Field Research in Soil Science 1996

(Soils Series #142)

Miscellaneous Publication 90–1996
Minnesota Agricultural Experiment Station
University of Minnesota

St. Paul, Minnesota

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SOIL SERIES #142
Field Research in Soil Science

ACKNOWLEDGEMENTS

This 1996 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, Water, and Climate; 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.

The investigators also greatly appreciate the cooperation of the many farmers, agents, technical assistants, secretaries, and farm and business representatives who contribute time, land, machinery and materials which assist or enable the research this publication reports. Much of the research would not be possible without that support.

DISCLAIMERS

Some of the results reported in this publication are from 1995 experiments and should be regarded on this basis. Since most of the data is from 1995 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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1995 CLIMATOLOGY REVIEW

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

Abstract

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

1995 Hydrologic Year Precipitation

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

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

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

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

1995 Soil Water Measurements

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

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

Long-Term Temperature and Precipitation Trends

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

[1]State Climatology Office, Dept. Natural Resources

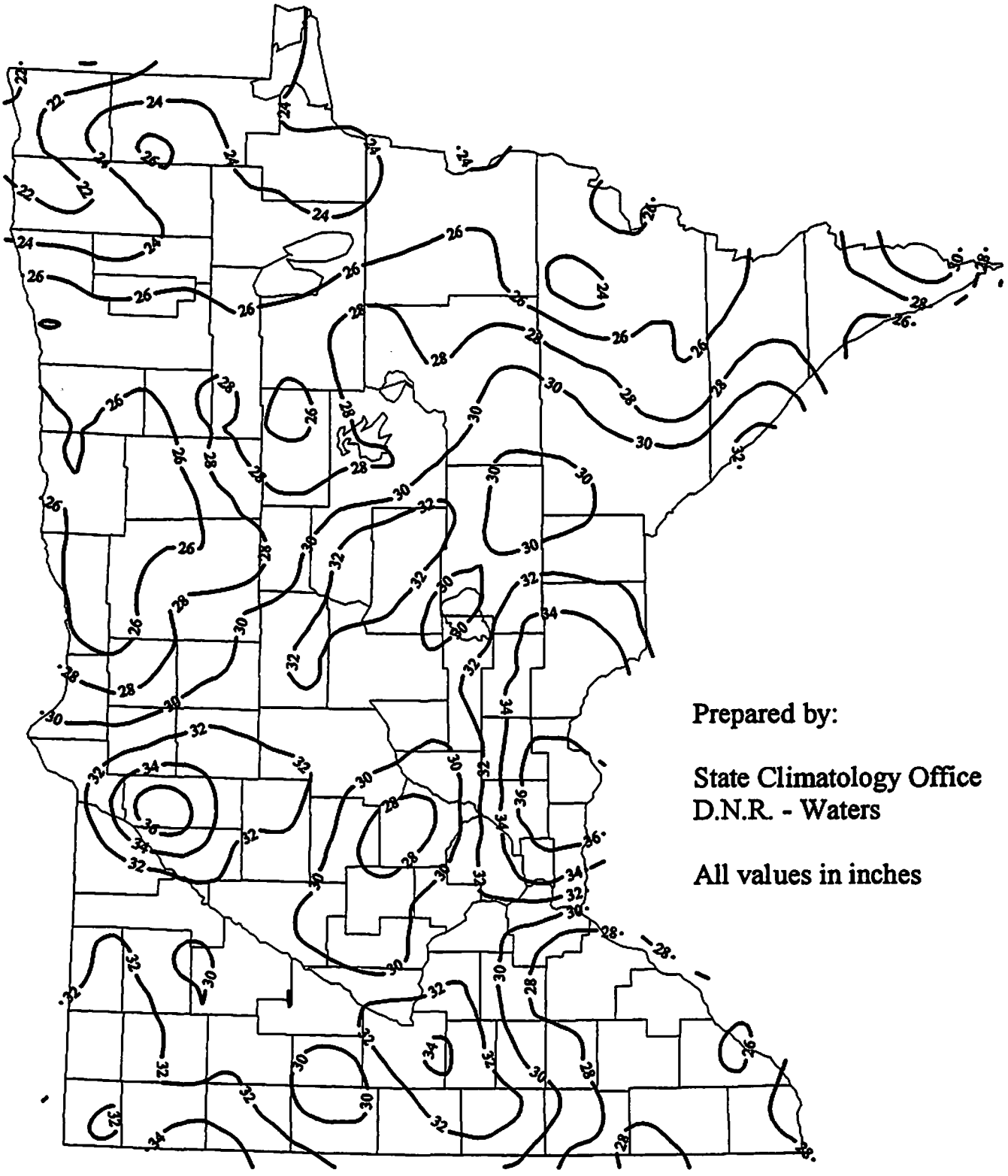
[2]Southern Experiment Station

[3]Southwestern Experiment Station

[4]Dept. Of Soil, Water, and Climate

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

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



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

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

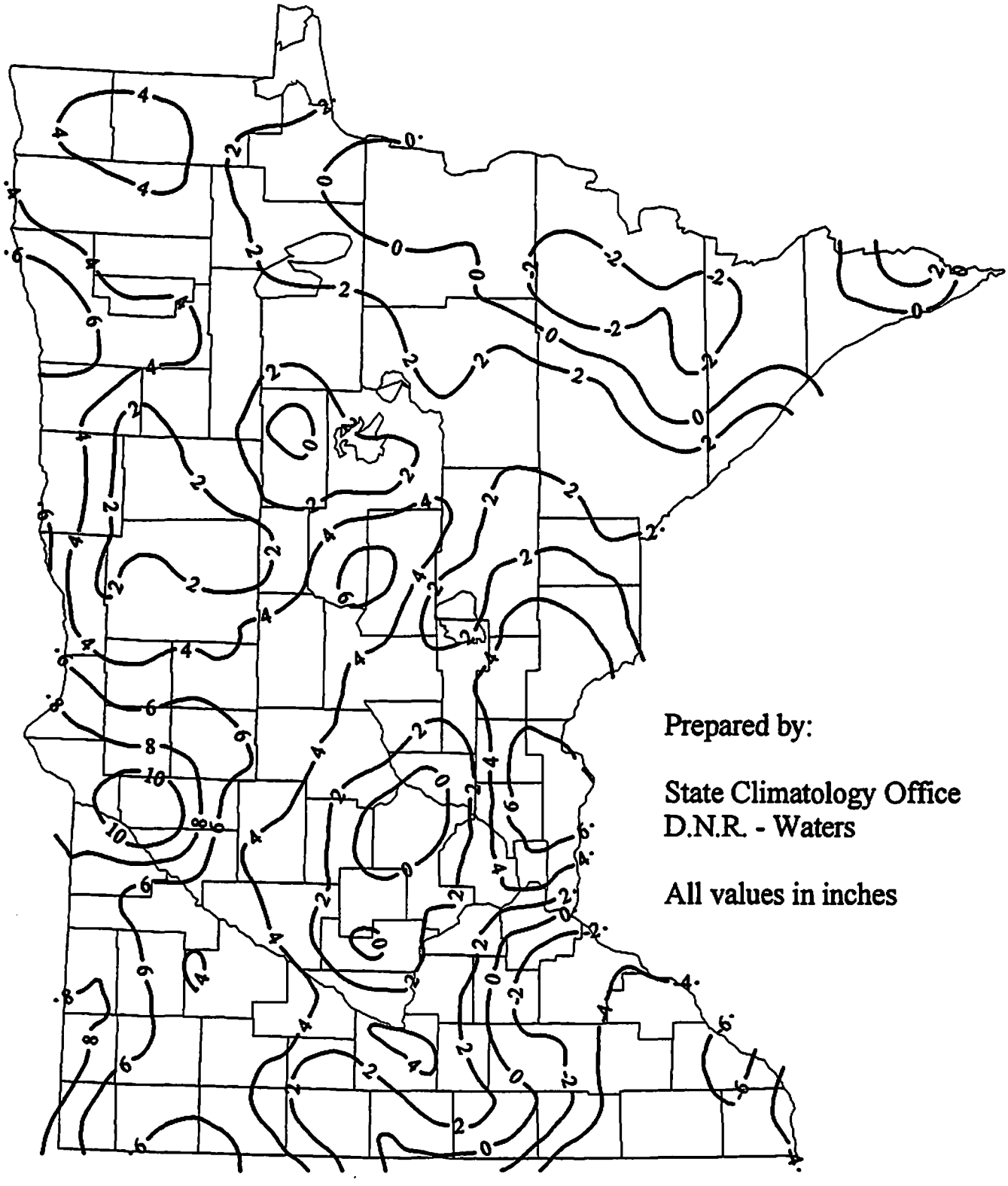


Fig. 2. Hydrologic year (October, 1994 - September, 1995) precipitation departure from normal (1961-1990).

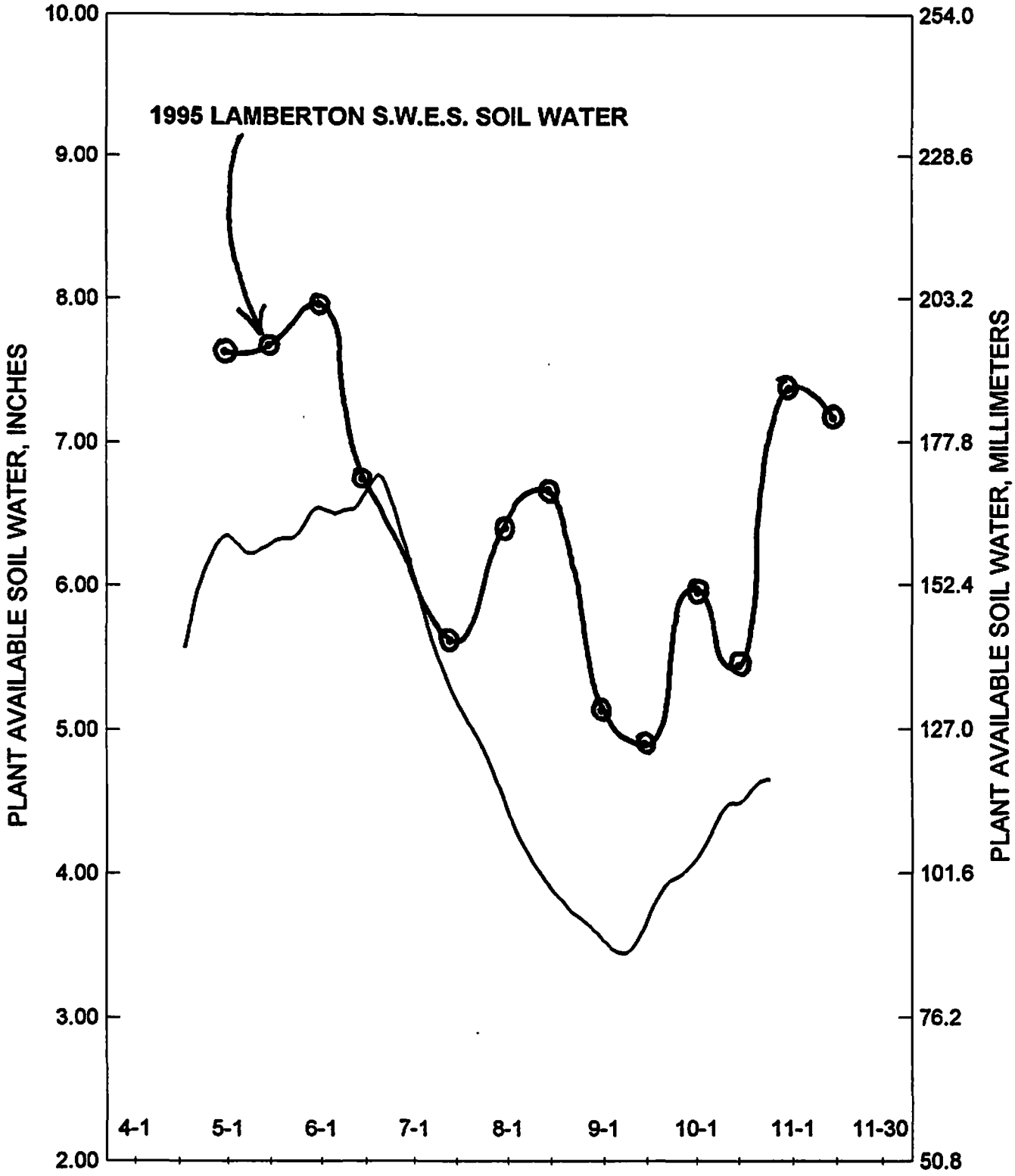


Fig. 3. Total plant available soil water in a 5-foot column of soil under corn at the Lamberton S.W.E.S. in 1995 shown against the 1964-1995 average.

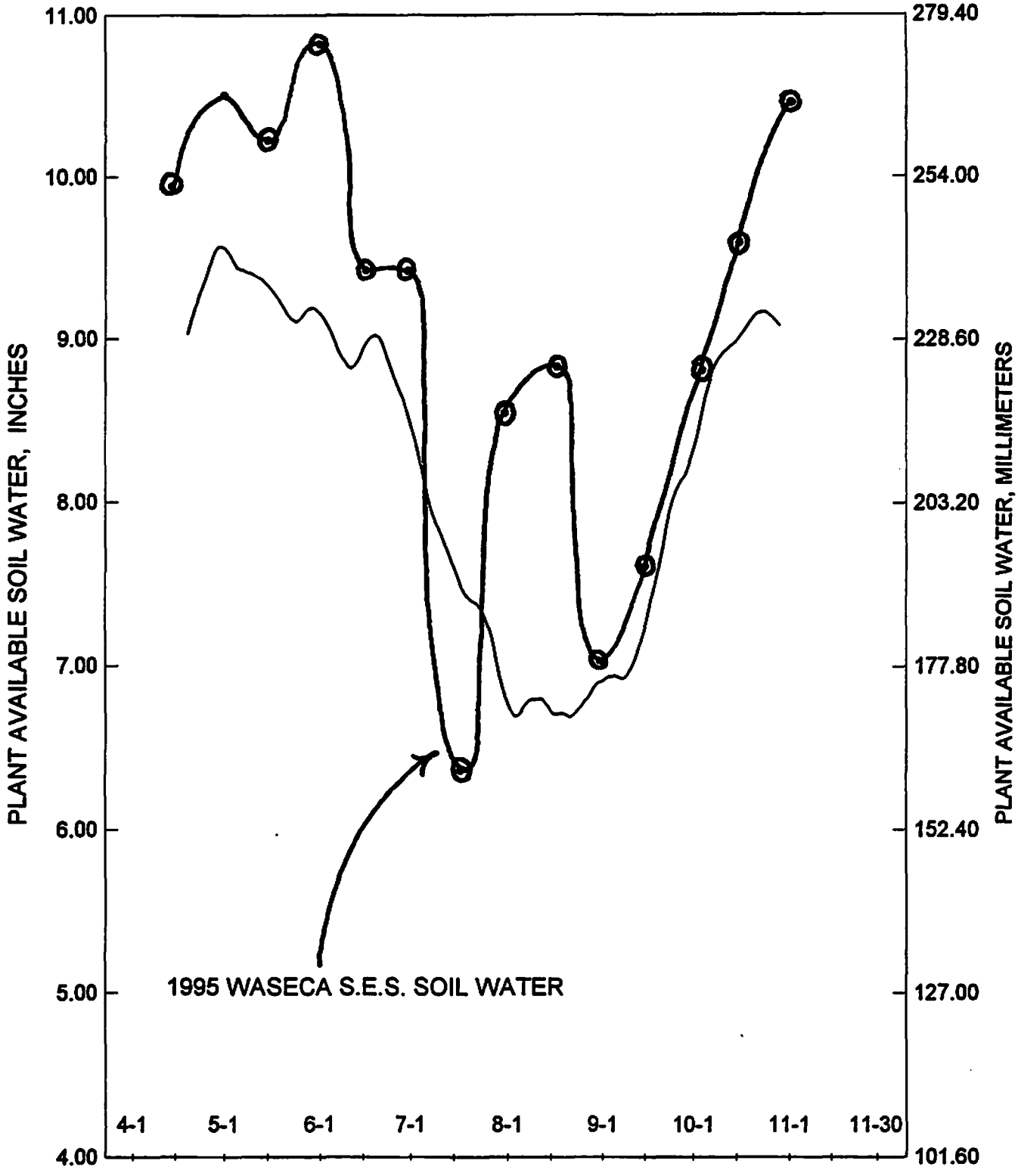


Fig. 4. Total plant available soil water in a 5-foot column of soil under corn at the Waseca S.E.S in 1995 shown against the 1977-1995 average.

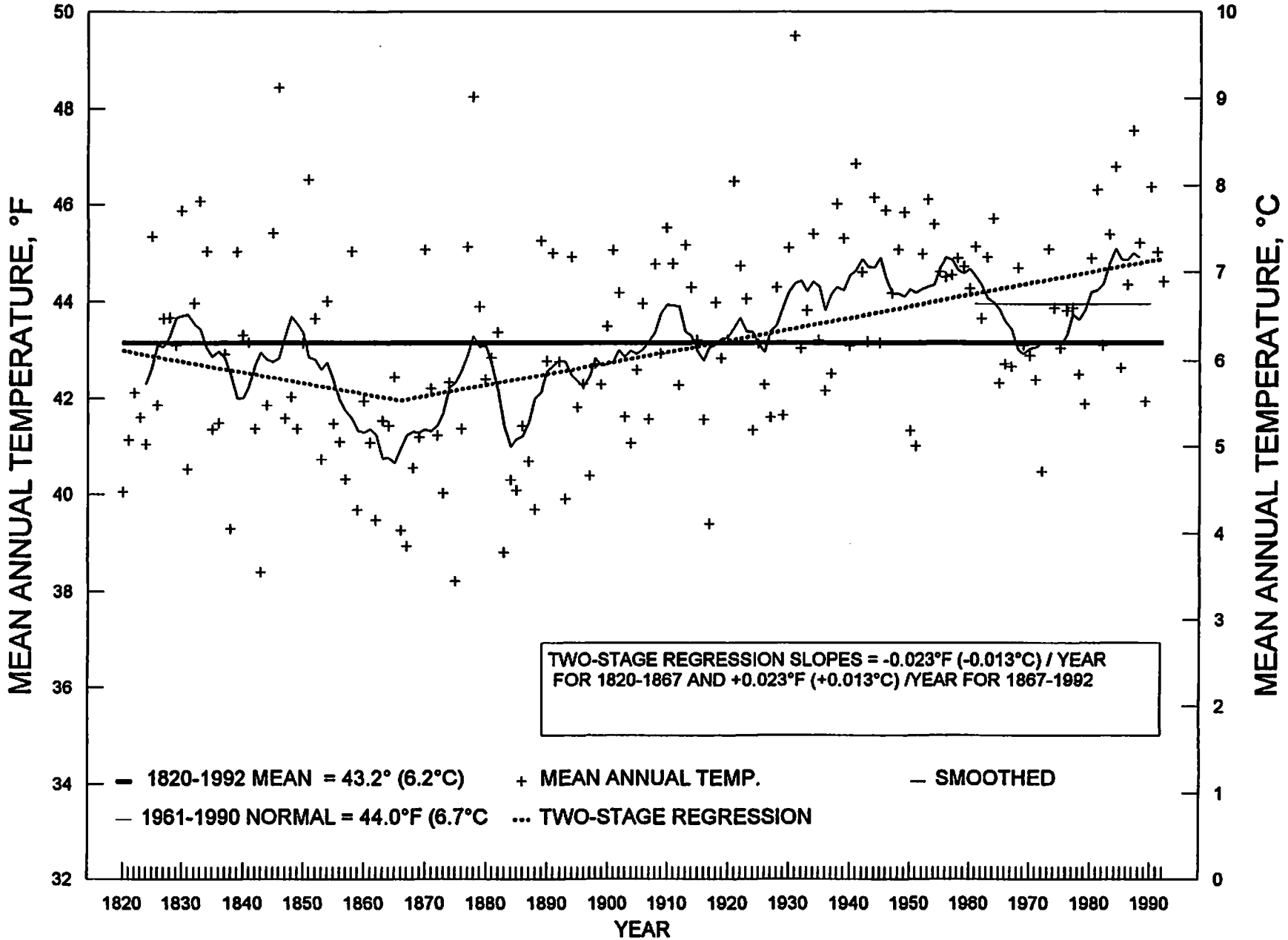


Fig. 5. Eastern Minnesota mean annual temperature for the years 1820-1992.

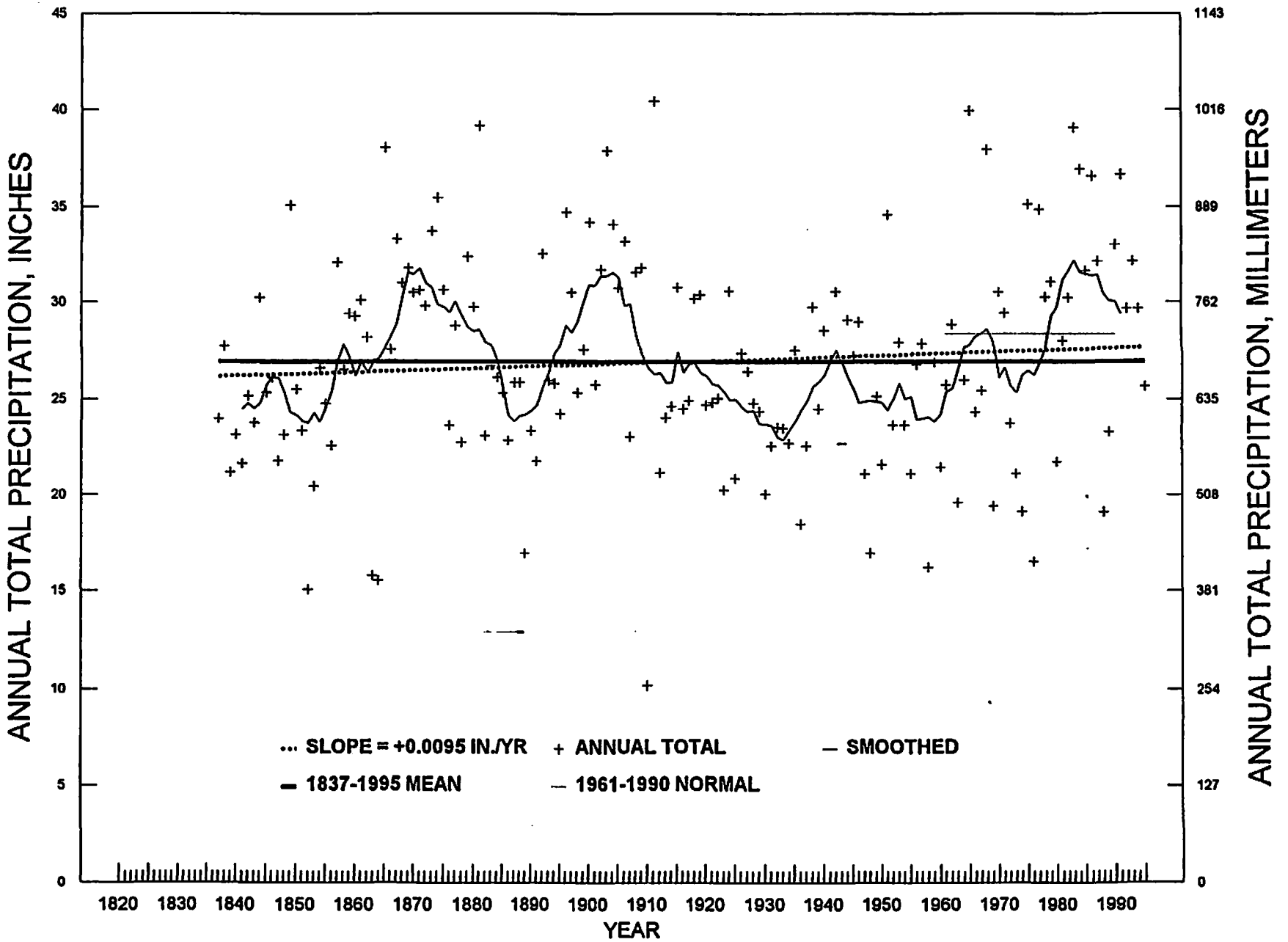


Fig. 6. Eastern Minnesota annual precipitation for the years 1837-1995.

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

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

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

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

Materials and Methods

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

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

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

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

Results

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

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

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

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

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

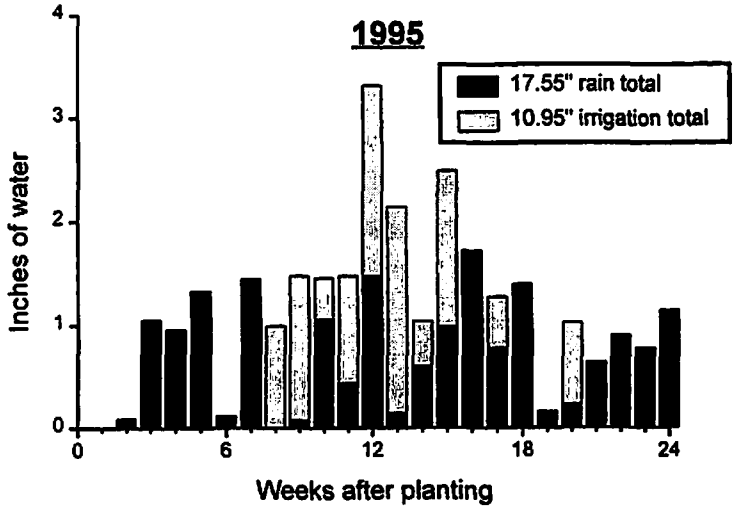


Figure 1. Rainfall and irrigation at Becker, MN during the 1995 growing season.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Carl Rosen and Dave Birong[2]

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

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

Procedures

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

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

Specific procedures at each site are as follows:

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

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

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

Results

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Materials and Methods:

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

Results:

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

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

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

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

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

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

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

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

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

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

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

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

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

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

EXPERIMENTAL PROCEDURES

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

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

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

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

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

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

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

Specific methods for analyses were as follows:

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

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

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

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

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

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

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

RESULTS

Tuber and Vine Yield, Specific Gravity, Hollow Heart. The effect of the various potassium treatments on graded yield, specific gravity, and hollow heart is presented in Table 1. Potato yields increased with banded applications of 0-0-60 up to 240 lb K_2O/A. The 320 lb K_2O/A rate tended to decrease yields presumably due to excessive salts. Particularly noticeable was the drop in 6-12 oz tuber in the 320 lb/A treatment. At equivalent K_2O rates, yields with broadcast plus banding did not differ from those with banding alone. Hollow heart tended to decrease with added potassium fertilizer. Specific gravity was not consistently

affected by K fertilizer but tended to be lower as K fertilizer level increased. The treatments with potassium nitrate (13-0-44) had yields comparable to those provided with potassium chloride (0-0-60). Slight effects of potassium nitrate were observed but in general, supplying potassium after planting does not appear to dramatically affect potato yield or quality. Vine yield responses to K fertilizer were similar to those recorded for tuber yield.

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

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

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

SUMMARY

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

ABSTRACT

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

INTRODUCTION

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

METHODS AND MATERIALS

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

RESULTS

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

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

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

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

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[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.

Table 1. Nitrate-Pesticide Movement Plot Management for 1995

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

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

Cropping System - CORN-soybean

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

Cropping System - SOYBEAN-corn

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

Table 2. Analysis of Variance - 1995 Corn Yields

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

Table 3. 1995 cropping system yields

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

* Significant difference

± Yield LSD does not include soybean yield

Table 4. Analysis of Variance - Tile Drainage Discharge

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

Table 5. Tile Flow as influenced by cropping system

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

* Significant treatment differences

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

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

* Significant treatment differences

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

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

* Significant treatment differences

NITROGEN FERTILITY MANAGEMENT OF CORN

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

ABSTRACT

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

METHODS AND MATERIALS

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

RESULTS AND DISCUSSION

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

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

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

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

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

Table 1. Available Soil Moisture

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

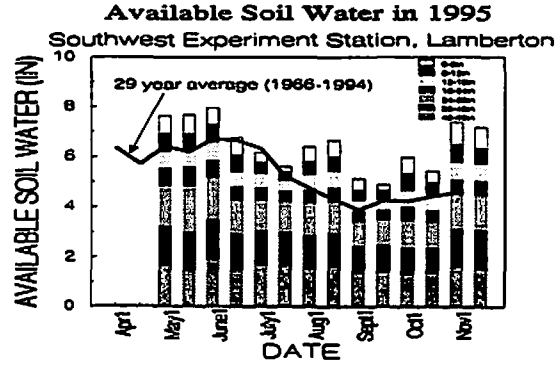

Figure 1. Available Soil Water at Southwest Experiment Station

[1] L.D. Klossner, and D.R. Huggins, are Assistant Scientist, Assistant Professor, at the Southwest Experiment Station, Lamberton, MN 56152. G.L. Malzer is Professor the Department of Soil, Water and Climate, University of Minnesota, St. Paul, MN.

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

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

* Fall fertilizer treatments applied prior to fall tillage

Table 3. Analysis of Variance - Continuous Corn

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

Table 4. Corn Yields in 1995- Continuous Corn

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

* Significant treatment differences

Table 5. Analysis of Variance - Corn/Soybean

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

Table 6. Corn Yields in 1995 - Corn/Soybean

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

* Significant treatment differences

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

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

ABSTRACT

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

INTRODUCTION

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

EXPERIMENTAL DESIGN AND TREATMENTS

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

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

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 (11-33-11)
4. Without row cleaners and with starter fertilizer (11-33-11)
5. Anhydrous pre-plant indexed on the row (120 lb N/A), with row cleaners and starter fertilizer (11-33-11)

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 AND DISCUSSION

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

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

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

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

Table 1. 1995 Corn Plot Management

Corn Sub-Treatments Within Tillage Systems

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

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