment and weed composition and yield in the **no-till plots only** at the Yellow Medicine County tillage study, 1994.

Seeder	Corn Residue	Soybean Stand	Stand Estab.	Weed Composition Grass	Broad	Soybean Yield
	%cover	#/Ax1000		-------%--------		bu/A
Sweep	37.7b[1]	55b	27.8b	68.3a	31.7a	46.1a
Case Int	52.7a	72b	45.8ab	68.8a	31.2a	48.7a
JD 750	52.2a	137a	57.3a	53.0a	47.0a	50.3a
Pr>F						
drill	0.028	0.037	0.086	0.708	0.708	0.760

1. Data followed by the same letter in the same column are not significantly different at the 0.10 level, n=9.

SOYBEAN STAND ESTABLISHMENT UNDER NO TILL CONDITIONS FOLLOWING CORN IN SOUTHWESTERN MN, 1994[1]

William E. Lueschen, Jim B. Nesseth, Wayne W. Schoper, Bob J. Byrnes, Steve R. Quiring, John F. Moncrief, Phyllis M. Bongard, and Brian J. Johnson[2]

Abstract: Stand establishment, height, lodging, and yield of soybeans were evaluated over a range in seeding rates under no till conditions following corn at five sites in southwestern MN. Stands ranged from 61 to 251 thousand plants per acre. When stands were over about 200 thousand plants per acre plants were slightly shorter but there was no effect of stand density on lodging. There was no affect of stand density on soybean yield at any site.

Introduction

This study was designed to assess the effect of no till soybeans following corn on stand loss and yield. Sites were established at the Lamberton Experiment Station and on four farms with assistance from cooperating farmers. Drills were set using manufacturer's recommendations to get a range in seeding rate from 125 to 250,000 seeds per acre in 25 thousand seeds per acre increments. Stands were measured at least once during the season. In some cases height and lodging observations were made.

Results

The only site that had appreciable stand loss was at Lamberton. The other four sites had stands close to the seeding rate. Height differences were related to seeding density were statistically significant where the measurements were made. Generally after about 200 thousand plants per acre heights were slightly lower. Lodging was not related to stand densities however. Final stands ranged from about 120 to 240 thousand plants per acre at the four "on farm" sites. At the Lamberton site the range was from 60 to 150 thousand plants per acre. There was no affect of stand density on soybean yield at any site.

Table 1a. Cultural practices used in the soybean seeding rate trial at the Lamberton Experiment Station, 1994.

Tillage system No-till

Planting and harvest information

Variety	Planting date	Harvest
Parker	5/17/94	10/14/94

(no inoculant or fungicide)
Planted with a John Deere 750 no-till (7")
Stands estimated by counts on 1m²/plot

Crop history 1993-Corn

Fertilizer applied

	Soil Test		Applied		
Date	P	K	N	P_2O_5	K_2O
	---ppm--		-----lb/A-----		
1992	15	110			
10/93			0	100	100

Soils
Ves loam (Udic Haplustoll)

Weed control

Date	Product	Rate
		lb ai/A
5/12	Glyphosate (Roundup)	0.75
5/20	Metolachlor (Dual) +	2.5
	Metribuzan (Sencor)	0.25

Experimental Design
Randomized Complete Block with 3 replications

1 This project was supported by the Midwest Soybean Grower Association, the MN Extension Service, and The MN Agricultural Experiment Station. Their support is greatly appreciated. Special thanks to Willis Wendland, Gary Veenstra, Dennis Whinsey, and Dave Knutson for allowing this study on their farms and providing assistance in treatment establishment and measurements of crop response.

2 William E. Lueschen and Steve R. Quiring are Head and Senior Plot Technician respectively at the Southwest Agricultural Experiment Station, Lamberton, MN; Jim B. Nesseth, Wayne W. Schoper, and Bob J. Byrnes are Extension Educators in Jackson, Brown, and Lyon Counties respectively; John F. Moncrief and Brian J. Johnson are Extension Soil Scientist and Assistant Scientist in the Soil, Water, and Climate Department, St. Paul, MN; Phyllis M. Bongard is an independent data analysis specialist, Faribault, MN.

Table 1b. Effect of seeding rate on soybean height, lodging, harvest population, and yield, October 14, 1994.

Seeding Rate	Height	Harvest Lodging	Soybean Population[2]	Yield
seeds/A	inches	score	plants/Ax1000	bu/A
125,000	24.0bc[1]	2.0a	97.2bc	42.8a
150,000	15.0c	2.3a	60.7c	41.2a
175,000	22.3bc	2.0a	90.4bc	40.7a
200,000	32.3ab	2.7a	130.9ab	42.5a
225,000	25.3bc	2.3a	102.6bc	43.8a
250,000	36.3a	2.7a	147.1a	43.1a
Pr>F				
Seeding rate	0.064	0.574	0.064	0.739

1. Data followed by the same letter in the same column are not significantly different at the 0.10 level, n=18.
2. Stand was measured by 1 meter square/plot.

Table 2a. Cultural practices used in the soybean seeding rate trial at the Willis Wendland farm in Lyon County, Minnesota, 1994.

Tillage system
No-till

Planting and harvest information

Variety	Planting date	Harvest
Parker	5/16/94	10/12/94

Planted with a John Deere 750 no-till drill (7" rows)

Crop history
1993 Corn

Fertilizer applied
none

Soil
Barnes loam (Udic Haploboroll)

Weed control

Date	Product	Rate
		lb ai/A
5/12 PPI	(Treflan)	1.0
6/8 Post	Imazethapyr (Pursuit)	0.032

Experimental Design
Randomized Complete Block with 3 replications. Stands were estimated by counting 10feet of row three places in each plot.

Table 2b. Effect of seeding rate on soybean harvest population, moisture content and yield at the Wendland farm, October 12, 1994.

Seeding Rate	Harvest Population[2]	Moisture Content	Soybean Yield
seeds/A	plt/Ax1000	--%--	bu/A
125,000	162.9c[1]	10.8a	47.2a
150,000	153.6c	10.7a	49.0a
175,000	165.3c	10.6a	50.2a
200,000	202.5b	11.1a	49.8a
225,000	207.2b	11.0a	48.8a
250,000	251.4a	10.9a	48.0a
Pr>F			
Seeding rate	<0.001	0.124	0.279

1. Data followed by the same letter in the same column are not significantly different at the 0.10 level, n=18.
2. Stand was measured by 10 ft. Counted, 3 places/plot.

Table 3a. Cultural practices used in the soybean seeding rate trial at the Gary Veenstra farm in Brown County, Minnesota, 1994.

Tillage system
No-till

Planting and harvest information

Variety	Planting date	Harvest
ICI 213	5/4/94	10/13/94

treated with fungicide
Planted with John Deere 750 no-till drill (10" rows)

Crop history
1993 - Corn (C-S rotation)

Fertilizer applied
None (fertilizer applied in corn years)

Soil
Ves and Storden loams 2-6% slope
(Udic Haplustoll & Typic Eutrochrept)

Weed control

Date	Product	Rate
		lb ai/A
6/7	Imazethapyr (Pursuit)	0.047

Observed weed pressure: light to moderate
Weeds present: Foxtail sp., Quackgrass, Dandelion, Thistles, Mares tail, slight volunteer corn

Experimental Design
Randomized Complete Block with 3 replications

Estimated crop residue cover
Before planting 77%
After planting 69%
(Estimates by G. Tennant of Brown Co. SCS)

Table 3b. Effect of seeding rate on soybean population (7/13), harvest moisture content and yield (10/13) at the Veenstra farm, 1994.

Seeding Rate	Soybean Population[2]	Moisture Content	Soybean Yield
seeds/A	plant/Ax1000	--%--	bu/A
125,000	130.7[1]	10.2a	45.5a
150,000	167.5	10.6a	48.4a
175,000	183.2	10.4a	52.4a
200,000	209.4	10.4a	48.2a
225,000	225.1	10.5a	49.1a
250,000	246.0	10.3a	46.2a
Pr>F			
Seeding rate		0.138	0.732

1. Data followed by the same letter in the same column are not significantly different at the 0.10 level, n=18.

Table 4a. Cultural practices used in the soybean seeding rate trial at the Dennis Whinsey farm in Jackson County, Minnesota, 1994.

Tillage system No-till
John Deere 750 no till drill (7.5" rows)

Planting and harvest information

Variety	Planting date	Harvest
Stine 2245	5/12/94	10/12/94

no inoculant or fungicide

Crop history 1993 - Corn (C-S normal rotation)

Soil
Canisteo-Glencoe clay loam 1% slope
(Typic Endoaquoll & Cumulic Endoaquoll)

Soil test (1990)	O.M.	pH	P	K
no fertilizer '94	6.5%	6.9	70 ppm	500 ppm

Weed control

Date	Product	Rate lb ai/A
5/4	Glyphosate (Roundup) +	0.38
	2,4-D	0.5
6/4	Bentazon + Aciflourfen	
	(Galaxy) &	0.69
	Imazethapyr (Pursuit)	0.032
6/20	Clethodim (Select)	0.125

Experimental Design
Randomized Complete Block with 3 replications. Stands were estimated by counting plants in 10 feet of row in 3 places in each plot.

Estimated crop residue cover
Before planting 75%
After planting 80%

Table 4b. Effect of seeding rate on soybean populations at stages V2 and physiological maturity (PM), soybean height, and yield at the Whinsey farm, 1994.

Seeding Rate	V2[2] Population	PM Population	Soybean Height	Soybean Yield
seeds/A	plants/A x 1000		inches	bu/A
125,000	124.7f[1]	124.0f	41.0a	48.4a
150,000	138.7e	138.2e	41.0a	50.0a
175,000	167.3d	166.2d	41.0a	51.3a
200,000	209.3c	210.8c	40.0b	49.3a
225,000	224.3b	221.3b	40.0b	50.0a
250,000	243.3a	238.7a	39.0c	48.4a
Pr>F				
Seeding rate	<0.001	<0.001	<0.001	0.685

1. Data followed by the same letter in the same column are not significantly different at the 0.10 level, n=18.
2. Stand was measured by 10 ft. Count, 3 places/plot.

Table 5a. Cultural practices used in the soybean seeding rate trial at the Dave Knutson farm in Jackson County, Minnesota, 1994.

Tillage system No-till

Planting and harvest information

Variety	Planting date	Harvest
DeKalb 232	5/15/94	10/9/94

no inoculant or fungicide (10" rows)

Crop history 1993-Corn (C-S rotation)

Fertilizer applied none

Soil Clarion loam 2-6% slope (Typic Hapludoll)

Soil test (1992)

O.M.	pH	P	K
3.7%	6.1	47 ppm	203 ppm

Weed control

Date	Product	Rate
		lb ai/A
5/8	Glyphosate (Roundup) +	0.75
	2,4-D	0.5
6/4	Bentazon + Aciflourfen	
	(Galaxy) &	0.69
	Imazethapyr (Pursuit)	0.032

Experimental Design

Randomized Complete Block with 3 replications. Stands were estimated by counting plants in 10 feet of row in 3 places in each plot.

Estimated crop residue cover

Before planting 70%

After planting 60%

Table 5b. Effect of seeding rate on soybean population at stages V2 and physiological maturity (PM), soybean height, moisture content, and yield (10/9) at the Knutson farm, 1994.

Seeding Rate	V2 Population	PM Population	Soybean Height	Moisture Content	Soybean Yield
seeds/A	plants/A x 1000[2]		inches	--%--	bu/A
125,000	122.8d[1]	121.7e	40.7a	13.2a	48.4a
150,000	143.8c	140.3d	40.0a	13.3a	49.5a
175,000	154.5c	154.7cd	40.0a	13.3a	53.0a
200,000	158.8c	158.7bc	40.0a	13.0a	55.2a
225,000	177.4b	176.7b	40.0a	12.3a	48.8a
250,000	241.4a	237.3a	38.0b	13.3a	54.2a
Pr>F					
Seeding rate	<0.001	<0.001	0.001	0.708	0.312

1. Data followed by the same letter in the same column are not significantly different at the 0.10 level, n=18.
2. Stand was measured by 10 ft. Count, 3 places/plot.

INTEGRATION OF MANURE AND ALFALFA N SOURCES INTO RESIDUE MANAGEMENT SYSTEMS FOR KARST AREAS OF MN, 1994[1]

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-N. R. Broadwater, T.L. Wagar, B.J. Johnson
P M. Bongard, and T.L. Heiden[2]

Abstract Tillage and N source were evaluated for corn and soybean production on four farms in southeastern MN. Generally "in row" cover with corn or soybean residue reduced corn development. Soybean growth was slowed in some instances but no yields. Tillage had variable effects on grain yields. Manure generally resulted in increased early growth and development compared to commercial fertilizer.

Introduction

This study was initiated in the spring of 1993 to evaluate manure utilization strategies within residue management systems in southeastern MN. The same farmer cooperators agreed to another year in three counties in 1994. Each demonstration was tailored to fit within the project guidelines and also address particular farmer interests. Residue management systems are the convention in this part of the state due to the erosive nature of the soils. This is the second and final year of this study.

Tony and Walter Hammel Farm

This site had first year corn following alfalfa in 1993. Treatments in 1993 included aspect and timing of alfalfa killing as variables. For a detailed description of treatments see the 1994 copy of this publication. In 1994 in addition to these two variables planter applied fertilzier was evaluated on second year corn. The design is a randomized complete block with split, split plots. Time of alfalfa kill are main plots, the first subplot is aspect, and the second subplot is starter fertilizer. The planter used was equipped with a 2 inch fluted coulter.

Residue levels are shown in table 1b. Killing the alfalfa in the spring of 1993 compared to the fall of 1992 resulted in higher levels of residue in the row after planting in 1994 (72 compared to 65%). This is largely due to higher densities of weed and alfalfa residues. Fluted coulters reduced "in row" cover from 74 to 63%. This is much higher than optimum for corn growth and development.

Early growth, stand, and tasselling rate are shown in table 1c. Starter fertilizer increased corn stands by about 1,600 plants per acre. Starter also increased early growth by .5 leaves per plant. None of the treatments affected the tasselling rate, however. The silking data shows an effect of aspect (table 1d). Southern aspect had about 25% more plants with silk emerged on 7/18 and 7/22.

Inadvertently one replication was lost by harvest by the cooperating farmer. For this reason yield parameters do not have a statistical analysis. Means of the remaining two replications are presented to show trends. No conclusions can be drawn however.

Jim Holty Farm

At the Jim Holty farm two studies were conducted. The first evaluated tillage and nitrogen source on corn response followig corn. The second evaluated tillage effects on soybean production. The corn study is shown in tables 2b-2d. In this study the two N sources (manure and anhydrous) and two tillage systems were evelauted (chisel and no till). Soil cover with corn residue was influenced strongly by the rolling finger type row cleaners. After planting there was about the same "in row" cover for both the no till and chisel systems (about 37%) although there was large differences between the row. At the second residue measurement (6/27) the residue had blown back into the row with the no till treatment. The increase was more with the manure application than with the anhydrous N source (20 vs 10%). These values are much to high for effective early corn growth and

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development.

Tillage and N source did not affect stands (table 2c). Both did affect early growth. The no till system reduced early growth 1.3 leaves per plant compared to the chisel system. The manure N source increased early growth by .4 leaves. The growth advantage of the corn grown with chisel plowing also hastened tasselling. The manure N source showed a similar trend. Development trends also carried through silk emergence (table 2d).

Chisel plowing resulted in a 45 bushel per acre yield advantage over the no till system. This is a greater difference than other studies have shown considering the size of the early growth differnces. There was a small yield advantage of the manure N source (7 bushels per acre).

The soybean study compared no till and chisel tillage system effects on soybean response (tables 2e and 2f). Corn residue levels were about 20% higher with no tillage. Chisel plowing followed with secondary tillage left greater than 30% cover.

Soybean stands were similar and more than adequate. Although there was a slight early growth difference (.2 nodes per plant) grain yields were identical. This is typical on these soils when weeds are effectively controlled.

Dan Graskamp Farm

At this site two sources of N (liquid pig manure and anhydrous ammonia), two rates of manure (1,500 and 3,000 gallons per acre resulting in 80 and 160 pounds of estimated available N per acre), and row cultivation was evaluated on second year corn. Results are given in tables 3a-3c.

Corn residue levels were greater than 40% and slightly higher in the row (apparently the result of the planter mounted fluted coulters). It is also interesting that row cultivation tended to increase cover with corn residue. Soil cover in the row is much higher than recommended.

Stands, early growth and yield are shown in table 3c. The high rate of manure increased stands about 2,000 plants per acre. Cultivation reduced stands 1,000 plants per acre. Stand levels are high enough that it is unlikely that they affected yields. Cultivation decreased early growth by .4 leaves per plant. A similar trend was found in the rate of silk emergence and grain moisture.

Yields were not affected by N source, rate, or cultivation.

Daryl Highum Farm

Treatments at this site are tillage, corn hybrid, and N source. Tillage systems evaluated are chisel plowing followed by discing and a no till approach. Nitrogen sources are anhydrous ammonia and liquid hog manure. Manure application was made in the spring followed by tillage and planting. Anhydrous ammonia was applied side dress June 15. The results from this demonstration is presented in tables 4a-4d and figures 1-6. Back ground information for is shown in table 4a.

Soil cover with soybean residue was about 9% for both tillage systems after planting. The fluted coulters did an usually good job of removing residue from the row area with both tillage sytems. On the second date of residue measurment (only 9 days later) "in row" cover increased about 30% with the no till system. Manure increased soil cover slightly with the discing system but reduced it with no tillage.

The main effects of tillage, N source, and hybrid did not affect stands. There was a significant interaction between N source and tillage. Tillage surprisingly did not affect early growth. There was an effect of N source and corn hybrid. Manure and the Cargill hybrid increased early growth .3 leaves per plant. The manure N source and Cargill hybrid resulted in earlier tasselling and silk emergence. There were no significant main effects for grain moisture although there were several interactions. Grain yields were only affected by corn hybrid (P3578 was 10 bushels per acre higher than Cargill 4327).

Sigificant interactions are shown in figures 1-4. The Cargill hybrid tasselled much earlier than the Pioneer hybrid under the discing tillage system. Grain moisture showed an opposite trend which is expected. Grain yield differences between hybrids were greater under the discing tillage system.

The relationship between "in row" cover with corn residue and early growth for the two hybrids is shown in figures 5 and 6. Residue effects on early growth increased with time for the Cargill hybrid and decreased with time for the Pioneer hybrid.

Table 1a. Cultural practices used at the Hammel farm sodkill (1993), aspect (1993), and starter fertilizer (1994) corn study Houston County, MN, 1994.

Tillage system
No-till (not a variable)

Planting and harvest information

Crop	Hybrid	Planted	Seeds	Harvested
Corn	DK 451 (100 day)	4/20	29,000s/A	9/15/94

New Idea planter with Kinsey planting units and 2" fluted coulters

Crop history
1993 - Corn; 1992 Alfalfa

Fertilizer nutrients applied

Date	Analysis	applied (lb/A) N	P_2O_5	K_2O
4/20/94	9-23-30	9	23	30

Liquid dairy manure applied

Manure Analysis (lb/1000 gallons) Total N	NH_4^+	Org. N	P_2O_5	K_2O
48	24	24	19	31

Date	Rate	Nutrients applied Total N	N_{avail}[1]	P_2O_5	K_2O
	gal/A	--------------lb/A---------------			
11/93	3000	145	94	56	93

1. Estimated available N from manure = 100% mineral N + 30% organic N (Assumes 50% org. and 50% inorg.)
Liquid dairy manure stored in earthen lagoon.

Soils
Black Hammer-Southridge silty clay loam
Nodine-Rollingstone silty clay loam
(Typic Hapludalfs & Typic Paleudalfs respectively)

Weed control

Date	Herbicide	Rate
		lb ai/A
5/9/94	Acetachlor (Harness)	1.75
"	Dicamba (Banvel)	0.25
"	Flumetsulam (Broadstrike)	0.04

Fall '92 or Spring '93 glyphosate (Roundup) for alfalfa sod kill

Weed (6/27)	Whole site % cover
Foxtail sp.	40
Quackgrass	15
Com. lambsquarters	10
Dandelion	1.5
Alfalfa	1
Common milkweed	1
Blackseed plantain	1
Hedge bindweed	0.5

Aspect		Mean
North slope	14-22%	17.8
South slope	16-21%	17.2

Table 1b. Effect of sodkill, aspect, and starter fertilizer on corn residue in and between the rows at the Hammel farm demonstration, June 1994.

			Corn Residue					
			6/9/94		6/27/94		Mean	
Sodkill	Aspect	Starter	In	Between	In	Between	In	Between
			----------------% cover----------------					
Fall	North	Yes	57.5a[1]	67.5a	67.5	72.5	62.5	70.0
		No	62.5a	75.0a	62.5	72.5	62.5	73.8
	South	Yes	62.5a	65.0a	55.0	67.5	58.8	66.2
		No	52.5a	77.5a	50.0	72.5	51.2	75.0
Spring	North	Yes	65.0a	70.0a	62.5	77.5	63.8	73.8
		No	70.0a	80.0a	70.0	70.0	70.0	75.0
	South	Yes	77.5a	82.5a	72.5	80.0	75.0	81.2
		No	62.5a	77.5a	60.0	77.5	61.2	77.5
Fall[2]			65.0a		65.0a		65.0a	
Spring			73.1a		71.2a		72.2b	
	North[2]		8.4a		69.4a		68.9a	
	South		69.7a		66.9a		68.3a	
		Starter[2]	68.4a		69.4a		68.9a	
		No starter	69.7a		66.9a		68.3a	
		Row pos.	63.8a	74.4a	62.5a	73.8b	63.1a	74.1a
Pr>F								
Sodkill			0.190		0.186		0.028	
Aspect			0.728		0.314		0.808	
Sodkill*Aspect			0.508		0.116		0.238	
Starter			0.811		0.732		0.920	
Starter*Sodkill			0.637		0.863		0.763	
Starter*Aspect			0.315		0.863		0.586	
Starter*Sodkill*Aspect			0.558		0.732		0.654	
Row Position			0.174		0.064		0.108	
Row position*sodkill			0.799		0.817		0.803	
Row position*aspect			0.865		0.494		0.690	
Row position*starter			0.502		0.817		0.620	
Row pos.*sodkill*aspect			1.00		0.817		0.920	
Row pos.*sodkill*starter			0.865		0.645		0.765	
Row pos.*aspect*starter			0.672		0.494		0.586	
RowP.*sodkill*aspect*starter			0.799		0.645		0.960	

1. Data followed by the same letter in the same group (by date) are not significantly different at the 0.10 level, n=32.
2. Means are over row position.

Table 1c. Effect of sodkill, aspect and starter fertilizer on corn population, corn leaf numbers, and tasselling at the Hammel farm, 1994.

			Corn Population			Leaf Numbers			Corn Tasselling		
Sodkill	Aspect	Starter	6/9	6/27	Mean	6/9	6/27	Mean	7/18	7/22	Mean
			--plants/A x 1000----			----leaves/plant---			------% plants------		
Fall	North	Yes	18.6a[1]	19.2a	18.9ab	4.6a	7.2a	6.0a	55.8a	92.3a	74.0a
		No	19.9a	19.9a	19.9ab	4.2a	6.2a	5.2a	49.2a	81.2a	65.2a
	South	Yes	19.9a	21.3a	20.6ab	5.1a	8.4a	6.8a	88.3a	100.0a	94.2a
		No	17.9a	17.9a	17.9b	5.0a	8.0a	6.5a	95.4a	100.0a	97.8a
Spring	North	Yes	24.0a	24.7a	24.4a	5.0a	7.6a	6.4a	83.4a	100.0a	91.7a
		No	22.0a	22.0a	22.0ab	4.5a	8.4a	6.4a	85.0a	100.0a	92.5a
	South	Yes	20.6a	20.6a	20.6ab	5.5a	8.5a	7.0a	97.4a	100.0a	98.7a
		No	17.2a	19.2a	18.2b	4.9a	6.8a	5.8a	78.6a	85.7a	81.2a
Fall			19.1a	19.6a	19.3a	4.8a	7.4a	6.1a	72.2a	93.4a	82.8a
Spring			21.0a	21.6a	21.3a	5.0a	7.8a	6.4a	86.0a	96.4a	91.3a
	North		21.1a	21.5a	21.3a	4.6a	7.4a	6.0a	68.3a	93.4a	80.9a
	South		18.9a	19.8b	19.3a	5.1a	7.9a	6.5a	89.9a	96.4a	93.2a
		Starter	20.8a	21.5a	21.1a	5.1a	7.9a	6.5a	81.2a	98.1a	89.7a
		No Starter	19.2b	19.8a	19.5b	4.6a	7.3a	6.0a	77.0a	91.7a	84.4a
Pr>F											
Sodkill			0.500	0.442	0.471	0.153	0.667	0.549	0.228	0.775	0.429
Aspect			0.238	0.072	0.163	0.231	0.369	0.270	0.145	0.656	0.238
Sodkill*Aspect			0.294	0.072	0.187	0.793	0.193	0.322	0.194	0.226	0.199
Starter			0.027	0.142	0.069	0.143	0.155	0.113	0.639	0.159	0.400
Starter*Sodkill			0.057	0.734	0.306	0.522	0.794	0.856	0.614	0.841	0.663
Starter*Aspect			0.057	0.506	0.225	0.895	0.300	0.483	0.846	0.841	0.834
Starter*Sodkill*Aspect			0.320	0.218	0.225	0.696	0.089	0.176	0.356	0.159	0.254

1. Data followed by the same letter in the same column group are not significantly different at the 0.10 level, n=16.

Table 1d. Effect of sodkill, aspect, and starter fertilizer on corn silking, harvest population, grain moisture and corn yield at the Hammel farm, September 9, 1994.

			Corn silking			Harvest	Harvestable		
Sodkill	Aspect	Starter	7/18	7/22	Mean	Pop.	Ears	Moisture	Yield
			-------% plants--------			plts/Ax1000	%	%	bu/A
Fall	North	Yes	0.0a	42.0a	21.0a	17.9	100.0	30.8	76.1
		No	0.0a	31.9a	16.0a	16.5	100.0	30.4	75.2
	South	Yes	36.6a	96.2a	66.4a	19.2	78.6	47.4	54.2
		No	32.2a	90.9a	61.6a	16.5	100.0	29.4	73.6
Spring	North	Yes	20.1a	96.6a	58.4a	20.6	96.2	29.4	116.2
		No	24.6a	78.2a	51.4a	19.2	95.6	34.1	94.3
	South	Yes	37.3a	90.2a	63.8a	19.6	95.3	28.0	107.1
		No	35.7a	67.8a	51.8a	21.3	85.0	29.4	110.4
Fall			17.2a	65.2a	41.2a	17.5	94.6	34.5	69.8
Spring			29.4a	83.2a	56.4a	20.2	93.0	30.2	107.0
	North		11.2a	62.2b	36.7b	18.6	98.0	31.2	90.4
	South		35.5a	86.3a	60.9a	19.2	89.7	33.4	86.3
	Starter		23.5a	81.3a	52.4a	19.3	92.5	33.9	88.4
	No Starter		23.1a	67.2a	45.2a	18.4	95.2	30.8	88.4
Pr>F									
Sodkill			0.609	0.468	0.533				
Aspect			0.142	0.042	0.037				
Sodkill*Aspect			0.428	0.024	0.047				
Starter			0.955	0.225	0.399				
Starter*Sodkill			0.783	0.550	0.784				
Starter*Aspect			0.694	0.982	0.883				
Starter*Sodkill*Aspect			0.949	0.834	0.871				

1. Data followed by the same letter in the same column group are not significantly different at the 0.10 level, n=16.

Table 2a. Cultural practices used at the Holty farm corn and soybean tillage studies, Houston County, 1994.

Tillage systems

1. No-till
2. Spring disced (4/20/94) 14' Case IH; chisel plowed (4/23/94) Case IH with 2" shovels;

Planting and harvest information

Crop	Hybrid/Var.	Plant	Population	Harvest
Corn	Keltgen 2550	4/23	29,000s/A	11/16
Sybn	Asgrow 2234	4/26	210,000s/A	11/16

Corn planted with Case IH 800 with Yetter rolling finger row cleaners.

Soybeans planted with Case IH grain drill equipped with a Yetter coulter cart.

Crop history

1993 - Corn at both demonstration sites

Fertilizer nutrients applied (corn only)

Date	Analysis	N	P_2O_5	K_2O
		applied (lb/A)		
4/18/94	82-0-0	131	0	0
4/20/94	9-23-30	12	30	39

Beef manure nutrients applied

Manure Analysis (lb/ton)

Total N	NH_4^+	Org. N	P_2O_5	K_2O
16	3	13		

Nutrients applied

Date	Rate	Total N	N_{avail}[1]	P_2O_5	K_2O
	ton/A	----------lb/A----------			
4/12/94	21	336	158		

1. Estimated available N from manure =100% mineral N + 35% organic N Solid beef manure from cement lot.

Soils

Port Byron silt loam 3-6% slope (Typic Hapludoll)

Weed control

Date	Product	Rate
Corn		lb ai/A
5/15/94	Dicamba+Atrazine (Marksman)	1.0
"	Metolachlor (Dual)	1.3
"	Atrazine	0.6
6/3 & 6/16	Row cultivator- Case IH 4-38" rows & 5 Danish tines/row	
Soybean		
Rep 1		lb ai/A
5/3	Imazethapyr + Pendimethalin (Pursuit Plus)	0.9
"	Pendimethalin (Prowl)	0.5
Rep 2		
6/21/94	Imazethapyr (Pursuit)	0.063
"	Thifensulfuron (Pinnacle)	0.001

Weeds present	Whole site % cover
Corn	
Foxtail sp	4.0
Quackgrass	2.0
Horsetail	0.5
Velvetleaf	0.1
Dandelion	0.5
Soybean	
No-till plots	
Quackgrass	2.0
Horsetail	0.5
Red clover	0.05
Maple trees	0.05
Chisel plots	
Quackgrass	1.0
Velvetleaf	1.0

Table 2b. Effect of tillage and manure on corn residue (6/9 and 6/27) in the corn demonstration at the Holty farm, 1994.

Tillage	N Source	Corn Residue 6/9 Row Position In	Between	Corn Residue 6/27 Row Position In	Between	Corn Residue Mean In	Between
		------% cover					
No-till	Manure	38.2bc[1]	70.8a	63.2a	65.5a	51.0ab	68.2a
	An.NH_3	40.8bc	60.0ab	49.5a	60.5a	45.2ab	60.2ab
Chisel/disc	Manure	32.5c	40.8bc	43.8a	46.0a	38.2b	43.5ab
	An.NH_3	35.8bc	38.8bc	55.2a	55.0a	45.5ab	47.0ab
No-till[2]		52.4a		59.7a		56.2a	
Chisel/disc		36.9a		50.0a		43.6a	
	Manure[2]	45.6a		54.6a		50.2a	
	An.NH_3	43.8a		55.1a		49.5a	
	Row position	36.8b	52.6a	52.9b	56.8a	45.0b	54.8a
Pr>F							
Tillage		0.136		0.267		0.184	
N Source		0.619		0.941		0.776	
Tillage*N Source		0.512		0.203		0.118	
Row position		0.003		0.053		0.006	
Row position*tillage		0.013		0.115		0.025	
Row position*N Source		0.124		0.327		0.456	
Row pos*tillage* N Source		0.449		0.115		0.847	

1. Data followed by the same letter in the same column or row group (by date) are not significantly different at the 0.10 level, n=16.
2. Means within row position.

Significant interactions from Table 2b.

Tillage	Residue 6/9 Row position In	Between	Residue 6/27 Row position In	Between	Corn Residue means In	Between
	------%cover					
No-till	39.5b	65.4a	56.4	63.0	48.1	64.2
Chisel	34.2b	39.8b	49.5	50.5	41.9	45.2

Table 2c. Effect of tillage and N source on corn population, leaf numbers, tasselling, silking and harvest data in the corn demonstration at the Holty farm, 1994.

Tillage	N Source	Corn Population 6/9	6/27	Mean	Leaf Numbers 6/9	6/27	Mean	Tasselling 7/13	7/17	Mean
		---plants/A x 1000---			------leaves/plant------			---------% plants--------		
No-till	Manure	21.2a[1]	20.4a	20.9a	4.9b	7.4bc	6.2b	16.6a	72.7a	44.6a
	An.NH_3	20.9a	20.3a	20.6a	4.9b	7.2c	6.1b	6.8a	69.6a	38.2a
Chisel/	Manure	23.3a	23.5a	23.4a	5.6a	9.8a	7.8a	50.4a	92.1a	71.2a
disc	An.NH_3	23.6a	24.2a	24.0a	5.2ab	9.2ab	7.2ab	32.8a	84.4a	58.6a
No-till		21.0a	20.4a	20.7a	4.9a	7.3b	6.2b	11.7b	71.1a	41.4a
Chisel/disc		23.5a	23.8a	23.4a	5.4a	9.5a	7.5a	41.6b	88.2b	65.0a
	Manure	22.2a	22.0a	22.1a	5.3a	8.6a	7.0a	33.4a	82.4a	58.0a
	An.NH_3	22.2a	22.3a	22.3a	5.1a	8.2a	6.6a	19.8a	77.0a	48.4a
Pr>F										
Tillage		0.451	0.407	0.426	0.114	0.080	0.084	0.291	0.073	0.168
N Source		1.00	0.795	0.916	0.057	0.226	0.137	0.113	0.586	0.245
Tillage*N		0.838	0.752	0.755	0.057	0.457	0.237	0.521	0.812	0.652

1. Data followed by the same letter in the same column group are not significantly different at the 0.10 level, n=8.

Table 2d. Effect of tillage and N source on corn silking, grain moisture, and corn yield in the demonstration at the Holty farm, 1994.

Tillage	Source	Corn Silking 7/13	7/17	Mean	Grain Moisture	Corn Yield
		------% plants------			%	bu/A
No-till	Manure	0.0a	15.2a	7.6a	19.2a	117a
	An.NH_3	0.0a	22.4a	11.2a	19.4a	102a
Chisel	Manure	11.0a	79.0a	45.0a	19.8a	154a
	An.NH_3	4.8a	47.4a	26.1a	19.4a	153a
No-till		0.0a	18.8a	9.4a	19.3a	109a
Chisel		7.9a	63.2a	35.6a	19.6a	154a
	Manure	5.5a	47.0a	26.3a	19.6a	135a
	An.NH_3	2.4a	34.9a	18.7a	19.4a	127a
Pr>F						
Tillage		0.202	0.141	0.150	0.644	0.114
N Source		0.280	0.252	0.158	0.168	0.117
Tillage*N Source		0.280	0.126	0.082	0.038	0.135

1. Data followed by the same letter in the column group are not significantly different at the 0.10 level, n=8.

Table 2e. Effect of tillage on corn residue in and across the rows in the soybean study at the Holty farm, 1994.

Tillage	Residue (6/17) Row Position In	Across	Residue (6/24) Row Position In	Across	Residue means Row Position In	Across
	------------------------%cover------------------------					
No-till	52.5a[1]	54.3a	62.5a	52.2a	57.5a	53.2a
Chisel	30.0a	30.7a	33.3a	34.3a	31.7a	32.6a
No-till[2]	53.4a		57.3a		55.4a	
Chisel	30.4a		33.8a		32.1a	
RowPos.	41.2a	42.5a	47.9a	43.2a	44.6a	42.9a
Pr>F						
Tillage	0.146		0.160		0.153	
RowPos.	0.775		0.263		0.660	
Till*RPos.		0.899		0.202		0.523

1. Data followed by the same letter in the column group are not significantly different at the 0.10 level, n=8.
2. Means over row position.

Table 2f. Effect of tillage on soybean population, node numbers and harvest data in the soybean demonstration at the Holty farm, June 1994.

Tillage	Soybean Population 6/8	6/24	Mean	Node Numbers 6/8	6/24	Mean	Harvest Moisture	Soybean Yield
	plt/Ax1000			nodes/plant			--%--	bu/A
No-till	206a	192a	199a	3.1b	6.8a	5.0a	14.2a	57.4a
Chisel/Disc	227a	220a	224a	3.3a	7.0a	5.2a	14.6a	57.4a
Pr>F								
Tillage	0.747	0.683	0.713	0.052	0.205	0.126	0.395	1.00

1. Data followed by the same letter in the same column are not significantly different at the 0.10 level, n=4.

Table 3a. Cultural practices used in the Graskamp farm nitrogen source and cultivation corn study near Fountain in Fillmore County, 1994.

Tillage systems

1. Coulter-Chisel plow (fall) 13' John Deere with straight discs at 7" spacing in front of 3" shanks at 18" spacing in back followed by a feld cultivator (5/2/94) 21' w/ 2" shanks at 6" spacings

2. No till

Planting and harvest information

Crop	Hybrid	Plant	Population	Harvest
Corn	Agrigene 3965	5/2	25,500s/A	11/9

Corn planted with John Deere 7000 with 2" fluted coulters

Crop history

1993 - Corn

Soil

Fayette silt loam 2-6% slope
(Typic Hapludalf)

Insect Control

5/2 Terbufos (Counter) 1.2 oz ai/1000' row (1.0 lb ai/A)

Nutrients applied (lb/A)

Date	Analysis	N	P_2O_5	K_2O
4/20/94	82-0-0	125	0	0
5/2/94	8-20-27	10	25	34

Liquid hog manure applied

Manure Analysis (lb/1000 gallons)

Total N	NH_4^+	Org. N	P_2O_5	K_2O
57.1	51.0	6.1		

Nutrients applied

Date	Rate	Total N	N_{avail}[1]	P_2O_5	K_2O
	gal/A	---------------lb/A---------------			
11/93	3000	171	160		
"	1500	86	80		

1. Estimated available N from manure = 100% mineral N + 35% organic N Liquid hog manure stored in a pit.

Weed control

Date	Control	Rate
		lb ai/A
5/12/94	Dicamba + Atrazine (Marksman)	1.0
	Pendimethalin (Prowl)	1.25
	Cyanizine (Bladex)	0.9
6/16/94	Row cultivator 13' John Deere (4-38"rows) w/ 4-2" sweeps between rows	

Weeds present	% cover
Foxtail sp	1.5
Quackgrass	1.0
Velvetleaf	1.0

Table 3b. Effect of nitrogen source and cultivation on corn residue in and between the rows at the Graskamp farm, 1994.

N		Corn residue					
		5/31/94		6/21/94		Means	
Source	Cultivation	In	Between	In	Between	In	Between
		---------------%cover---------------					
Anhyd. NH_3	No	46.2a[1]	43.4ab	40.4a	39.2a	43.5a	39.8abc
	Yes			45.4a	44.2a		
Manure	No	43.9a	30.2c	45.8a	40.8a	44.8a	35.6c
1500g/A	Yes			52.0a	43.6a		
Manure	No	45.2a	33.8bc	39.1a	40.1a	42.2ab	37.0bc
3000g/A	Yes			42.2a	38.4a		
Anhyd. NH_3[2]		43.5a		42.3a		41.7a	
Manure (1500g/A)		37.1a		45.5a		40.2a	
Manure (3000g/A)		39.5a		40.0a		39.6a	
No Cultivation[2]				40.9a			
Cultivation				44.3a			
Row position		45.2a	34.8b	44.1a	41.1a	43.5a	37.4b
Pr>F							
N Source			0.296		0.166		0.674
Cultivation					0.141		
N Source*Cultivation				0.669			
Row Position		<0.001		0.118		0.004	
Row pos.*N Source		0.237		0.414		0.360	
Row pos.*Cultivation				0.473			
Row pos*N*Cultivation				0.864			

[1]Data followed by the same letter in the same group (by date) are not significantly different at the 0.10 level. n=24 (before cultivation); n=48 (after cultivation)
[2]Means over row position.

Table 3c. Effect of nitrogen source and cultivation on corn population, corn leaf numbers, silking score (7/25), and harvest data (11/9) at the Graskamp farm, 1994.

N Source	Cultiva-tion	Corn Population[1] 5/31	6/21	Mean	Leaf Numbers 5/31	6/21	Mean	Silk Score[2]	Grain Moisture	Corn Yield
		----plants/Ax1000----			------leaves/plant------			score	%	bu/A
An. NH3	No		24.1bc[3]			6.9a		1.2a	13.7a	140a
	Yes		24.8abc			6.5abc		1.2a	13.2b	143a
Manure	No		22.9c			6.9a		1.2a	13.6a	148a
1500g/A	Yes		25.4ab			6.4bc		1.0a	13.4a	146a
Manure	No		26.4a			6.8ab		1.4a	13.3ab	150a
3000g/A	Yes		26.5a			6.2c		1.1a	13.1b	152a
An. NH_3		23.8b	24.4b	24.1b	2.4a	6.7a	4.6a	1.2a	13.4a	142a
Man.-1500g/A		24.3b	24.2b	24.2b	2.4a	6.6a	4.6a	1.1a	13.5a	147a
Man.-3000g/A		26.4a	26.4a	26.4a	2.4a	6.5a	4.4a	1.2a	13.2a	151a
No Cultivation				24.5b			6.8a	1.3a	13.5a	146a
Cultivation				25.5a			6.4b	1.1a	13.2b	147a
Pr>F										
N Source		0.010	0.056	0.016	0.831	0.632	0.584	0.670	0.195	0.341
Cultivation			0.094			0.001		0.117	0.031	0.542
N*Cultivation			0.266			0.681		0.500	0.501	0.584

[1]Late emergence noted in heavy residue areas.
[2]Silking score based on color: 1=white or yellow (not pollinated) 5=brown (pollinated).
[3]Data followed by the same letter in the same column group are not significantly different at the 0.10 level. n=12 (before cultivation) n=24 (after cultivation).

Table 4a. Cultural practices used in the Highum farm tillage, nitrogen source, and corn variety study near Rushford in Fillmore County, 1994.

Tillage systems
1. Disc (4/22/94) 19' Ford with 20" discs
2. No till

Planting and harvest information

Crop	Hybrid	Plant	Pop.	Harvest
Corn	P3578	4/23&29	30,000s/A	10/24
"	Cg4327	"	"	"

105 day RM for both corn hybrids
Corn planted with Allis Chalmers with 2" fluted coulters

Crop history
1993 - Soybeans

Soils
Alluvial soil

Nutrients applied

Actual applied (lb/A)Date	Analysis	N	P_2O_5	K_2O
4/23&29	9-23-30	14	34	45
6/6/94	82-0-0	102	0	0

Liquid hog manure applied
Manure Analysis (lb/1000 gallons)

Total N	NH_4^+	Org. N	P_2O_5	K_2O
70.3	44.1	26.1		

Nutrients applied

Date	Rate	Total N	N_{avail}[1]	P_2O_5	K_2O
	gal/A	---------------lb/A--------------			
11/93	2500	176	133		

1. Estimated available N from manure =100% mineral N + 35% organic N Liquid hog manure stored in a pit.

Weed control

Date	Control	Rate
		lb ai/A
5/6/94	Dicamba + Atrazine	
	(Marksman) +	1.2
"	Metolachlor (Dual)	2.0
6/2/94	Nicosulfuron (Accent)	0.03

Weeds present	% cover
Velvetleaf	1.0

Table 4b. Effect of tillage, nitrogen source, and hybrid on soybean residue, corn population, and corn leaf numbers at the Highum Farm, 1994.

			Soybean Residue					
	Nitrogen		6/1/94		6/18/94		Means	
Tillage	Source	Hybrid	In	Between	In	Between	In	Between
			--------------%cover--------------					
Disc	An.NH_3	Cg4327	7.5	14.4	8.1	15.6	8.0	15.1
		P3578	7.5	16.9	11.9	19.4	9.8	18.2
	Manure	Cg4327	16.2	16.9	15.6	23.1	16.0	20.1
		P3578	6.9	12.5	10.0	21.2	8.6	17.0
No-till	An.NH_3	Cg4327	38.1	51.9	39.4	53.8	38.8	52.9
		P3578	26.2	48.8	36.9	48.8	31.6	48.8
	Manure	Cg4327	21.9	56.9	37.5	59.4	29.9	58.2
		P3578	29.4	58.1	36.9	53.1	33.2	55.8
Disc[1]			12.3b[2]		15.6b		14.1b	
No-till			41.4a		45.7a		43.6a	
	An.NH_3[1]		26.4a		29.2a		27.9a	
	Manure		27.3a		32.1a		29.9a	
		Cg4327[1]	28.0a		31.6a		29.9a	
		P3578	25.8a		29.8a		27.9a	
		Row pos.	19.2b	34.5a	24.5b	36.8a	22.0b	35.8a
Pr>F								
Tillage			0.008		0.005		0.006	
N Source			0.703		0.264		0.404	
Tillage*N			0.798		0.727		0.764	
Hybrid			0.416		0.584		0.454	
Hybrid*Tillage			0.814		0.584		0.822	
Hybrid*N			0.724		0.584		0.878	
Tillage*N*Hybrid			0.078		0.552		0.208	
Row position			<0.001		<0.001		<0.001	
Row position*Tillage			<0.001		0.018		<0.001	
Row position*N			0.235		0.205		0.131	
Row position*Hybrid			0.494		0.718		0.796	
Row position*Tillage*N			0.015		0.505		0.041	
Row position*Tillage*Hybrid			0.731		0.332		0.428	
Row position*N*Hybrid			0.393		0.959		0.575	
Row position*Tillage*N*Hybid			0.235		0.572		0.276	

[1]Means over row position.
[2]Data followed by the same letter in the same group (by date) are not significantly different at the 0.10 level. n=64

Significant interactions from Table 4b.

		Residue 6/9		Means	
		Row position		Row Pos.	
Tillage	N	In	Between	In	Between
		---------%cover-----------			
Disc	NH_3	7.5	15.6	8.9	16.6
	Manure	11.6	14.7	12.0	18.6
No-till	NH3	32.2	50.3	35.2	50.8
	Manure	25.6	57.5	31.6	57.0

	Residue 6/9		Residue 6/18		Residue means	
	Row position		Row position		Row position	
Tillage	In	Between	In	Between	In	Between
	-----------------%cover------------------					
Disc	9.5	15.2	11.4	19.8	10.6	17.6
No-till	8.9	53.9	37.6	53.8	33.4	53.9

Table 4c. Effect of tillage, nitrogen source, and hybrid on corn population, and corn leaf numbers at the Highum farm, 1994.

Tillage	N Source	Hybrid	Corn Population 6/1	6/18	Mean	Leaf Numbers 6/1	6/18	Mean
			----plants/Ax1000----			-----leaves/plant-----		
Disc	An.NH_3	Cg4327	19.8a[1]	20.0a	19.9a	4.6abc	8.2a	6.4ab
		P3578	20.7a	21.8a	21.2a	4.4abc	7.9ab	6.2ab
	Manure	Cg4327	21.8a	22.4a	22.1a	4.9a	8.3a	6.6a
		P3578	24.4a	25.0a	24.7a	4.7abc	8.1ab	6.4ab
No-till	An.NH_3	Cg4327	22.6a	23.5a	23.1a	4.4abc	7.4b	6.0ab
		P3578	23.5a	22.6a	23.1a	4.1c	7.6b	5.9b
	Manure	Cg4327	19.6a	20.2a	20.0a	4.7ab	8.1ab	6.4ab
		P3578	22.4a	21.6a	22.0a	4.3bc	7.9ab	6.2ab
Disc			21.7a	22.3a	22.0a	4.6a	8.1a	6.4a
No-till			22.0a	22.0a	22.1a	4.4a	7.7a	6.1a
	An.NH_3		21.7a	22.0a	21.9a	4.4b	7.8b	6.1b
	Manure		22.0a	22.3a	22.2a	4.6a	8.1a	6.4a
		Cg4327	21.0a	21.6a	21.3a	4.7a	8.0a	6.4a
		P3578	22.8a	22.8a	22.8a	4.4b	7.9a	6.1b
Pr>F								
Tillage			0.895	0.923	0.989	0.445	0.305	0.388
N Source			0.756	0.806	0.784	0.006	0.022	0.014
Tillage*N			0.082	0.097	0.087	0.651	0.138	0.363
Hybrid			0.172	0.270	0.201	0.003	0.515	0.088
Hybrid*Tillage			0.966	0.362	0.688	0.408	0.400	0.642
Hybrid*N			0.468	0.476	0.459	0.939	0.694	0.717
Tillage*N*Hybrid			0.966	0.758	0.863	0.939	0.474	0.570

[1]Data followed by the same letter in the same column group are not significantly different at the 0.10 level. n=32

Significant interactions from Table 4c.

Tillage	Populaction 6/1 N Source NH_3	Manure	Population 6/18 N Source NH_3	Manure
	-------------plants/A x 1000-----------			
Disc	20.2	23.1	20.9	23.7
No-till	23.1	21.0	23.1	20.9

Table 4d. Effect of tillage, N source, and hybrid on corn tasselling, silking and grain moisture and yield (10/24) at the Highum Farm, 1994.

Tillage	Source	Hybrid	Tasselling 7/11	Tasselling 7/15	Tasselling Mean	Silking 7/11	Silking 7/15	Silking Mean	Grain Moisture	Corn Yield
			-----	-----	% plants	-----	-----	-----	--%--	bu/A
Disc	An.NH_3	Cg4327	46.9ab[1]	93.0a	70.0ab	9.0ab	63.5ab	36.3ab	21.1ab	173.0a
		P3578	3.5c	46.5a	25.0c	2.1b	19.6bc	10.8bc	20.7ab	194.0a
	Manure	Cg4327	62.7a	95.5a	79.1a	20.8a	83.4a	52.1a	20.6ab	180.0a
		P3578	14.9bc	67.3a	41.1abc	2.8b	35.7bc	19.2a	20.6ab	193.4a
No-till	An.NH_3	Cg4327	7.8bc	75.1a	41.5abc	1.2b	38.2bc	19.8bc	19.6b	187.2a
		P3578	3.6c	52.7a	28.2bc	0.0b	10.0c	5.0c	22.8a	189.6a
	Manure	Cg4327	30.1abc	90.8a	60.5abc	2.7b	60.0ab	31.4abc	20.4b	185.8a
		P3578	6.2bc	41.0a	23.6c	1.8b	15.9c	8.9bc	20.2b	190.5a
Disc			32.0a	75.6a	53.8a	8.6a	50.4a	29.6a	20.7a	185.1a
No-till			11.9a	64.9a	38.5a	1.4a	31.0a	16.2a	20.8a	188.3a
	An.NH_3		15.5b	66.8a	41.2b	3.1b	32.8b	18.0b	21.0a	186.0a
	Manure		28.4a	73.7a	51.1a	7.0a	48.7a	27.9a	20.4a	187.4a
		Cg4327	36.8a	88.6a	62.8a	8.4a	61.3a	34.9a	20.4a	181.5b
		P3578	7.0b	51.9b	29.5b	1.7b	20.3b	11.0b	21.0a	191.9a
Pr>F										
Tillage			0.271	0.642	0.452	0.334	0.355	0.343	0.966	0.707
N Source			0.014	0.310	0.007	0.062	0.005	<0.001	0.410	0.538
Tillage*N Source			0.878	0.465	0.319	0.231	0.592	0.162	0.695	0.477
Hybrid			<0.001	<0.001	<0.001	0.023	<0.001	<0.001	0.151	0.025
Hybrid*Tillage			0.018	0.924	0.046	0.047	0.284	0.078	0.071	0.117
Hybrid*N Source			0.319	0.736	0.282	0.325	0.280	0.193	0.107	0.756
Tillage*N*Hybrid			0.519	0.110	0.060	0.289	0.498	0.980	0.049	0.549

[1]Data followed by the same letter in the same column group are not significantly different at the 0.10 level. n=32

Significant interactions from Table 4d.

Tillage	Tasselling 7/11 Hybrid Cg4327	Tasselling 7/11 Hybrid P3578	Silking 7/11 Hybrid Cg4327	Silking 7/11 Hybrid P3578	Grain Moisture Hybrid Cg4327	Grain Moisture Hybrid P3578	Corn Yield Hybrid Cg4327	Corn Yield Hybrid P3578
	-----%plants-----				---%---		--bu/A--	
Disc	54.8	9.2	14.9	2.4	20.8	20.6	176	194
No-till	19.0	4.9	2.0	0.9	20.0	21.5	186	190

N Source	Grain Moisture Hybrid Cg4327	Grain Moisture Hybrid P3578
NH_3	20.4	21.7
Manure	20.5	20.4

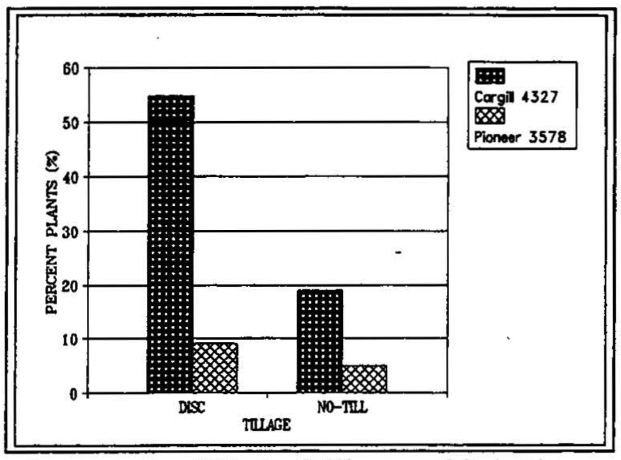

Figure 1. Effect of tillage and hybrid on corn tasselling at the Highum farm, July 11, 1994.

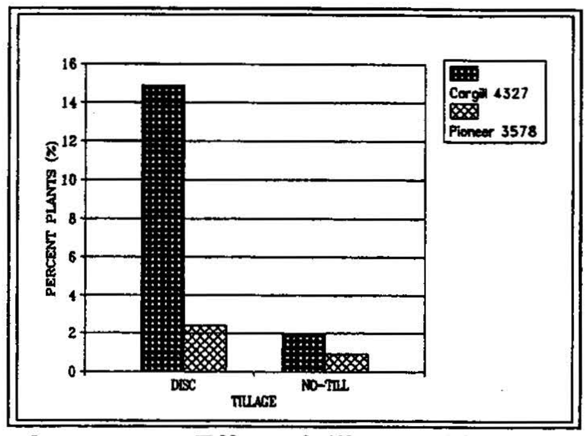

Figure 2. Effect of tillage and hybrid on corn silking at the Highum farm, July 11, 1994.

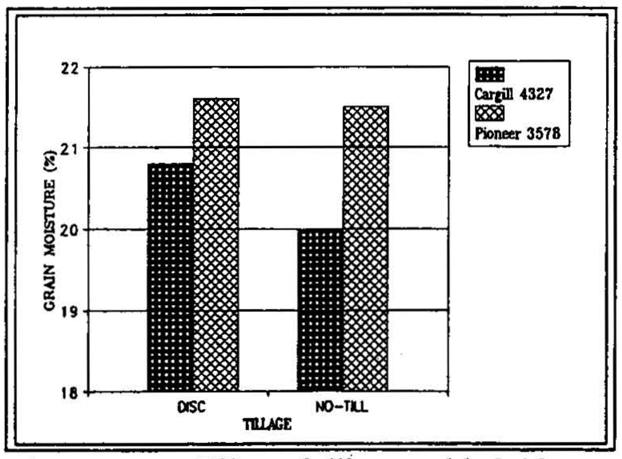

Figure 3. Effect of tillage and hybrid on grain moisture at the Highum farm, October 24, 1994.

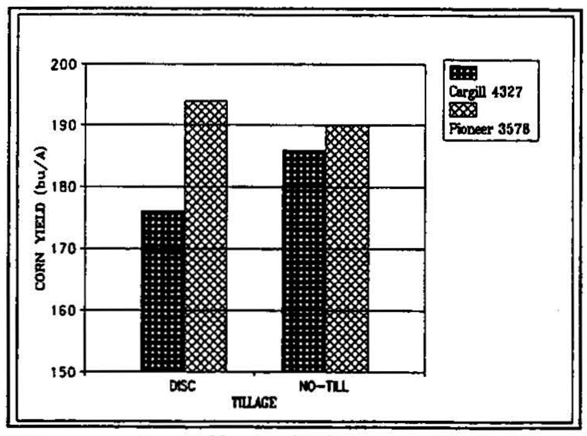

Figure 4. Effect of tillage and hybrid on corn yield at the Highum farm, October 24, 1994.

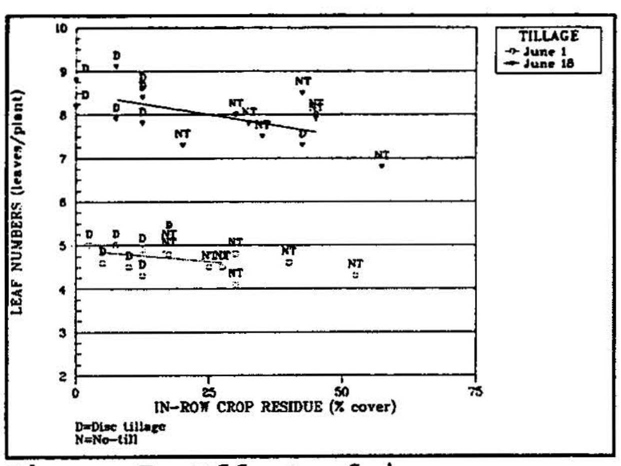

Figure 5. Effect of in-row crop residue on corn leaf numbers (**Cg4327**) June 1 and 18 at the Highum farm, 1994.

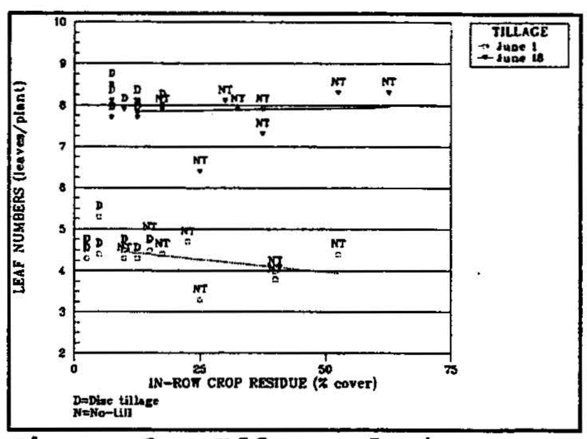

Figure 6. Effect of in-row crop residue on corn leaf numbers **(P3578)** June 1 and 18 at the Highum farm, 1994.

EFFECTS OF TILLAGE AND LIQUID DAIRY MANURE ON NITROGEN AVAILABILITY TO CORN[1]

T. W. Schumacher, J. F. Moncrief, and B. J. Johnson[2]

Abstract: The study to determine the influence of tillage and manure application on corn production at the Dale Flueger farm in Goodhue county, MN was continued in 1994. Results from 1994 showed much greater yields and lower moisture contents than the previous two years at this site. Annually applied manure produced the greatest yields (142 bu/A) and anhydrous ammonia applied at 200 lb N/A produced 123 bu/A. Biennially applied manure produced 115 bu/A of grain in the year of application and 64 bu/A of grain in the year following application. Triennially applied manure produced 98 bu/A the year of application, 88 bu/A the year after application, and 55 bu/A two years after application. Due to a damaged mixer in the manure pit, the manure applied to the plots in 1994 was unusually watery and resulted in numbers not typical to what would be expected from liquid dairy manure under a sloted floor barn.

Introduction

This study is being conducted to determine the long term impacts of tillage and frequency of manure application on corn yield and soil N levels. The Dale Flueger farm is located near Red Wing in Goodhue County, Minnesota. The research plots are on a Seaton silt loam soil. This study began in 1982.

The experimental design is a randomized complete block with tillage main plots (chisel plow and no till) with N source (commercial fertilizer and manure) and N frequency (annual, biennial, and triennially applied manure) subplots. Liquid dairy manure is injected each spring into the chisel plow and no till annual manure plots, and into the biennial manure plots that did not receive manure the previous year. Triennially applied manure plots only receive chisel plowing, and liquid dairy manure is injected at the same time into the plots that did not receive manure over the previous two years. Commercial fertilizer (anhydrous ammonia) was applied side dress and manure injected in the spring, preplant. Zero N check treatments are also included in this study. Refer to table 1 for details on N treatments and other cultural practices.

From 1982 to 1986 the manure treatments were split with 0 and 200 lbs/A K_2O treatments, and the commercial fertilizer treatments were split with 0, 200, and 400 lbs/A K_2O treatments. These potassium additions were stopped in 1987, but some data in this report is split by K_2O treatment to check for residual effects of the added potassium.

Results and Discussion

The cultural practices and timing of the cultural practices at the Flueger farm can be seen in Table 1. The effects of the various annual and biennial treatments on corn grain yields, grain moisture, and grain percent N, can be found in Table 2. Grain yields were greater than in recent years, probably due to more favorable weather conditions. The trend of yields was as follows: annual manure>biennial manure in year of application>commercial fertilizer>biennial manure in the year following application. Grain moisture was much lower in 1994 compared to recent years, most likely due to the dry autumn and the good weather during the growing season. The effects of the various triennial treatments on corn grain yields and grain moisture can be found in Table 3. Grain yields, as expected, decreased with each year after N was applied.

1. Support for this project was provided by the USDA-CSRS, LCMR, and the Natural Resource Conservation Service. Their support is greatly appreciated.

2. Research Assistant, Associate Professor, and Assistant Scientist respectively, at the Soil, Water, and Climate Dept., University of Minnesota, St. Paul, MN 55108.

Table 1. 1994 cultural practices at the Flueger farm in Goodhue County, MN.

Soil: Seaton silt loam (mixed, mesic, fine silty Typic hapludalf), well drained, 2 to 12% slope.

Cropping History:

1981-1988	Corn	Pioneer 3906
1989	Corn	Pioneer 3737
1990	Corn	Pioneer 3751
1991	Corn	NK 3624
1992-1993	Corn	Pioneer 3751
1994	Corn	Pioneer 3769

Manure Application and Analysis: Liquid dairy manure injected on May 6, 1994.

	1994 rate Mean
Manure (gal/A)	9320
Total N (lbs/A)	535
NH_4 N (lbs/A)	265
Solids (%)	2.2

Fertilizer:

Material	Tillage	N (lbs/A)	Date Applied	Application
82-0-0	Both	200	June 21, 1994	Injected
5-14-42	Both	6	May 16, 1994	As a starter

Planting and Harvest Information: A four row John Deere Maxi-Emerge planter with two inch fluted coulters was used to plant on May 16, 1994. Corn was harvested on October 29, 1994.

Insect control: 5.2 lbs/A Thimet 20G applied May 16, 1994.

Table 2. Grain yield and grain moisture as influenced by tillage, N source and frequency and potassium rates at the Flueger farm in Goodhue Co., MN.

N source & freq.	K_2O lbs/A	Grain Yield NoTill	Grain Yield Chsl	Grain Yield Mean	Grain Moisture NoTill	Grain Moisture Chsl	Grain Moisture Mean
		------bu/A------			--------%-------		
Annual	0	111	164	**138**	20.0	18.9	**19.5**
Manure	200	131	159	**145**	18.8	18.2	**18.5**
	Mean	**121**	**162**	**142**	**19.4**	**18.6**	**19.0**
Biennial	0	99	137	**118**	19.7	19.9	**19.8**
Manure	200	84	141	**113**	19.1	17.9	**18.5**
(yr of)	**Mean**	**92**	**139**	**115**	**19.4**	**18.9**	**19.2**
Biennial	0	45	91	**68**	20.7	19.0	**19.9**
Manure	200	30	87	**59**	19.9	20.8	**20.4**
(yr after)	**Mean**	**38**	**89**	**64**	**20.3**	**19.9**	**20.1**
Anhydrous	0	91	145	**118**	23.9	19.0	**21.5**
Ammonia	200	97	149	**123**	22.4	18.9	**20.7**
	400	115	139	**127**	22.5	21.4	**22.0**
	Mean	**101**	**144**	**123**	**22.9**	**19.8**	**21.4**
Overall Mean		**88**	**134**	**111**	**20.5**	**19.3**	**19.9**
Check (0 N)[1]		43	54	**49**	18.2	19.4	**18.8**

	Till(T)	N source(N)	T*N	K rate(K)	K*T	K*N	K*N*T
Grain Yield	.000	.000	.949	.842	.445	.840	.893
Grain Moisture	.096	.011	.019	.285	.095	.836	.754

[1] Check plots not included in the statistical analysis.

Table 3. Grain yields and percent moisture at harvest for triennially applied manure with chisel plowing system at the Flueger farm in Goodhue Co., MN.

Year of manure Application	**K_2O** lbs/A	**Grain Yield** ---bu/A----	**Grain Moisture** ------%-----
First Year	0	102	20.6
	200	94	20.7
	Mean	**98**	**20.7**
Second Year	0	82	19.5
	200	94	18.8
	Mean	**88**	**19.2**
Third Year	0	53	20.6
	200	57	20.1
	Mean	**55**	**20.4**

THE EFFECT OF TIME OF MANURE APPLICATION ON CORN RESPONSE FOLLOWING SOYBEANS ON POORLY DRAINED SOILS[1]

R.D. Ault, T.J. Arlt, J.F. Moncrief, P.M. Bongard, and B.J. Johnson[2]

Abstract Time of application of a 50-50 mix of liquid hog and liquid chicken egg layer manure was evaluated for corn production following soybeans on poorly drained soils. Corn yields with N were about 30 bushels per acre higher than the no N control. There was no difference in grain yields between fall, winter, and side dress manure applications. Manure applied in the spring before planting and side dress fertilizer N resulted in a modest yield advantage over other treatments (3-7 bushels per acre).

Results

This study was designed to evaluate the timing of manure applications as an N source for corn production on poorly drained soils in southern MN. Corn was grown following soybeans with a ridge till tillage system (four row-38" equipment). All plots received dry starter fertilizer (8 pounds N per acre). Manure was applied in the fall before "freeze up", in the winter "after snow fall", in the "spring preplant", and "side dress" at ridging. The manure source was a 50-50 mix of liquid manure from a chicken egg laying operation and a finishing pig facility. Manure was applied in a band on either side of the ridge. The 2,000 gallons per acre manure rate was based on a chemical analysis and designed to deliver about 85 pounds per acre of estimated available N. This was based on the assumption that all of the ammonium-N and 35% of the organic-N in the manure was available in the year of application. There was a fertilized and unfertilized control. The commercial N source was a urea-ammonium nitrate solution (28% N) applied and incorporated with the ridge till cultivator at 100 pounds N per acre. Although the total N in the manure at the three times of application varied very little, the proportion of ammonium and organic N varied considerably. Estimated available N ranged from 79 to 97 pounds per acre from the fall to side dress applications, respectively.

The grain yields are shown in table 2. Corn yields with N were about 30 bushels per acre higher than the no N control. There was no difference in grain yields between fall, winter, and side dress manure applications. Manure applied in the spring before planting and side dress fertilizer N resulted in a modest yield advantage over other treatments (3-7 bushels per acre). This study will be continued for two more years.

Table 1. Cultural practices used in the manure application study at Dwight Ault's farm in Mower County, 1994.

Study design
Design is a randomized complete block with six treatments and four replications:

1. Fall manure application (11/1/93), after ridges built in the fall due to wet conditions in 1993 preventing ridging during the growing season
2. Winter manure application, 6-7 inches of snow (1/94)
3. Early spring manure application (5/10/94)
4. Side dress-at cultivation manure application (6/16/94)
5. No manure (starter fertilizer only)
6. Fertilizer N (UAN-28%) applied at 1st cultivation (6/17/94)

The method of application is surface band with two tubes delivering to the middle of the center two rows and one each to the outside rows. This method was used to avoid the wheel traffic areas.

Tillage
Ridge till system

Fall 1993 ridged - 4-36" row Buffalo ridge till cultivator with 1-14" sweep per row with ridging wings

Planting and harvest information

Crop	Hybrid	Planted	Pop.	Harvested
Corn	P3751	5/10	27,000s/A	11/9

Cropping history
1993-Soybeans

Soils
Shandep silty clay loam (Cumulic Haplaquoll)
Mayer loam (Typic Endoaquoll)
Soils test high in P, medium in K

Fertilizer

		Applied (lb/A)		
Date	Analysis	N	P_2O_5	K_2O
5/10	7-18-36	8	20	40
6/17	28-0-0	100	0	0

[1] This project was supported by the MN Department of Agriculture and the MN Extension Service. Their support is greatly appreciated.

[2] Dwight Ault is a farmer in Mower County MN; Tim J. Arlt is the Steele County Extension Educator, Owatonna, MN; John F. Moncrief and Brian J. Johnson are Extension Specialist and Assistant Scientist, Department of Soil, Water, and Climate, Univ. of MN, St. Paul, MN; Phyllis Bongard is an independent data analysis specialist, Faribault, MN.

Manure analysis and application

Date	Total N	NH_4^+	Org.N	P_2O_5	K_2O
	--------------	lb/1000 gal.	--------------		
11/93	53.3	32.0	21.3	44.2	31.2
1/94	54.4	29.8	24.6	32.3	30.6
6/94	57.8	43.4	14.4	23.0	24.6
Mean	**55.2**	**35.1**	**20.1**	**33.2**	**28.8**

Manure is a mix of liquid hog and egg laying poultry manures (approx. 50:50).

		Est. Nutrients Applied			
Date	Rate	N_{tot}	N_{avail}	P_2O_5	K_2O
	gal/A	-----------	lb/A	------------	
11/93	2000	107	79	88	62
1/94	2000	109	77	65	61
6/94	2000	116	97	46	49
Mean		111	84	66	57

N Availability = 100% Mineral N + 35% Organic

Weed Control

Date	Product	Rate (lb ai/A)
6/14	Nicosulfuron (Accent) +	0.01
	Bromoxynil (Buctril)	0.10
	applied in 12" bands over the row	

6/17 Cultivation only once 4-row with 1-14" sweep per row and ridging wings

Table 2. Effect of timing of manure application on corn grain moisture and yield at the Ault farm, November 9, 1994.

Treatment	Grain Moisture	Corn Yield
	--%--	bu/A
Early fall manure	17.8a[1]	137.5b
Winter manure	17.8a	135.8b
Early spring manure	17.8a	144.3a
side dress-at cult. manure	17.8a	137.5b
None	17.8a	108.3c
UAN (28%) at 1st cult.	17.8a	140.3ab
Pr>F		
Treatment	0.248	<0.001

1. Data followed by the same letter in the same column are not significantly different at the 0.10 level.

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