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SOIL SERIES #141
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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

Some of the results reported in this publication are from 1994 experiments and should be regarded on this basis. Since most of the data is from 1994 studies only, stated conclusions may not be absolutely conclusive, and thus are not for further publication without the written consent of the individual researchers involved.

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1994 Climate Summary

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.

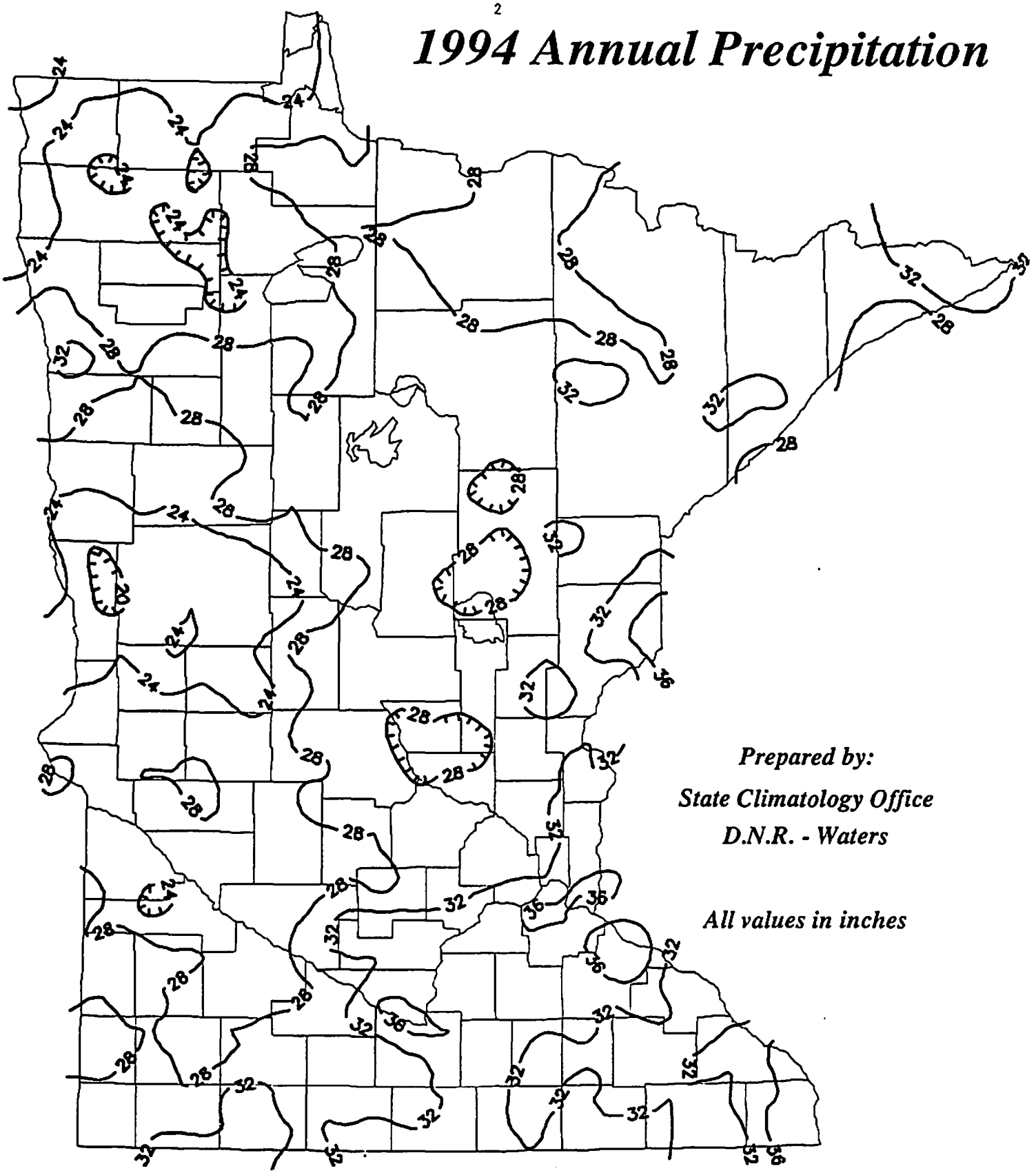
The first significant snowfall of the season came on November 18 in Northern Minnesota, and November 27 for the remainder of the state. These dates roughly match the average occurrence of the first measurable snowfall, and contrast with the late-October and early-November first-snows experienced earlier 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.

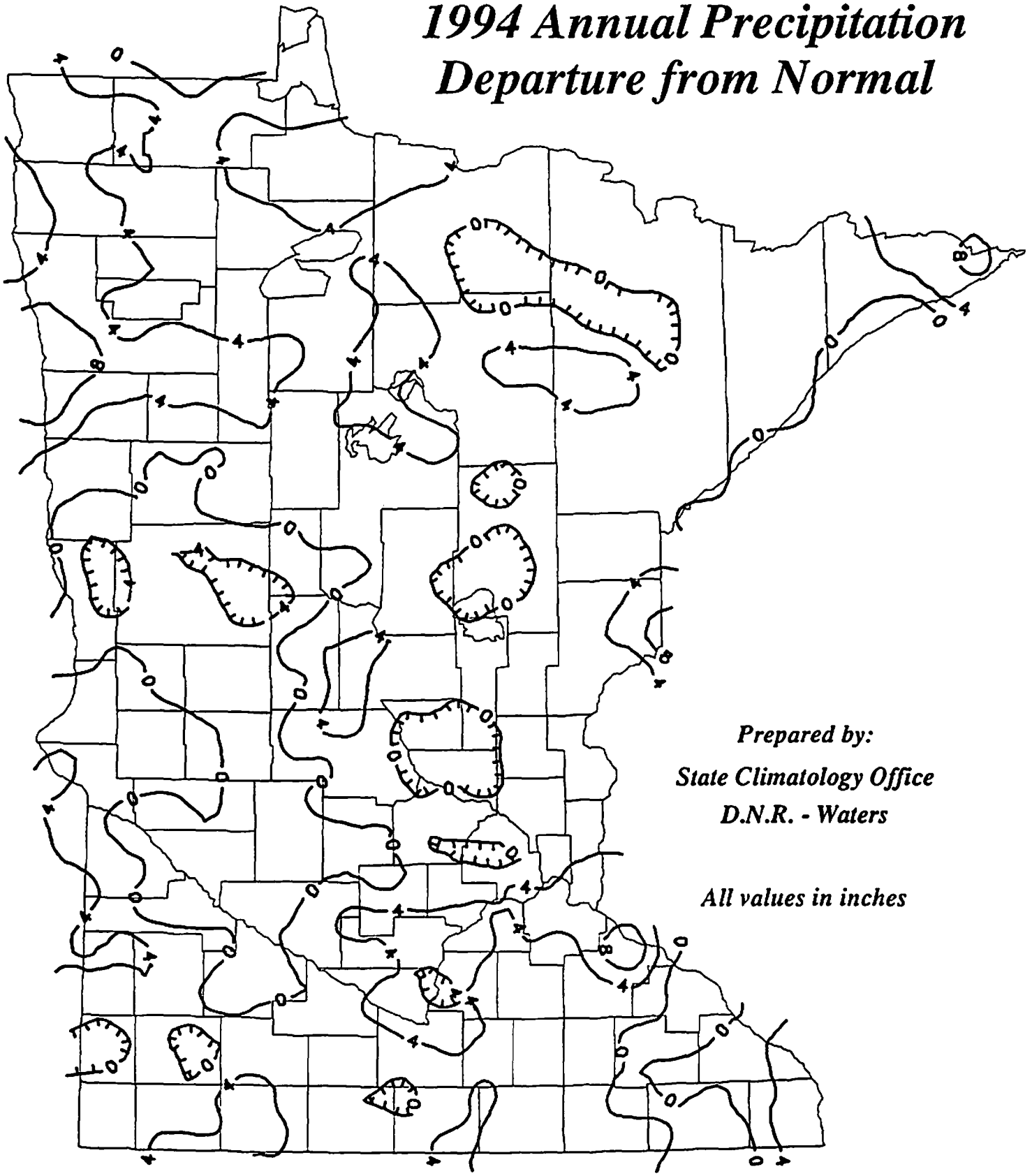
State Climatology Office, DNR - Division of Waters

1994 Annual Precipitation



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



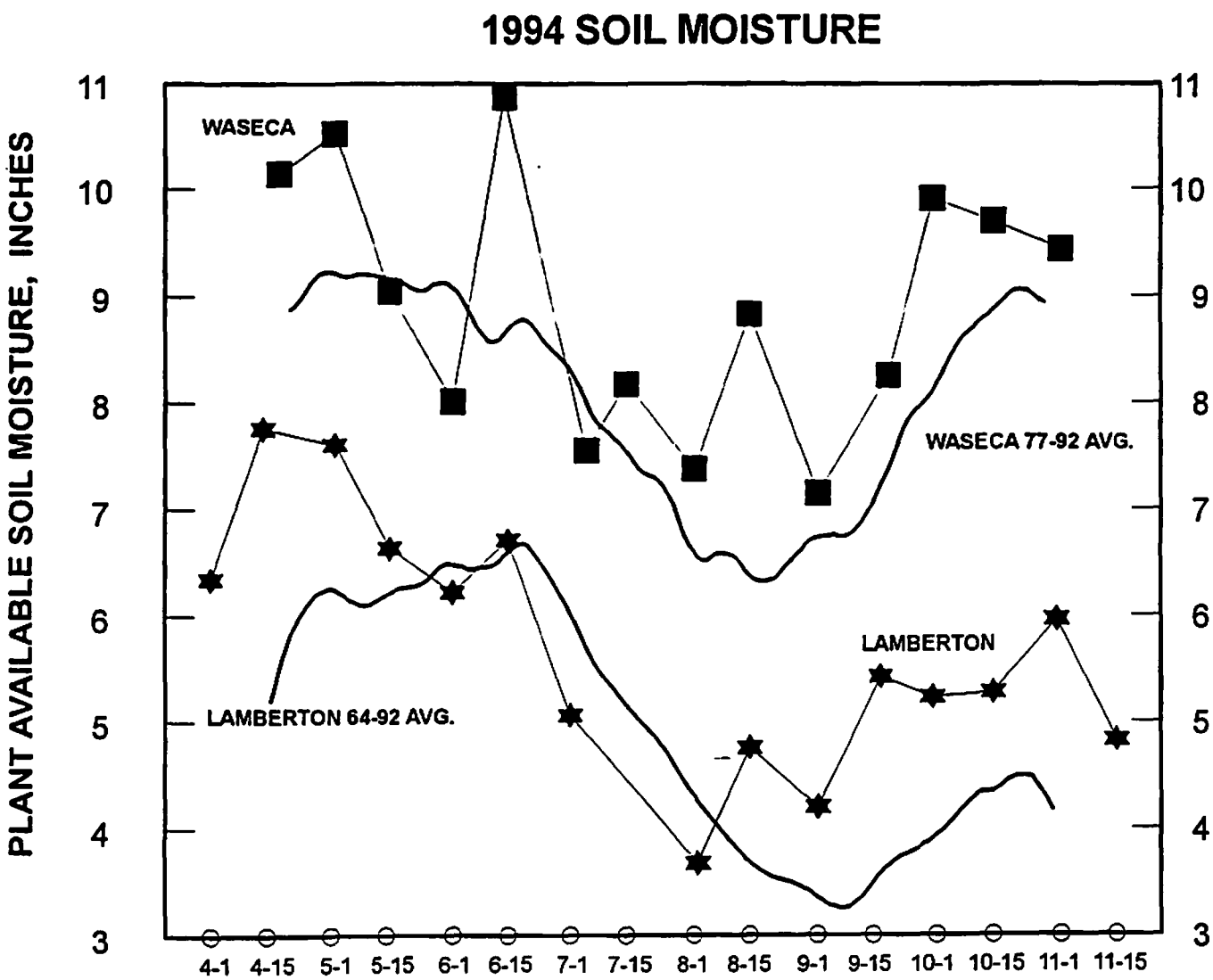
Data sources: National Weather Service, Soil & Water Conservation Districts, DNR - Forestry, Metro Mosquito Control District, DNR/NWS Backyard Rain Gauge Network, Minnesota Association of Watersheds, Future Farmers of America, Minnesota Power and Light, Deep Portage Conservation District, Metropolitan 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					
N source	N timing	0 to 1 foot	1 to 2 foot	2 to 3 foot	Field total
		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				dry matter				N concentration		
	N source	N timing	Tubers	Tuber	Vine	Root	Total	Tuber	Vine	Root
			-#/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			Nitrogen content			N concentration		Dry matter		
	N source	N timing	Vines	Tubers	Total	Vine	Tubers	Vines	Tubers	Total
			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			
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)	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			
N source	N timing	dry weight Petiole-N	sap Horiba	sap Hach	sap 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.

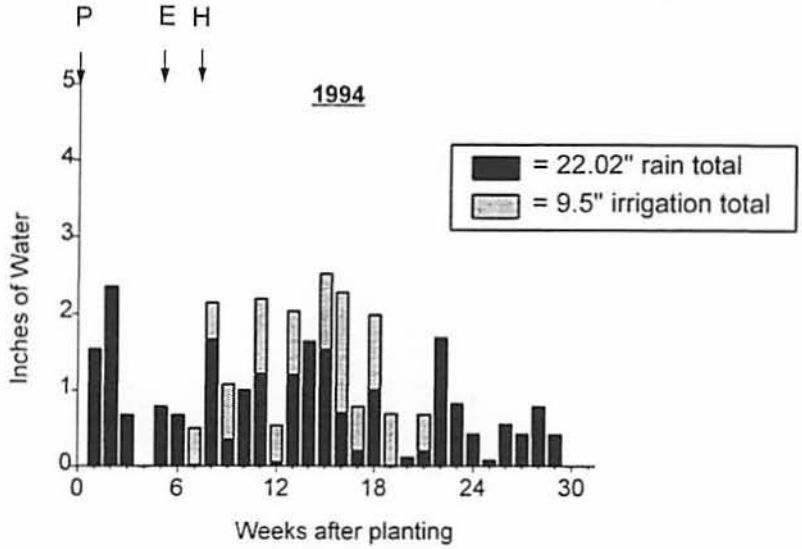


Figure 1. Rainfall and irrigation at Becker, MN during the 1994 growing season. P, H and E = planting, emergence and hilling, respectively.

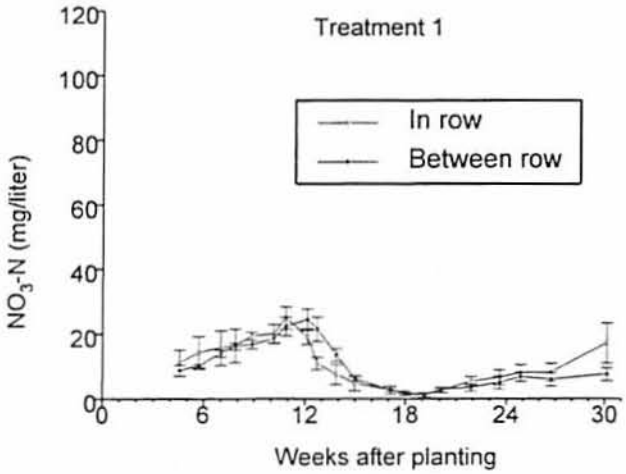


Figure 2. Nitrate - N concentration in soil water sampled in the row and between the row at the 4 ft. depth, over the 1994 growing season. Nitrogen application rate: no nitrogen. Error bars represent SE of the mean.

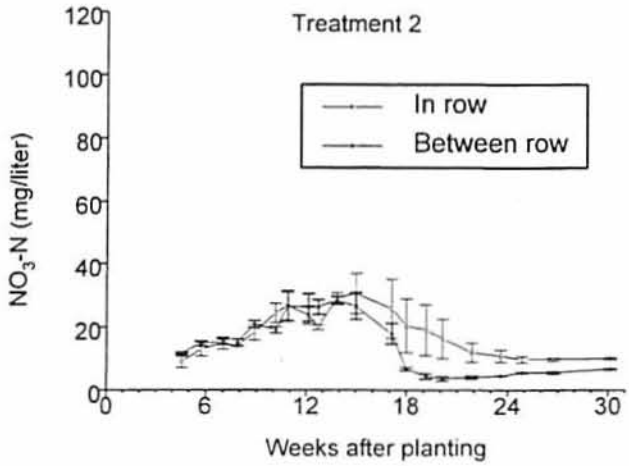


Figure 3. Nitrate - N concentration in soil water sampled in the row and between the row at the 4 ft. depth, over the 1994 growing season. Nitrogen application rate: 40 lb N/A at planting, 100 lb at emergence and hilling (46-0-0). Error bars represent SE of the mean.

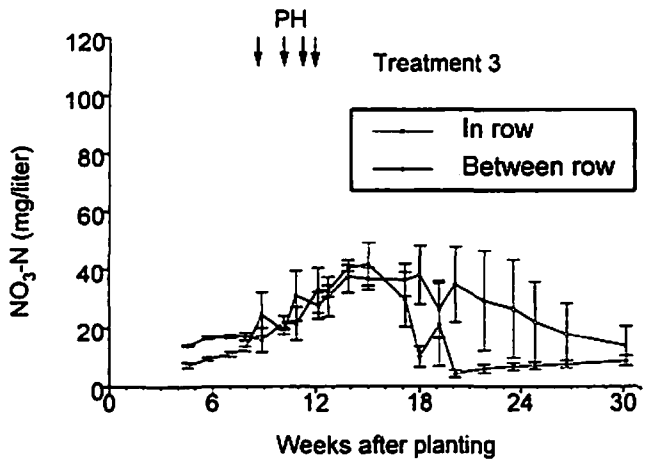


Figure 4. Nitrate - N concentration in soil water sampled in the row and between the row at the 4 ft. depth, over the 1994 growing season. Nitrogen application rate: 20 lb N/A at planting, 70 lb at emergence and hilling, plus 4 post-hilling applications at 20 lb N/A each (46-0-0). Error bars represent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

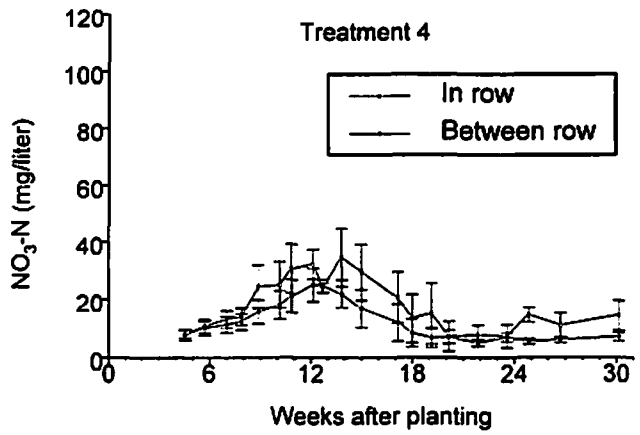


Figure 5. Nitrate - N concentration in soil water sampled in the row and between the row at the 4 ft. depth, over the 1994 growing season. Nitrogen application rate: 20 lb N/A at planting and 70 lb at emergence and hilling (46-0-0). Error bars represent SE of the mean.

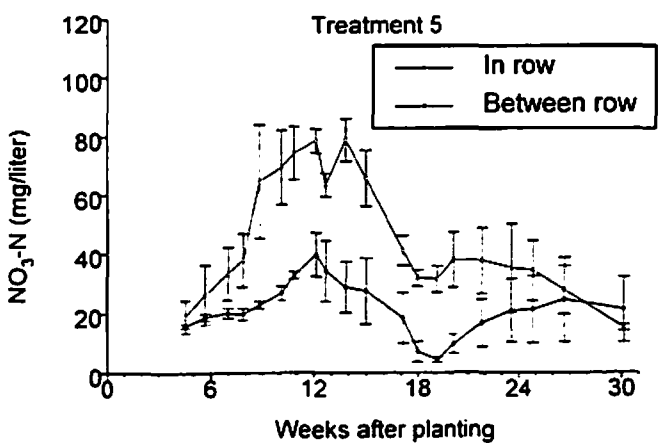


Figure 6. Nitrate - N concentration in soil water sampled in the row and between the row at the 4 ft. depth, over the 1994 growing season. Nitrogen application rate: 40 lb N/A at planting, 100 lb at emergence and hilling (34-0-0). Error bars represent SE of the mean.

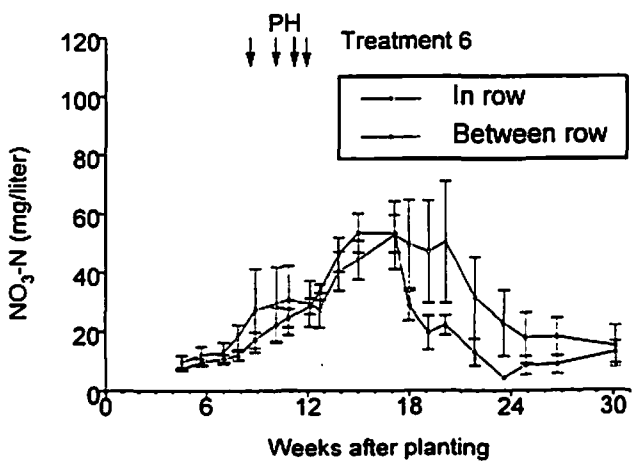


Figure 7. Nitrate - N concentration in soil water sampled in the row and between the row at the 4 ft. depth, over the 1994 growing season. Nitrogen application rate: 20 lb N/A at planting, 70 lb at emergence and hilling, plus 4 post-hilling applications at 20 lb N/A each (34-0-0). Error bars represent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

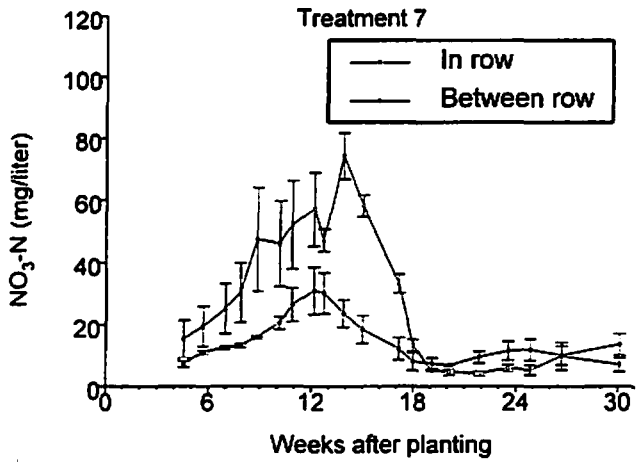


Figure 8. Nitrate - N concentration in soil water sampled in the row and between the row at the 4 ft. depth, over the 1994 growing season. Nitrogen application rate: 20 lb N/A at planting and 70 lb at emergence and hilling (34-0-0). Error bars represent SE of the mean.

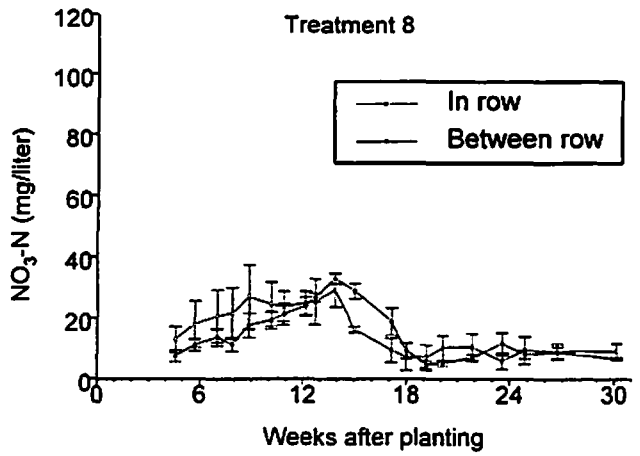


Figure 9. Nitrate - N concentration in soil water sampled in the row and between the row at the 4 ft. depth, over the 1994 growing season. Nitrogen application rate: 40 lb N/A at planting, emergence and hilling (34-0-0). Error bars represent SE of the mean.

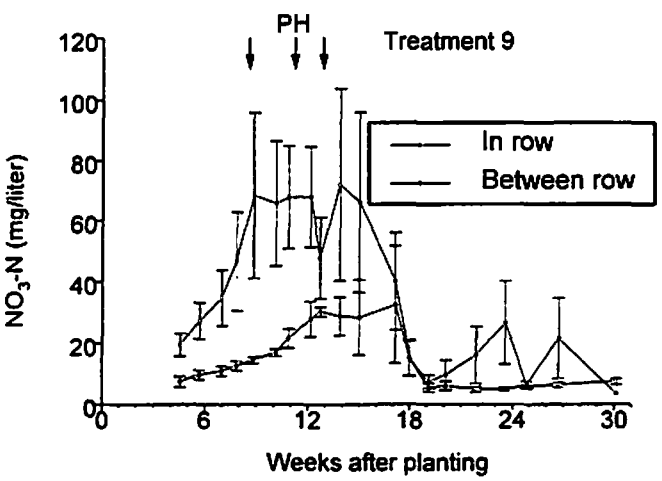


Figure 10. Nitrate - N concentration in soil water sampled in the row and between the row at the 4 ft. depth, over the 1994 growing season. Nitrogen application rate: 40 lb N/A at planting, emergence and hilling, plus 3 post-hilling applications at 20 lb N/A each (34-0-0). Error bars represent SE of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

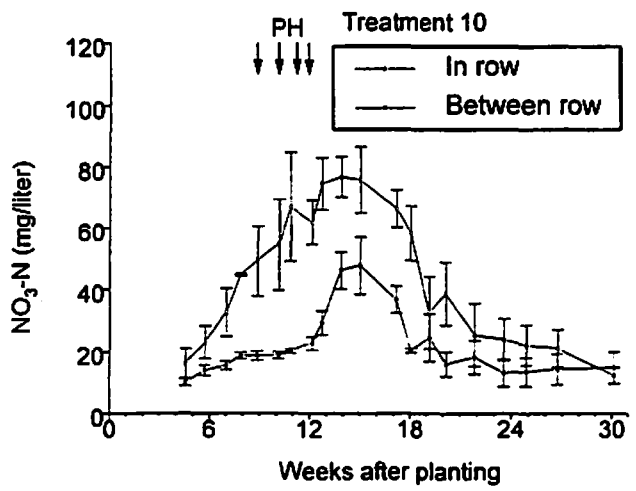


Figure 11. Nitrate - N concentration in soil water sampled in the row and between the row at the 4 ft. depth, over the 1994 growing season. Nitrogen application rate: 40 lb N/A at planting, emergence and hilling, plus 4 post-hilling applications at 20 lb N/A each (34-0-0). Error bars represent SE of 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			dry matter			
		Tubers	Tuber	Vine	Root	Total
K_2O source	K_2O timing	-#/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		Fresh weight							Specific	Hollow
		Vines	Knobs	<3 oz	3-6 oz	6-12 oz	>12 oz	Total	Gravity	Heart-%
K_2O source	K_2O timing	Tons/A	cwt/A							incidence
1. Control	(0 K_2O/A)	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 content			K concentration		Dry matter		
K_2O source	K_2O timing	Vines	Tubers	Total	Vines	Tubers	Vines	Tubers	Total
		----------lbs/A---------			-----% K------		----------Tons/A--------		
1. Control	(0 K_2O/A)	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		----------Date----------							
		June 6				June 17			
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)	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		Date							
		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		Date							
		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							
K_2O source	K_2O timing	----- Exchangeable K -----			--- Nonexchangeable K ----		
		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

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[2]Extension Soil Scientist and Assistant Scientist, respectively, Dept. of Soil, Water and Climate; Supervisor, Sand Plain Research Farm.

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	Element P	K	Mg	Ca
	%	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	Element P	K	Mg	Ca
	%	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	Plant Part: whole plant	whole plant	kernel	ear green	ear husked	kernel moisture	useable ears	ear length	plant population
	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	Element									
	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						Specific Gravity	Hollow Heart
		Tuber Size						
	Knobs	<3 oz	3-7 oz	7-14 oz	>14 oz	Total		
	cwt/A							% incidence
0	8.6	120.1	226.[illegible]	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
	Element									
	%					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						Specific Gravity	Hollow Heart
		Tuber Size						
	Knobs	<3 oz	3-6 oz	6-13 oz	>13 oz	Total		
	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						Specific Gravity	Hollow Heart
		Tuber Size						
	Knobs	<3 oz	3-6 oz	6-13 oz	>13 oz	Total		
	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

[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 per plant
	grams/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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[1] L.D. Klossner, and D.R. Huggins are Assistant Scientist, and Assistant Professor at the Southwest Experiment Station, Lamberton, MN. G.W. Randall is Professor at the Southern Experiment Station, Waseca, MN. M.P. Russelle is Soil Scientist at the USDA-ARS-US Dairy Forage Research Center, St. Paul, MN. D.J. Fuchs is former Scientist at the Southwest Experiment Station, Lamberton, MN.

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 143 lb N/A - crp-Corn None - alf-Corn	6/6/94 6/6/94
Herbicide	Lasso Bladex	4 lb/A (ai) 3 lb/A (ai)	4/21/94
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 Bladex	4 lb/A (ai) 3 lb/A (ai)	4/21/94
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 Pursuit	4 lb/A (ai) 4 oz/A (ai)	4/21/94
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 (NH_4NO_3) broadcast 5/13/94	Trt 4 and 5 Parker 200,000/A		Pinnacle 0.25 oz/A Select 6 oz/A
	4	JD 752	None		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 (NH_4NO_3) broadcast 5/13/94	Trt 4 and 5 Parker 200,000/A		
	4	JD 752	None		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 (NH_4NO_3) broadcast 5/13/94	Trt 4 and 5 Parker 200,000/A		
Fall 93	4	JD 752	None		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 (NH_4NO_3) broadcast 5/13/94	Trt 4 and 5 Parker 200,000/A		
Fall 93	4	JD 752	None		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 (NH_4NO_3) broadcast 5/13/94	Trt 4 and 5 Parker 200,000/A		
	4	JD 752	None		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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[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. 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