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SOIL SERIES #143
Field Research in Soil Science

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Climate Summary - 1996

January brought an assortment of mild and frigid temperatures. A powerful storm sweeping through the Midwest on January 17 and 18 produced heavy snow in the north and west, and left southeastern Minnesota covered with ice. Throughout the State, schools and offices closed, travel was difficult, and power outages occurred.

Late January and early February brought a cold spell of historic proportions to the Upper Midwest. Various locations across Minnesota set all-time low temperature records. A location near Tower broke the all-time Minnesota low temperature record with minus 60 degrees F on February 2. Temperatures moderated by the second week of February and slowly melted the snow cover from southern Minnesota, easing flooding concerns in those areas. However, northern Minnesota lost relatively little snow cover. By late March, snow depths were still greater than 18 inches over large areas of the north..

After enduring one of the harshest winters of the century, northern Minnesota experienced a very cold spring. Significant snow cover persisted in the North well into mid-April. Spring runoff from the heavy snow cover led to flooding, with northwestern Minnesota experiencing the most serious flooding.

Southern Minnesota also experienced an unusually cold spring. Temperatures averaged three to five degrees below normal for April and May. The Twin Cities reached 67 degrees on April 10, the first time the temperature reached 60 or more for nearly six months. The cold temperatures suppressed soil warming and drying, leading to significant delays in spring planting.

Heavy rains in mid-May dropped two to six inches of water on the already saturated Red River Valley, further delaying agricultural field operations and leading to more flooding. May also brought the usual severe spring weather to western and southern Minnesota, leading to significant property damage in some areas.

The weather was highly variable across the state in June. Very dry weather for the first three weeks of the month led to forest fires in the north, especially northeastern Minnesota. Fortunately, late June rains quelled the fire potential. In contrast to the dryness of the north, some areas of southern Minnesota received torrential rains in mid-June. A slow moving low pressure system, plodding through the Upper Midwest produced a deluge in south central Minnesota on June 16 and 17. Rainfall totals exceeded six inches in portions of Nicollet and Blue Earth counties leading to small stream and urban flooding as well as mud slides.

Relatively dry weather was the major climate issue of July. As of late July, many areas of central and western Minnesota had received just 50 to 75 percent of normal precipitation for the season. However, there was a notable exception to this pattern. Extreme northwestern Minnesota received substantial rains in July and precipitation totals were well above normal for the season.

Dry and pleasant weather was the rule throughout the late summer and early fall across Minnesota. For some regions of the state, dry weather was a continuation of a very dry growing season. In a few communities, the precipitation deficit was similar to the worst droughts of the century. Fortunately, moderate summer temperatures led to reduced evaporation rates, mitigating the impact of the rainfall shortage. The Palmer Drought Severity Index indicated that southeastern Minnesota was in the "moderate drought" category in the fall. Northwestern, central, and east central Minnesota fell in the "moderate drought" category for much of the summer and early fall.

A notable exception to the dry late summer weather was in the Mankato area in early September. For the second time in 1996, the area received extremely heavy rains leading to urban flooding, mud slides and sewer backups. Rainfall totals exceeded six inches.

Agricultural production across Minnesota showed mixed results. Those areas receiving adequate rainfall reaped the benefits of stress-free temperatures. Meanwhile, those areas with precipitation deficits experienced significant yield reductions. Many communities saw their first light frost in mid September, and all of Minnesota experienced a hard freeze in the first week of October.

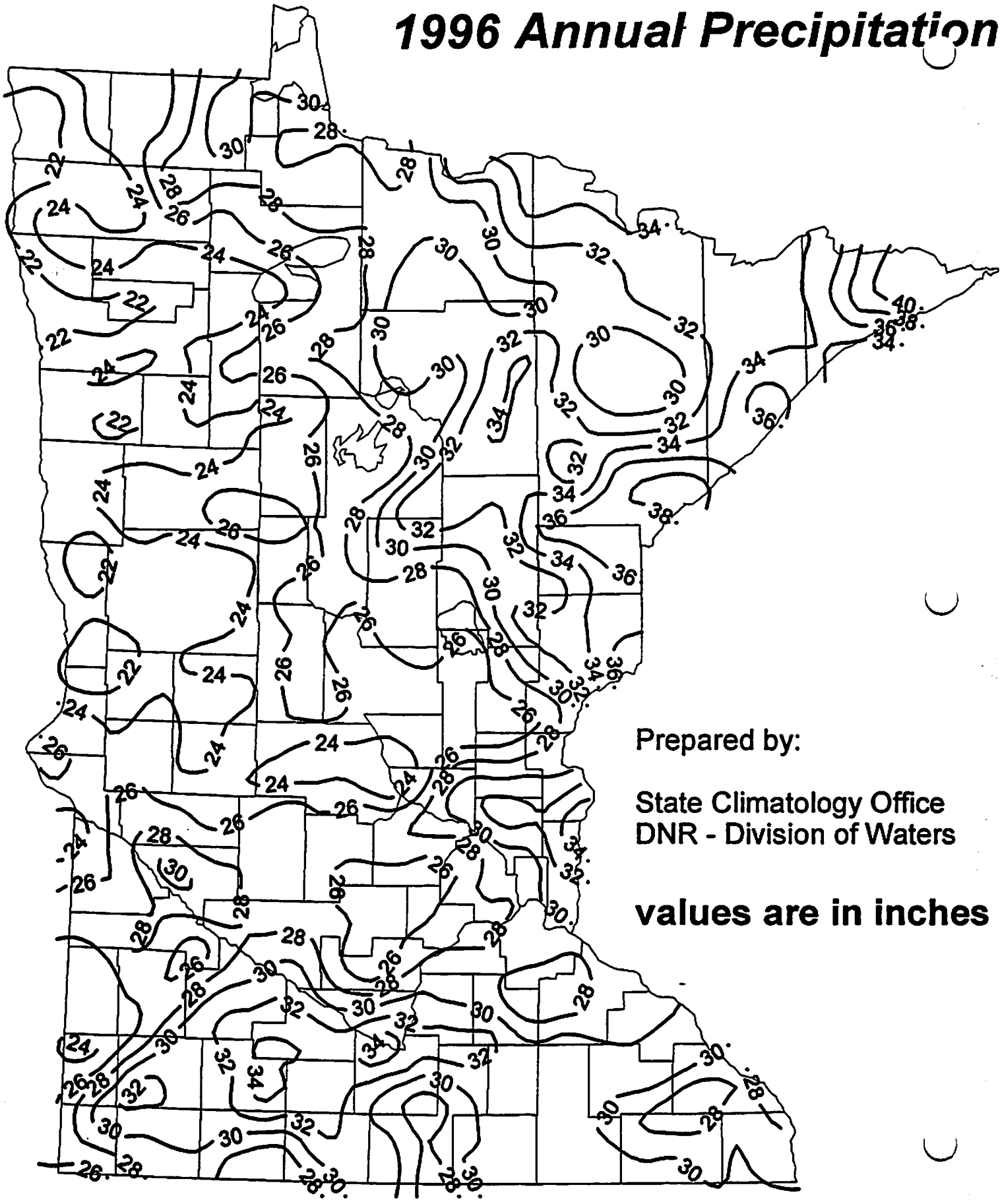
After a dry growing season, much of Minnesota experienced an extremely wet fall. For considerable areas of the state, precipitation totals for October and November ranged from four to eight inches. The October plus November precipitation totals ranked above the 95th percentile across large sections of Minnesota. Much of this precipitation fell before the soil froze and helped to replenish diminishing soil moisture reserves.

A major storm system passing through the central United States brought a wintry mess to the state in mid-November. Precipitation types included snow, rain, sleet and freezing rain. Some areas of northwestern Minnesota received over a foot of snow, making travel treacherous. Portions of eastern Minnesota reported nearly four inches of rain, dampening basements and causing minor urban flooding. Freezing rain in southwestern Minnesota brought down power lines, cutting electrical service to many. Southwestern Minnesota experienced yet another freezing rain event roughly one week later, hindering recovery from the first ice storm.

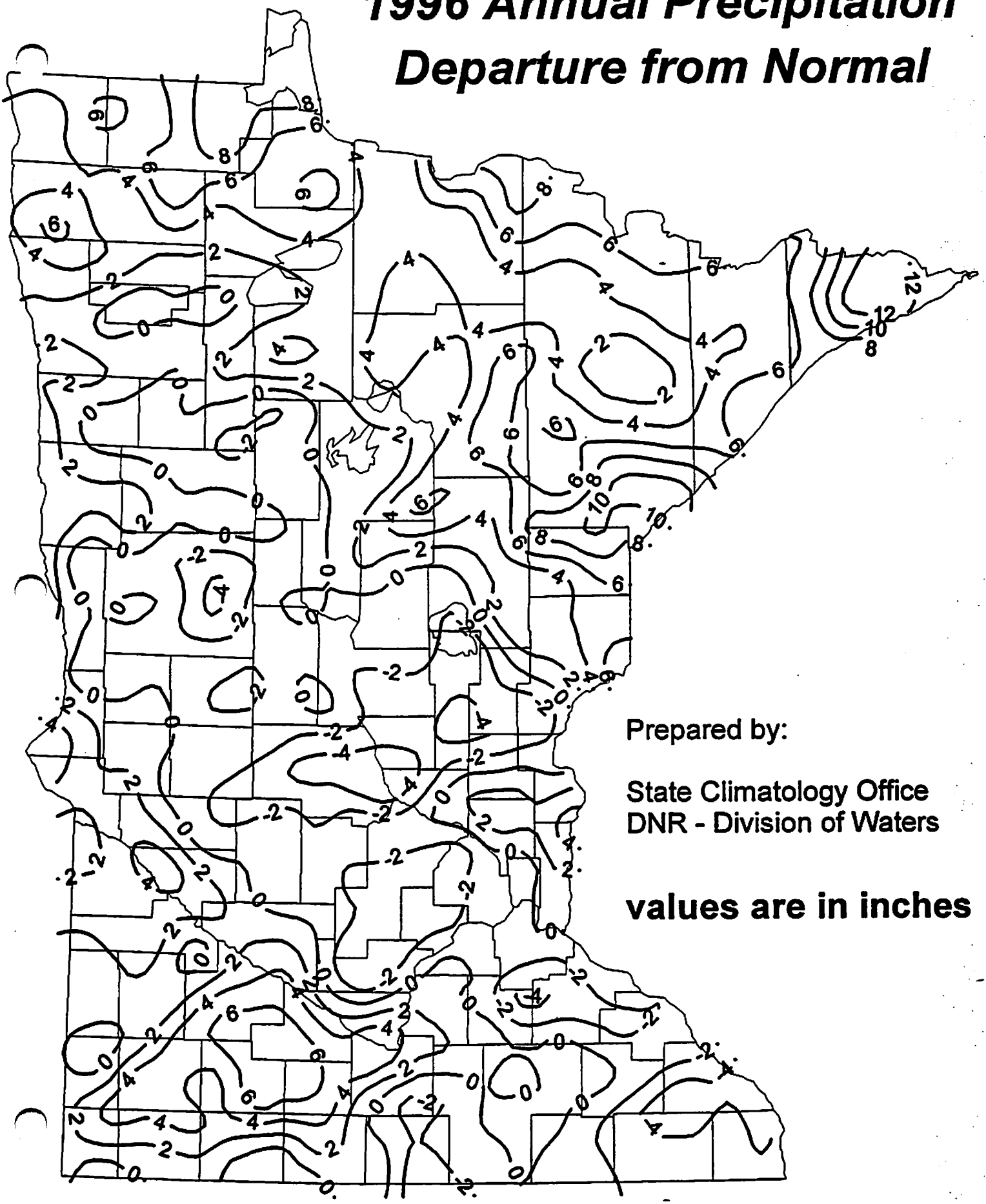
Mean November temperatures were considerably colder than normal. For many Minnesota communities it was one of the coldest Novembers of the century. November of 1996 was also one of the wettest this century, with a good deal of both freezing rain and snowfall.

Significant winter storms also occurred in December. Freezing rain events, snow storms, and full-fledged blizzards occurred throughout the month. Hardest hit was the western one third of Minnesota, where the prairie landscape did little to slow the arctic winds. Schools and offices closed across western Minnesota in mid-December. Christmas Day, 1996 will go down in history as the coldest and most snow-covered on record for many Minnesota communities. Cold temperature records fell across the state. Christmas Day snow depths over western and central Minnesota were at or near record levels for the date.

1996 Annual Precipitation



1996 Annual Precipitation Departure from Normal



Prepared by:

State Climatology Office
DNR - Division of Waters

values are in inches

LONG TERM EVAPORATION AND SOIL WATER RECORDS COMPARED TO 1996 RESULTS

By Donald G. Baker and David L. Ruschy

Evaporation is the loss of water from a moist surface into the atmosphere in the form of vapor. Except under unusual circumstances it is invisible. Because of this, the amount of water lost through evaporation is seldom appreciated. In Minnesota the loss is on the order of 20-30 inches per year. Evaporation estimates are ordinarily obtained by measuring the daily loss of water from a pan which measures 48 inches in diameter. Water depth in the pan is maintained at a depth of about 10 inches.

Unlike a lake the pan is extremely limited in area and, unlike a living leaf containing minute pores through which the water escapes to the atmosphere, the pan presents a free water surface to the atmosphere. As a result, the evaporation on a unit area basis from a pan is, under most circumstances, greatly in excess of that from a lake or an actively transpiring crop. In fact the evaporation from these two natural surfaces is in the neighborhood of only 50-70% of the pan. Nevertheless, in spite of the difference between the pan and natural surfaces the pan data do provide a reasonable estimate of the evaporation losses if the reduction factor is applied. The pan has the added advantages of being easy to measure as well as providing a uniform measurement. As a result, comparisons can be made between stations and between years.

Evaporation pans have been in place at the Agricultural Experiment Stations located at Lamberton, Morris, St. Paul, and Waseca for a number of years. It is that data which is shown in Table 1 and Fig. 1 and will be discussed. Due to the very limited evaporation between October 11-April 20, largely the winter period of little evaporation, the data shown in Fig. 1 represent the annual total.

Perhaps the most striking feature of Fig. 1 is the high evaporation centered around 1976 and 1988, the years of two well remembered droughts in Minnesota. The severity of the two droughts is evident in Fig. 1 as well as in the precipitation totals for those two years at St. Paul: 14.39 inches in 1976 and 20.36 inches in 1988 compared to a normal of 28.41 inches (1961-1990).

The evaporation from 1991 to the present, averaging 34.73 inches, has been considerably below the long term average, of 38.21 inches, Fig. 1, indicating relatively humid conditions and adequate precipitation.

Table 1. Mean total pan evaporation, inches, April 21-October 10, 1972-1996.

Station	Mean	Standard Deviation	Maximum/year	Minimum/year
Lamberton	40.21 in.	5.57 in.	56.95 in./1976	33.46 in./1972
Morris	39.33 in.	6.27 in.	58.22 in./1976	30.86 in./1996
St. Paul	38.21 in.	4.77 in.	51.41 in./1988	32.91 in./1993
Waseca	40.03 in.	4.59 in.	53.33 in./1988	32.99 in./1993

Lengthy soil water records are also available from the Lamberton and Waseca experiment stations. A comparison between the 1996 values and the long term average of plant available soil water under corn at the two stations is shown in Fig. 2 and 3. Except for a brief period in mid- to late June the soil water content at Lamberton was above average. Due to the relatively high end-of-season values it appears that the spring 1997 water content at Lamberton will be more than adequate.

The soil water at Waseca, Fig. 3, shows a market mid-season variation. First, there was an unusual low value which occurred in July, and second, it was followed by a temporary recovery in late August. The late fall values, Fig. 3 indicate that the soil water at Waseca will be quite adequate for the 1997 spring as it will be at Lamberton.

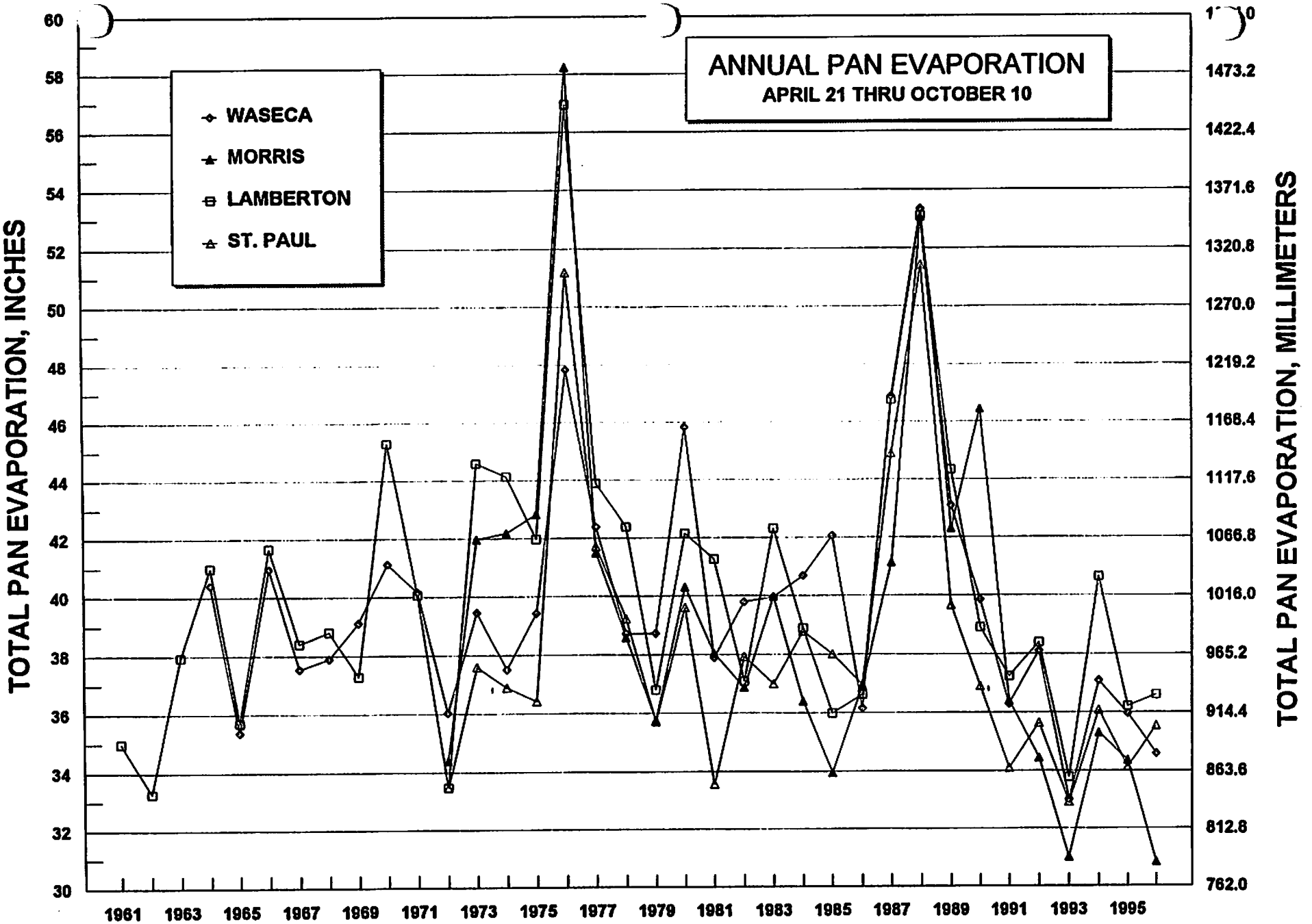


Fig. 1. Annual total pan evaporation for April 21 thru October 10.

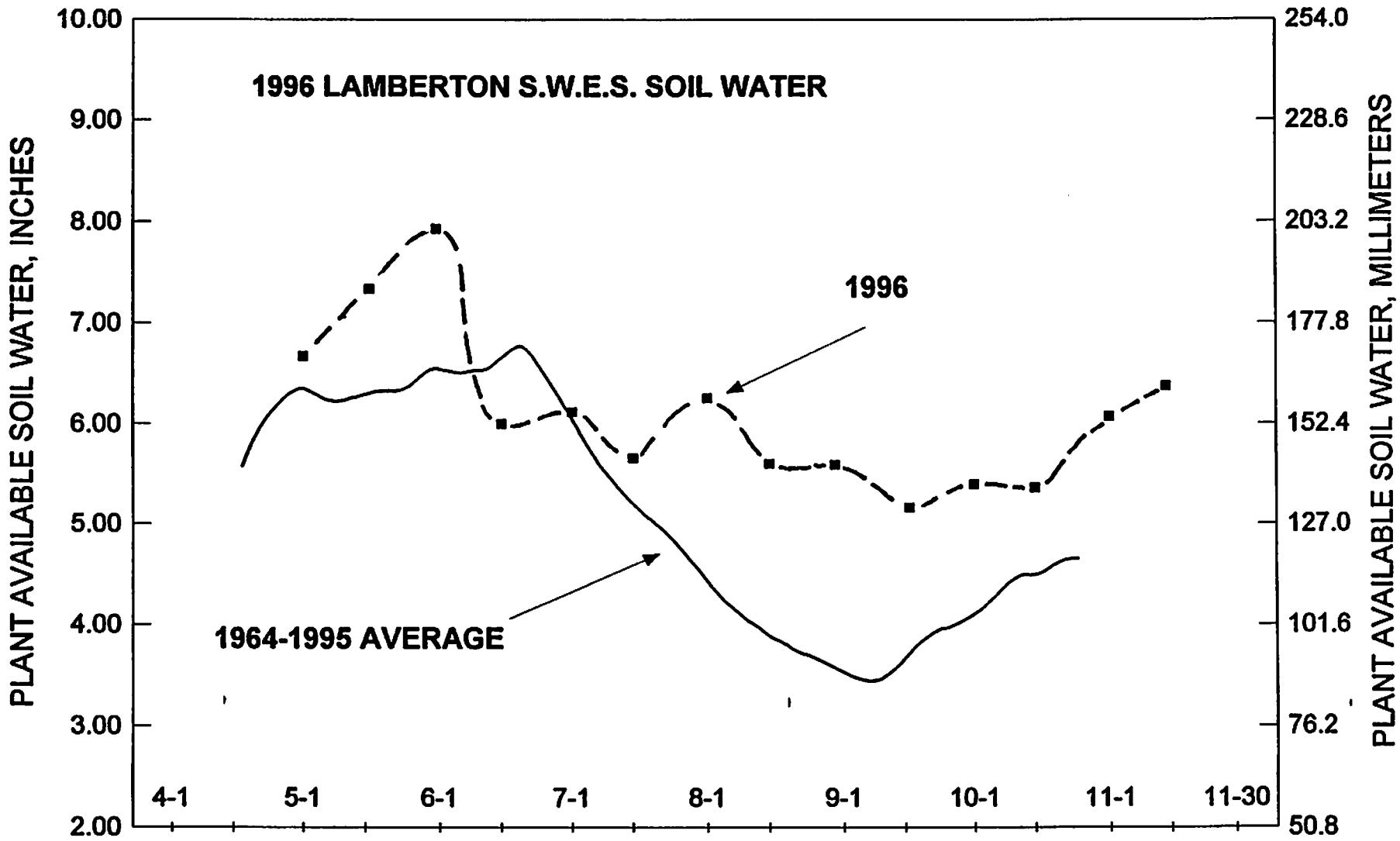


Fig. 2. Total plant available soil water in a 5-foot column of soil at the Lamberton S.W.E.S. in 1996 shown against the 1964-1995 average.

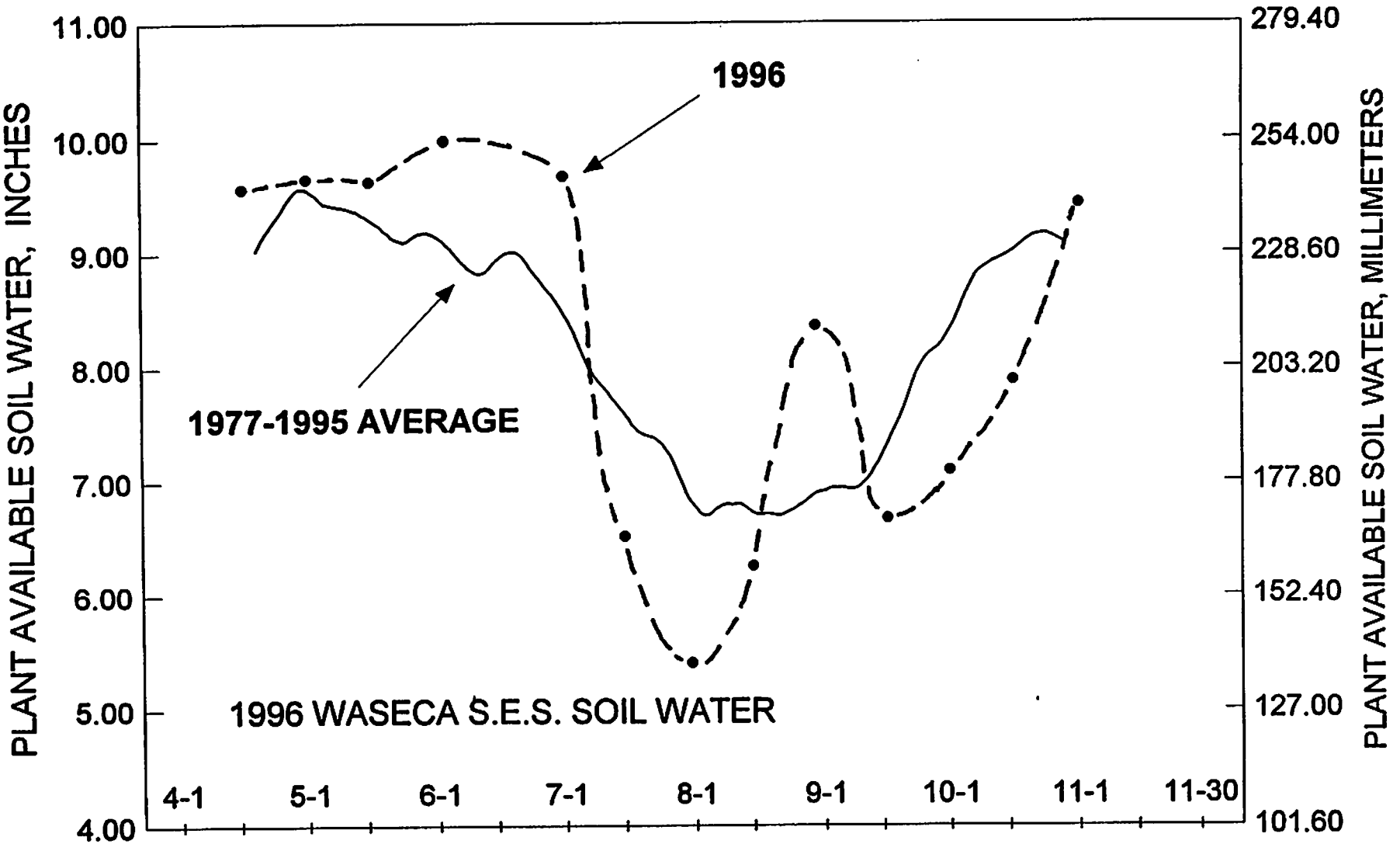


Fig. 3. Total plant available soil water in a 5-foot column of soil under corn at the Waseca S.E.S in 1996 shown against the 1977-1995 average.

RESPONSE OF SNOWDEN AND GOLDRUSH POTATO CULTIVARS TO NITROGEN ON AN IRRIGATED SOIL - 1996[1]

Carl Rosen and Dave Birong[2]

ABSTRACT: The second 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 Snowden and Goldrush potatoes. For Snowden, increasing N rate from 125 lb N/A to 285 lb N/A had no effect on total yield, but increased tuber size. Post-hilling applications of N had no effect on yiled, but tended to reduce hollow heart incidence. Increasing N rate increased total yield of Goldrush and tended to decrease tubers in the 3-6 oz category and increase tubers in the greater than 12 oz category. Post-hilling N application tended to decrease yield of Goldrush. The petiole nitrate test on both a dry weight and sap basis was useful for measuring the N status of the crop. For Snowden, petiole nitrate-N concentrations greater than 0.6% on a dry weight basis and 1000 ppm on a sap basis in mid-July were associated with the highest yields. For Goldrush, highest yields were associated with a petiole nitrate-N concentration of 1.0% on a dry weight basis and 1100 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. Shortage of nitrogen during the growing season can seriously limit yield and tuber size. 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 efficiency. 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 and calibrating the sap test for varieties other than Russet Burbank. The overall objective of this study was to characterize the nitrogen response and calibrate the petiole nitrate sap test for Snowden and Goldrush potato cultivars grown under irrigated conditions.

Materials and Methods

The experiment was conducted at the Sand Plain Research Farm in Becker, Minnesota on a Hubbard loamy sand. Selected chemical properties in the 0-6" depth were as follows: pH, 6.4; Bray P1, 49 ppm; and NH_4OAc K, 129 ppm. An average of 11 lb nitrate-N was available in the top. Prior to planting, 200 lbs/A 0-0-22 and 200 lbs/A 0-0-60 were broadcast and incorporated. Each cultivar was evaluated in adjacent strips. At planting, phosphate (11-48-0) and potash fertilizer (0-0-60 and 0-0-22) were banded 3 inches to the side and 2 inches below each tuber to supply 25 lb N/A, 110 lb P_2O_5/A, 200 lb K_2O/A, 20 lb Mg/A, and 34 lb S/A. Six nitrogen treatments were tested. For each cultivar, five of the six nitrogen 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 (banded as described above) and the remainder split equally between emergence (May 22 for Snowden and May 23 for Goldrush) and hilling (June 11). The sixth treatment was a post-hilling treatment where 165 lb N/A was applied through hilling as described above, followed by 80 lb N/A post-hilling applied as urea-ammonium nitrate at 40 lb N/A on June 22 and 40 lb N/A on July 6.

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. Goldrush and Snowden "A" size cut seed potatoes were planted by hand on April 23, 1996. Admire was applied in furrow for Colorado potato beetle control. Emergence N was sidedressed on May 23 for Snowden and May 23 for Goldrush, and hilling N was applied on June 11. Petioles were sampled at two week intervals starting June 20. 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. Snowden vines were killed September 4 and tubers harvested September 12. Goldrush vines were killed September 5 and tubers were harvested September 12. At 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.

Results

Snowden: Yield of Snowden tuber and vines is presented in Table 3. Increasing N rate from 120 lb N/A to 280 lb N/A did not significantly affect total yield; however, yield of the largest sized tubers (greater than 3") increased with increasing N rate.

Vine growth increased with increasing N rate. At equivalent N rates, post-hilling N did not significantly affect tuber yield or vine growth. Although numerically, the highest yield was obtained with a post-hilling application of nitrogen. Hollow heart incidence was lowest with the post-hilling treatment. Specific gravity was not affected with increasing N rate or post-hilling N application.

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

Nitrogen uptake increased with increasing N rate (Table 2). The highest N uptake was obtained with the posthilling N treatment, which was primarily due to more N in the vines at harvest. Tuber N concentrations and dry matter production were not affetced by treatment while vine dry matter and N concentrations at harvest increased with increasing N rate. On the first sampling date petiole nitrate-N was not affected by N treatment (Table 3). On all subsequent sampling dates petiole nitrate-N increased with increasing N rate. Highest yield and quality were associated with nitrate-N concentrations during tuber bulking greater than 0.6% on a dry weight basis and 1000 ppm on a sap basis. Posthilling N application significantly increased petiole nitrate-N from July 15 on.

Goldrush: Goldrush tuber and vine yield is presented in Table 4. Increasing N rate significantly increased total tuber yield and yield of tubers greater than 6 oz. Tubers less than 6 oz increased with increasing N rate. Post-hilling N application tended to decrease total yield as well as yield of 6-12 oz tubers. The practice of applying N after hilling for Goldrush seems questionable based on results from the past two years. Vine growth increased with increasing N rate. Hollow heart incidence increased and specific gravity decreased with increasing N rate.

Nitrogen uptake increased with increasing N rate (Table 5). The posthilling N treatment did not improve nitrogen uptake and tended to lower tuber dry matter production at harvest. Tuber and vine N concentrations increased with increasing N rate. Dry matter porduction was not affected by increasing N rate. On the first sampling date petiole nitrate-N was not affected by N treatment (Table 6). On all subsequent sampling dates petiole nitrate-N increased with increasing N rate. Highest yield and quality were associated with nitrate-N concentrations during tuber bulking greater than 1.0% on a dry weight basis and 1100 ppm on a sap basis. Posthilling N application significantly increased petiole nitrate-N from July 15 on.

Table 1. Effect of nitrogen treatments on Snowden tuber quality and fresh weight of vines and tubers - 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]	2.70	34.5	125.2	186.2	53.0	398.9	1.0905	2.0
2.	165	(25,70,70)	2.97	29.2	122.1	168.9	84.4	404.6	1.0906	4.0
3.	205	(25,90,90)	3.37	22.9	101.7	195.2	119.1	438.9	1.0903	2.0
4.	245	(25,110,110)	4.10	25.8	112.6	171.5	111.9	421.8	1.0928	5.0
5.	285	(25,130,130)	5.42	24.1	108.1	170.2	133.0	435.4	1.0913	4.0
6.	245	(25,70,70)+80[2]	4.40	30.5	106.1	195.6	118.8	451.0	1.0906	0.0
Significance			**	NS	NS	NS	*	NS	NS	NS
BLSD (0.05)			0.64	--	--	--	58.9	--	--	--
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
Post-hilling (4) vs (6)			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 5% and 1%, respectively.

Table 2. Effect of nitrogen treatments on Snowden nitrogen content, nitrogen 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]	6.8	108.1	114.9	1.29	1.14	0.26	4.72	4.98
2.	165	(25,70,70)	8.5	118.0	126.5	1.28	1.29	0.33	4.63	4.96
3.	205	(25,90,90)	9.1	124.9	134.0	1.37	1.27	0.34	4.94	5.28
4.	245	(25,110,110)	9.8	127.0	136.8	1.21	1.29	0.42	4.96	5.38
5.	285	(25,130,130)	15.4	131.7	147.1	1.50	1.26	0.52	5.22	5.74
6.	245	(25,70,70)+80[2]	18.2	130.9	149.1	1.80	1.26	0.51	5.21	5.72
Significance			**	NS	NS	*	NS	**	NS	NS
BLSD (0.05)			3.5	--	--	0.35	--	0.09	--	--
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

[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 3. Effect of nitrogen treatments on Snowden nitrate-N concentration in potato petioles (dry weight basis) and nitrate concentration in petiole sap - Becker, MN.

Treatment			Date					
			June 20		July 1		July 15	
			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]	26218	1650	14906	1450	899	355
2.	165	(25,70,70)	26578	1675	22000	1875	2316	553
3.	205	(25,90,90)	26737	1725	24460	1950	6636	1018
4.	245	(25,110,110)	27119	1775	24422	1925	11135	1250
5.	285	(25,130,130)	25811	1700	27842	2025	14691	1500
6.	245	(25,70,70)+80[2]	26194	1700	26315	1975	16630	1575
Significance			NS	NS	**	**	**	**
BLSD (0.05)			--	--	5026	218	1740	114
Contrasts								
Lin Rate N (1, 2, 3, 4, 5)			NS	NS	**	**	**	**
Quad Rate N (1, 2, 3, 4, 5)			NS	NS	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 3 cont. Effect of nitrogen treatments on Snowden nitrate-N concentration in potato petioles (dry weight basis) and nitrate concentration in petiole sap - Becker, MN.

Treatment			Date			
			July 25		August 6	
			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]	263	158	37	140
2.	165	(25,70,70)	991	185	397	193
3.	205	(25,90,90)	1313	443	537	228
4.	245	(25,110,110)	4143	838	1497	335
5.	285	(25,130,130)	9576	1200	3860	463
6.	245	(25,70,70)+80[2]	13242	1450	6322	593
Significance			**	**	**	**
BLSD (0.05)			1692	121	1857	104
Contrasts						
Lin Rate N (1, 2, 3, 4, 5)			**	**	**	**
Quad Rate N (1, 2, 3, 4, 5)			**	**	++	NS
Post-hilling (4) vs (6)			**	**	**	**

[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 4. Effect of nitrogen treatments on Goldrush tuber quality and fresh weight of vines and tubers - 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]	0.71	15.3	59.6	150.5	183.5	21.1	430.0	1.0823	4.0
2.	165	(25,70,70)	0.84	5.4	51.7	143.0	186.4	39.6	426.1	1.0805	7.0
3.	205	(25,90,90)	1.04	14.3	47.7	117.5	194.5	48.4	422.4	1.0792	4.0
4.	245	(25,110,110)	1.35	15.1	39.0	106.4	219.6	79.0	459.1	1.0769	9.0
5.	285	(25,130,130)	1.95	16.3	31.7	99.5	207.0	107.7	462.2	1.0776	10.0
6.	245	(25,70,70)+80[2]	1.75	18.6	38.9	100.8	177.1	76.8	412.2	1.0755	7.0
Significance			**	*	**	**	NS	**	NS	*	NS
BLSD (0.05)			0.40	8.1	13.1	24.3	--	26.1	--	0.0043	--
Contrasts											
Lin Rate N (1, 2, 3, 4, 5)			**	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; ++, *, and ** = significant at 10%, 5%, and 1%, respectively.

Table 5. Effect of nitrogen treatments on Goldrush nitrogen content, nitrogen 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]	5.8	100.2	106.0	1.51	1.11	0.20	4.50	4.70
2.	165	(25,70,70)	9.3	122.0	131.3	1.53	1.49	0.33	4.14	4.47
3.	205	(25,90,90)	9.9	122.5	132.4	1.84	1.42	0.27	4.30	4.57
4.	245	(25,110,110)	12.0	143.5	155.5	2.37	1.57	0.26	4.56	4.82
5.	285	(25,130,130)	11.4	152.0	163.4	2.23	1.76	0.26	4.33	4.59
6.	245	(25,70,70)+80[2]	12.4	120.3	132.7	2.46	1.52	0.25	3.95	4.20
Significance			NS	**	**	**	**	NS	++	NS
BLSD (0.05)			--	24.5	24.0	0.50	0.31	--	0.49	--
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	**	*

[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 Goldrush nitrate-N concentration in potato petioles (dry weight basis) and nitrate concentration in petiole sap - Becker, MN.

Treatment			Date					
			June 20		July 1		July 15	
			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]	22878	1450	12136	1225	2130	385
2.	165	(25,70,70)	23767	1525	18097	1650	324	568
3.	205	(25,90,90)	25163	1575	22227	1700	7104	750
4.	245	(25,110,110)	24473	1525	26415	1950	10378	1175
5.	285	(25,130,130)	23665	1475	27688	2000	16049	1450
6.	245	(25,70,70)+80[2]	24382	1525	24051	1900	14864	1450
Significance			NS	NS	**	**	**	**
BLSD (0.05)			--	--	2562	146	2815	293
Contrasts								
Lin Rate N (1, 2, 3, 4, 5)			NS	NS	**	**	**	**
Quad Rate N (1, 2, 3, 4, 5)			++	++	*	*	*	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 10%, 5% and 1%, respectively.

Table 6 cont. Effect of nitrogen treatments on Goldrush nitrate-N concentration in potato petioles (dry weight basis) and nitrate concentration in petiole sap - Becker, MN.

Treatment			Date			
			July 25		August 7	
			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]	304	143	450	145
2.	165	(25,70,70)	636	240	255	150
3.	205	(25,90,90)	864	353	994	210
4.	245	(25,110,110)	4130	740	2062	380
5.	285	(25,130,130)	7247	853	2575	493
6.	245	(25,70,70)+80[2]	12759	1250	5566	703
Significance			**	**	**	**
BLSD (0.05)			1979	211	1687	119
Contrasts						
Lin Rate N (1, 2, 3, 4, 5)			**	**	**	**
Quad Rate N (1, 2, 3, 4, 5)			**	NS	NS	++
Post-hilling (4) vs (6)			**	**	**	**

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

EVALUATION OF ROW SPACING EFFECTS ON YIELD AND QUALITY OF IRRIGATED POTATOES[1]
- 1996 -

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

Abstract: The second year of a three year field study was 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 Norland and Russet Burbank potato production. For Norland, total yield was significantly greater at 30 inch spacing compared to 36 inch spacing at both plant populations. This yield increase was primarily due to an increase in smaller (<2.25 inch) sized tubers. For Russet Burbank, between row spacing had no effect on total yield, but, yield of 6-12 oz tubers was greater with 36" row spacing compared to 30 inch row spacing.

Traditional spacing between rows for potatoes is 36 inches. However, row spacing for many of the rotation crops such as sweet corn and soybean is 30 inches. Efficiency in farming operations would be improved if all crops grown had the same row spacing since tractors could be used interchangeably. Before a switch to 30 inch row spacing is made, growers need to know how tuber production may be affected. Results from 1995 indicated that total yield of Russet Burbank was significantly greater at 30 inch spacing compared to 36 inch spacing at; however, the yield increase was primarily due to an increase in smaller (<6 oz) sized tubers. Because yield of smaller tubers increased with narrower rows, the potential for increased profitability may be greater for varieties such as Norland where smaller tubers are often preferred. The objective of this study therefore was to determine the effects of 30 inch row spacing on yield and quality of both Russet Burbank and Norland potatoes.

Materials and Methods

The experiment was conducted at the Sand Plain Research Farm at Becker on a Hubbard loamy sand following a previous crop of rye. Selected soil chemical properties (0-6") prior to planting were: Soil pH(1:1 - soil:water), 6.4; Bray P1, 30 ppm; and NH_4OAc K, 118 ppm. Nitrate-N in the top two feet prior to planting was 22 lb/A. Two between row spacings were tested using Russet Burbank and Red Norland cultivars. Each cultivar was grown in separate plots. The between row spacings were 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. For each cultivar, 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 sub plots. 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. Norland "B" size tubers were planted on April 17, 1996 and Russet Burbank "A" size cut tubers were planted on April 22, 1996. Admire was applied directly in furrow for insect control and the rows were then mechanically hilled. For Norland, N as ammonium nitrate was applied at the rate of 100 lb N/A at emergence (May 29), and 50 lb N/A at hilling (June 12). For Russet Burbank, N as ammonium nitrate was applied at the rate of 100 lb N/A at emergence (May 29) and 110 lb N/A at hilling (June 12). Norland vines were killed July 18 and the middle two rows of each plot were harvested July 31. Russet Burbank vines were killed on September 9 and the middle two rows of each plot were harvested September 16. Tubers were weighed and graded according to size.

Results

Norland: 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. As with the results from 1995 with Russet Burbank, this effect was due to an increase in the yield of smaller sized tubers (less than 2.25 inches). Yield of the largest sized tubers (greater than 3 inches) increased with wider spacing within rows (lower plant populations), but were not affected by between row spacing. Spacing had no effect on vine yield, hollow heart incidence, or growth cracks.

Petiole nitrate-N on June 28 was not significantly affected by spacing or plant population (Table 2). Even though tuber yield and total dry matter production was greater with 30 inch row spacing, there was no difference in N due to row spacing or plant population. The main reason for lack of an effect due to row spacing or plant poulation was due to numerically higher N concentrations in the vines and tubers of the 36" row spacing, which offset the higher yield of the 30" row spacing.

Russet Burbank: Yield and quality as affected by row spacing is presented in Table 3. Use of 30 inch row spacing had no effect on total yield compared to 36 inch spacing. However, yield of the 6-12 oz tubers was greater with the wider 36 inch rows. Misshapen tubers tended to be greater with 30 inch rows. Spacing had no effect on vine growth, hollow heart incidence or specific gravity.

Petiole nitrate-N on June 28 was lower for the 30 inch spacing compared to 36 inch spacing with no effect due to plant population (Table 4). Since plant populations were the same with each row spacing, the amount of N applied per plant was for each row spacing. Reasons for the lower petiole nitrate-N concentrations with the 30 inch row spacing are unclear. Dry matter production and N uptake by vines and tubers were not significantly affected by row spacing or plant population.

As in 1995, the results of this study suggest that 30 inch spacing would not be that useful for potatoes where larger sized tubers are required. However, for Norland or seed potatoes where smaller sized tubers are often desirable, 30 inch row spacing may be advantageous. At least one more year of study is needed before definite conclusions 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 Norland tubers - Becker, MN. (Vines killed July 18, 1996).

Between Row Spacing inches	Within Row Spacing inches	Plants per Acre	Vine Tons/A	Fresh weight: Tuber size <1½" (cwt/A)	1½-1⅞"	1⅞-2¼"	2¼-2½"	2½-3"	>3"	Total	Growth Cracks % incidence	Hollow Heart % incidence
30	11.4	18,340	11.6	12.7	28.8	131.4	102.2	101.6	9.5	386.2	0.0	1.0
30	13.2	15,840	11.1	10.8	33.7	125.5	98.6	105.6	14.9	389.1	0.0	1.0
36	9.5	18,340	13.0	9.0	26.3	106.2	91.1	99.1	10.2	341.9	0.0	0.0
36	11.0	15,840	12.2	7.4	21.7	100.3	89.6	102.6	11.8	333.4	0.0	0.0
Significance			NS	++	*	**	NS	NS	++	**	NS	NS
BLSD (0.05)			--	4.8	6.5	14.0	--	--	5.1	26.4	--	--
Spacing			NS	*	**	**	NS	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	NS

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

Table 2. Effect of row spacing and plant population on petiole nitrate-N (sampled June 28) and nitrogen content, concentration and dry matter production of Norland potatoes at harvest, Becker, MN.

Between Row Spacing inches	Within Row Spacing inches	Plants per Acre	Nitrogen content: Vine (lbs/A)	Tuber (lbs/A)	Total (lbs/A)	Nitrogen concentration: Petiole (ppm NO_3-N)	Vine (% N)	Tuber (% N)	Dry matter: Vine (Tons/A)	Tuber (Tons/A)	Total (Tons/A)
30	11.4	18,340	57.1	101.8	158.9	12,286	2.42	1.45	1.2	3.5	4.7
30	13.2	15,840	50.2	96.3	146.5	11,391	2.16	1.39	1.2	3.5	4.7
36	9.5	18,340	60.0	88.6	148.7	13,277	2.55	1.50	1.2	3.0	4.2
36	11.0	15,840	58.9	86.3	145.1	14,170	2.57	1.46	1.1	3.0	4.1
Significance			NS	*	NS	NS	NS	NS	NS	*	*
BLSD (0.05)			--	12.49	--	--	--	--	--	0.5	0.6
Spacing			NS	**	NS	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	NS

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

Table 3. Effect of row spacing and plant population on vine yield and yield and quality of Russet Burbank tubers, Becker, MN. (Vines killed September 9, 1996).

Between Row Spacing inches	Within Row Spacing inches	Plants per Acre	Fresh weight: Knobs (cwt/A)	Tuber Size <3 oz (cwt/A)	3-6 oz	6-12 oz	>12 oz	Total	Vine (Tons/A)	Specific Gravity	Hollow Heart %
30	11.4	18,340	18.6	63.2	162.2	206.3	80.4	530.7	9.6	1.0920	15.0
30	13.2	15,840	21.1	56.5	145.1	194.3	84.5	501.5	10.7	1.0905	12.0
36	9.5	18,340	4.9	56.2	172.5	224.2	70.8	528.6	10.0	1.0879	15.0
36	11.0	15,840	10.5	42.6	142.6	233.9	83.3	512.9	10.5	1.0893	15.0
Significance			**	*	NS	NS	NS	NS	NS	NS	NS
BLSD (0.05)			6.8	14.2	--	--	--	--	--	--	--
Spacing			**	*	NS	*	NS	NS	NS	NS	NS
Population			++	*	++	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 4. Effect of row spacing and plant population on petiole nitrate-N (sampled June 28) and nitrogen content, concentration and dry matter production of Russet Burbank potatoes at harvest. Becker, MN.

Between Row Spacing	Within Row Spacing	Plants per Acre	Nitrogen content			Nitrogen concentration			Dry matter		
			Vine	Tuber	Total	Petiole	Vine	Tuber	Vine	Tuber	Total
inches	inches		------	lbs/A	--------	ppm NO_3-N	--- % N ---		-----	Tons/A	-----
30	11.4	18,340	35.0	131.7	166.7	21,276	1.49	1.08	1.1	6.1	7.2
30	13.2	15,840	33.9	138.5	172.4	21,358	1.51	1.22	1.1	5.7	6.8
36	9.5	18,340	28.3	138.2	166.5	23,489	1.53	1.18	0.9	5.9	6.8
36	11.0	15,840	32.6	129.5	162.2	23,707	1.47	1.17	1.1	5.6	6.7
Significance			NS	NS	NS	NS	NS	NS	NS	NS	NS
BLSD (0.05)			--	--	--	--	--	--	--	--	--
Spacing			NS	NS	NS	*	NS	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

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

EFFECT OF NITROGEN RATE AND TIMING ON YIELD OF RED NORLAND POTATO[1]

Carl J. Rosen and Dave Birong[2]

ABSTRACT: The second 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 Red Norland potatoes. For early harvest Norland, increasing N rate from 125 to 285 lb N/A did not significantly affect total tuber yield; however, timing of N application affected tuber size distribution. Increasing N rate at planting at the 205 lb N/A rate tended to decrease total yield and larger sized (greater than 2.5 inches) tubers. Delaying Norland vine kill by three weeks increased tuber yield by about 100 cwt/A compared to the yield obtained with the early harvest. Increasing N rate from 165 to 245 lb N/A had no effect on total yield, suggesting that under the conditions of this study, 165 lb N/A was sufficient for optimum yield of mid/late season harvested Norland.

Norland is an early maturing red potato variety used primarily for the fresh market. Depending on the market, vines are killed from mid-July to late August. 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%. Few studies, however, have been conducted with Norland potato to determine the effects of N rate and timing on yield at various harvest dates. Nitrogen applied too early in the season may be susceptible to leaching losses than nitrogen applied during the period of maximum uptake. On the other hand, N fertilizer applied early in the season may affect tuber initiation, which in turn can affect tuber number and size. The overall objective of this study was to define optimum nitrogen application times and rates for the Norland variety where the crop is harvested for both an early and mid/late season market.

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, 6.4; Bray P, 45 ppm; and NH_4OAc K, 127 ppm. An average of 14 lb nitrate-N was available in the top 2 ft. Prior to planting, 200 lbs/A 0-0-22 and 200 lbs/A 0-0-60 were broadcast and incorporated. Effects of nitrogen treatments were evaluated at an early and late harvest date. Each harvest date was evaluated in separate strips. At planting, phosphate (11-48-0) and potash fertilizer (0-0-60 and 0-0-22) were banded 3 inches to the side and 2 inches below each tuber to supply 25 lb N/A, 110 lb P_2O_5/A, 200 lb K_2O/A, 20 lb Mg/A, and 34 lb S/A. For early harvest Red Norland, twelve N treatments were tested. Five of the twelve nitrogen 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 (banded as described above) and the remainder split equally between emergence and hilling. The remaining seven treatments were designed to evaluate the effect of increased starter N (25 to 85 lb N/A) on yield. Rates of N higher than 25 lb N/A in the starter were supplemented with urea and banded as described above. Various times of application were evaluated at the and 205 lb N/A rates. Specific timing of N application for each treatment for Norland is shown in Table 1. For the late season harvest, six treatments were tested at 165, 205, and 245 lb N/A with either 25 or 65 lb N/A in the starter (Table 4).

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 cut seed potatoes were planted on April 17, 1996 for both the harvest dates. Admire was applied in furrow for Colorado potato beetle control to all plots. Emergence N was applied on May 22 and hilling N was applied on June 11. For early harvest Norland, petioles were collected at two sampling dates (June 24 and July 17). Petioles from the mid-season harvest Norland were collected at five sampling dates starting June 20 at two week intervals. Half of the petioles collected were crushed to express the sap for quick nitrate determination, and the remainder were dried for conventional nitrate determination. Early Norland vines were killed July 17 and tubers were harvested July 31. Late season Norland vines were killed August 8 and tubers were harvested August 20. At each harvest, total yield, graded yield, 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.

Results

Early Harvest Norland: Yield of early harvested Norland tuber and vines is presented in Table 1. Increasing nitrogen rate from 120 lb N/A to 280 lb N/A did not significantly affect total tuber yield; however, increasing N rate at planting at the 205 lb N/A rate tended to decrease total yield and larger sized (greater than 2.5 inches) tubers. At the 165 lb N rate, increasing N in the starter had no effect no total yield but did tend to decrease the yield of larger sized tubers and increase the yield of smaller sized (less than 2.5 inches) tubers. Neither N rate nor timing significantly affected vine yield. Growth cracks and hollow heart incidence were not affected by treatment.

Nitrogen uptake tended to increase with increasing N rate (Table 2). Increasing N in the starter tended to decrease N uptake at the 205 lb N rate but had the opposite effect at the 165 lb N/A rate. Total dry matter accumulation was not affected by treatment. Petiole nitrate-N on June 24 increased with increasing N rate and decreased with increasing N in the starter (Table 3). On June 24, the highest yield and quality was associated with sap nitrate-N levels between 1400 and 1600 ppm and dry weight concentrations between 1.7 and 2.3%. By July 17 (one day before harvest), petiole nitrate-N increased with increasing N rate, but was not affected by N in the starter.

[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, & Climate.

Late season Harvest Norland: Delaying vine kill by 3 weeks increased yield on average by about 100 cwt/A. With 25 lb N/A in the starter, yield of the largest sized (greater than 3") tubers increased with N rate and yield of the 2.5 to 3" sized tubers decreased (Table 4). With 65 lb N/A in the starter, yield of the largest sized tubers tended decrease with N rate as did yield of tubers in the 2.25 to 2.5" category. Vine yield was not affected by N treatment. Growth cracks and hollow heart incidence were not consistently affected by N treatment.

Even though tuber yield increased at the later harvest date total N uptake was only slightly higher (5 to 10 lb N/A). The main reason for a lack of N uptake is that the crop had basically matured and most of the N had been taken up by mid-July. The N content in the vines at the later harvest was lower, while tuber N content was higher compared to the early harvest. Nitrogen content of vines and tubers at harvest increased with increasing N rate (Table 5). Starter N did not significantly affect N uptake. Dry matter production was not affected by N rate, but higher amounts of N in the starter tended to reduce dry matter production. On all sampling dates, petiole nitrate-N increased with increasing N rate, but was not affected by N in the starter.

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

Treatment			Fresh weight								Growth	Hollow
			Vine	<1½"	1½-1⅞"	1⅞-2¼"	2¼-2½"	2½-3"	>3"	Total	Cracks	Heart
	N total	N timing	Tons/A	cwt/A							% incidence	
1.	125	(25,50,50)[1]	4.00	11.5	29.9	144.6	94.3	64.3	12.8	357.4	0.0	1.0
2.	165	(25,70,70)	3.92	11.4	24.6	125.3	82.3	73.5	14.1	331.2	0.0	1.0
3.	205	(25,90,90)	4.75	12.8	30.0	139.8	90.2	77.3	12.8	362.9	0.0	0.0
4.	245	(25,110,110)	4.53	13.1	34.1	136.3	90.9	75.3	12.9	362.6	0.0	0.0
5.	285	(25,130,130)	4.47	13.4	27.9	123.2	81.8	76.1	8.3	330.7	0.0	0.0
6.	165	(45,60,60)	4.38	14.7	50.1	130.4	89.0	52.6	9.3	346.1	0.0	0.0
7.	165	(65,50,50)	4.41	19.5	35.6	149.5	95.5	60.2	8.9	369.2	0.0	1.0
8.	165	(85,40,40)	4.66	10.7	27.1	124.2	103.2	71.5	4.6	341.3	0.0	3.0
9.	205	(45,80,80)	4.59	17.1	28.5	139.1	74.6	68.5	9.1	336.9	0.0	1.0
10.	205	(65,70,70)	3.94	22.7	43.6	125.9	64.8	45.6	8.4	311.0	0.0	1.0
11.	205	(85,60,60)	4.75	20.8	32.7	137.9	79.5	56.8	6.1	333.8	0.0	1.0
12.	165	(25,110,30)	3.79	9.5	22.8	140.2	86.6	72.7	5.1	336.9	0.0	0.0
Significance			NS	**	*	NS	*	NS	NS	NS	NS	NS
BLSD (0.05)			--	5.8	16.4	--	22.7	--	--	--	--	--
Contrasts												
Lin Rate N (1, 2, 3, 4, 5)			NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Quad Rate N (1, 2, 3, 4, 5)			NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Lin Rate N (2, 6, 7, 8)			NS	NS	NS	NS	*	NS	*	NS	NS	NS
Quad Rate N (2, 6, 7, 8)			NS	**	**	++	NS	++	NS	NS	NS	NS
Lin Rate N (3, 9, 10, 11)			NS	**	NS	NS	NS	*	++	++	NS	NS
Quad Rate N (3, 9, 10, 11)			NS	NS	NS	NS	*	NS	NS	++	NS	NS
Planting rate (2,12) vs (7,8)			*	*	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 early harvest Norland nitrogen content, nitrogen 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]	16.5	96.1	112.6	2.32	1.64	0.36	2.93	3.29
2.	165	(25,70,70)	19.2	86.1	105.3	2.74	1.50	0.36	2.85	3.21
3.	205	(25,90,90)	29.1	102.5	131.6	3.43	1.71	0.44	3.00	3.44
4.	245	(25,110,110)	33.8	111.0	144.8	3.85	1.81	0.44	3.08	3.52
5.	285	(25,130,130)	32.3	95.2	127.5	3.71	1.77	0.44	2.69	3.13
6.	165	(45,60,60)	22.0	99.4	121.4	2.72	1.72	0.40	2.94	3.34
7.	165	(65,50,50)	19.9	97.4	117.3	2.31	1.61	0.43	3.05	3.48
8.	165	(85,40,40)	22.3	93.0	115.3	2.96	1.66	0.38	2.86	3.24
9.	205	(45,80,80)	26.9	99.7	126.6	3.21	1.83	0.42	2.75	3.17
10.	205	(65,70,70)	24.7	81.5	106.2	3.12	1.56	0.40	2.62	3.02
11.	205	(85,60,60)	26.4	94.7	121.1	2.91	1.73	0.45	2.74	3.19
12.	165	(25,110,30)	13.6	79.8	93.4	2.10	1.32	0.33	3.06	3.39
Significance			**	*	**	**	NS	*	NS	NS
BLSD (0.05)			4.0	18.6	15.2	0.47	--	0.10	--	--
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
Lin Rate N (2, 6, 7, 8)			NS	NS	NS	NS	NS	NS	NS	NS
Quad Rate N (2, 6, 7, 8)			NS	NS	++	++	NS	++	NS	NS
Lin Rate N (3, 9, 10, 11)			NS	++	*	*	NS	NS	NS	NS
Quad Rate N (3, 9, 10, 11)			NS	NS	++	NS	NS	NS	NS	NS
Planting rate (2,12) vs (7,8)			**	*	**	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 early harvest Norland nitrate-N concentration in potato petio... (dry weight basis) and nitrate concentration in petiole sap. Becker, MN.

Treatment			Date			
			June 24		July 17	
			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]	17750	1350	515	218
2.	165	(25,70,70)	17812	1400	2560	413
3.	205	(25,90,90)	21348	1625	6164	898
4.	245	(25,110,110)	23103	1675	11026	1045
5.	285	(25,130,130)	21586	1725	13312	1280
6.	165	(45,60,60)	17392	1475	2264	343
7.	165	(65,50,50)	17033	1425	918	318
8.	165	(85,40,40)	16427	1275	1751	343
9.	205	(45,80,80)	20086	1575	5360	773
10.	205	(65,70,70)	20577	1550	5773	683
11.	205	(85,60,60)	18851	1475	4672	743
12.	165	(25,110,30)	11471	1075	188	168
Significance			**	**	**	**
BLSD (0.05)			2212	100	3134	220
Contrasts						
Lin Rate N (1, 2, 3, 4, 5)			**	**	**	**
Quad Rate N (1, 2, 3, 4, 5)			NS	NS	NS	NS
Lin Rate N (2, 6, 7, 8)			NS	*	NS	NS
Quad Rate N (2, 6, 7, 8)			NS	**	NS	NS
Lin Rate N (3, 9, 10, 11)			++	**	NS	NS
Quad Rate N (3, 9, 10, 11)			NS	NS	NS	NS
Planting rate (2,12) vs (7,8)			*	**	NS	NS

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

Table 4. Effect of nitrogen treatments on late harvest Norland tuber quality and fresh weight of vines and tubers - 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.	165	(25,70,70)[1]	2.02	6.3	13.6	92.5	102.1	156.1	75.7	446.3	3.0	3.0
2.	205	(25,90,90)	2.31	6.2	13.5	92.5	98.3	164.7	76.4	451.6	0.0	2.0
3.	245	(25,110,110)	2.27	5.0	12.4	97.2	105.1	129.1	110.2	459.0	0.0	2.0
4.	165	(65,50,50)	2.27	7.1	19.3	109.2	122.3	152.4	43.6	453.9	1.0	2.0
5.	205	(65,70,70)	2.37	8.5	15.4	95.5	99.0	140.9	86.9	446.2	0.0	8.0
6.	245	(65,90,90)	2.27	10.3	17.0	106.6	100.2	144.2	58.2	436.5	0.0	4.0
Significance			NS	NS	NS	NS	*	NS	**	NS	*	NS
BLSD (0.05)			--	--	--	--	17.1	--	32.2	--	2.1	--
Contrasts												
Lin Rate N (1, 2, 3)			NS	NS	NS	NS	NS	++	*	NS	**	NS
Quad Rate N (1, 2, 3)			NS	NS	NS	NS	NS	++	NS	NS	++	NS
Lin Rate N (4, 5, 6)			NS	++	NS	NS	**	NS	NS	NS	NS	NS
Quad Rate N (4, 5, 6)			NS	NS	NS	NS	++	NS	*	NS	NS	++
Main Effects												
N rate												
165			2.15	6.7	16.4	100.8	112.2	154.2	59.7	450.0	2.0	2.5
205			2.34	7.4	14.5	94.0	98.7	152.8	81.7	449.1	0.0	5.0
245			2.27	7.7	14.7	101.9	102.6	136.6	84.2	447.7	0.0	3.0
Significance			NS	NS	NS	NS	*	NS	++	NS	**	NS
Contrasts												
Lin Rate N (1&4,2&5,3&6)			NS	NS	NS	NS	++	NS	*	NS	**	NS
Quad Rate N (1&4,2&5,3&6)			NS	NS	NS	NS	++	NS	NS	NS	++	NS
N timing												
25 planting			2.20	5.9	13.1	94.1	101.8	149.9	87.5	452.3	1.0	2.3
65 planting			2.30	8.6	17.3	103.8	107.2	145.8	62.9	445.6	0.3	4.7
Significance			NS	*	*	++	NS	NS	**	NS	NS	NS
Interaction												
N rate*N timing			NS	NS	NS	NS	++	NS	*	NS	NS	NS

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

Table 5. Effect of nitrogen treatments on late harvest Norland nitrogen content, nitrogen concentration and dry matter production. Becker, MN.

Treatment			Nitrogen content			N concentration		Dry matter		
	N total	N timing	Vine	Tuber	Total	Vine	Tuber	Vine	Tuber	Total
			-------- lbs/A -------			----- % N ----		-------- Tons/A ------		
1.	165	(25,70,70)[1]	9.9	115.9	125.8	1.86	1.44	0.27	4.02	4.29
2.	205	(25,90,90)	11.2	124.8	136.0	1.88	1.48	0.31	4.21	4.52
3.	245	(25,110,110)	15.2	128.1	143.3	2.37	1.53	0.32	4.19	4.51
4.	165	(65,50,50)	10.2	110.4	120.6	2.05	1.37	0.25	4.05	4.30
5.	205	(65,70,70)	14.8	125.2	140.0	2.31	1.61	0.32	3.90	4.22
6.	245	(65,90,90)	13.9	128.2	142.1	2.20	1.73	0.32	3.71	4.03
Significance			*	NS	++	NS	*	NS	NS	NS
BLSD (0.05)			4.0	--	21.3	--	0.24	--	--	--
Contrasts										
Lin Rate N (1, 2, 3)			**	NS	++	NS	NS	NS	NS	NS
Quad Rate N (1, 2, 3)			NS	NS	NS	NS	NS	NS	NS	NS
Lin Rate N (4, 5, 6)			*	*	*	NS	**	++	NS	NS
Quad Rate N (4, 5, 6)			++	NS	NS	NS	NS	NS	NS	NS
Main Effects										
N rate										
165			10.1	113.2	123.3	1.95	1.41	0.26	4.03	4.29
205			13.0	125.0	138.0	2.10	1.55	0.31	4.05	4.36
245			14.6	128.2	142.8	2.28	1.63	0.32	3.95	4.27
Significance			**	*	*	NS	*	++	NS	NS
Contrasts										
Lin Rate N (1&4,2&5,3&6)			**	*	**	NS	**	*	NS	NS
Quad Rate N (1&4,2&5,3&6)			NS	NS	NS	NS	NS	NS	NS	NS
N timing										
25 planting			12.1	122.9	135.0	2.03	1.48	0.30	4.14	4.44
65 planting			13.0	121.3	134.3	2.19	1.57	0.30	3.89	4.19
Significance			NS	NS	NS	NS	NS	NS	++	++
Interaction										
N rate*N timing			NS	NS	NS	NS	NS	NS	NS	NS

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

Table 6. Effect of nitrogen treatments on late harvest Norland nitrate-N concentration in potato petioles (dry weight basis) and nitrate concentration in petiole sap - Becker, MN.

Treatment			Date			
			June 24		July 1	
			dry weight Petiole-N	sap Horiba	dry weight Petiole-N	sap Horiba
	N total	N timing	ppm NO_3-N			
1.	165	(25,70,70)[1]	19450	1275	16925	1425
2.	205	(25,90,90)	21646	1375	24114	1825
3.	245	(25,110,110)	21836	1400	25768	1925
4.	165	(65,50,50)	18565	1250	15823	1400
5.	205	(65,70,70)	21616	1350	24391	1725
6.	245	(65,90,90)	24281	1400	25266	1875
Significance			**	**	**	**
BLSD (0.05)			2702	88	2201	139
Contrasts						
Lin Rate N (1, 2, 3)			++	**	**	**
Quad Rate N (1, 2, 3)			NS	NS	*	*
Lin Rate N (4, 5, 6)			**	**	**	**
Quad Rate N (4, 5, 6)			NS	NS	**	NS
Main Effects						
N rate						
165			19008	1263	16374	1413
205			21631	1363	24253	1775
245			23059	1400	25518	1900
Significance			**	**	**	**
Contrasts						
Lin Rate N (1&4,2&5,3&6)			**	**	**	**
Quad Rate N (1&4,2&5,3&6)			NS	NS	**	*
N timing						
25 planting			20978	1350	22269	1725
65 planting			21487	1333	21827	1667
Significance			NS	NS	NS	NS
Interaction						
N rate*N timing			NS	NS	NS	NS

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

Table 6 (cont.). Effect of nitrogen treatments on late harvest Norland nitrate-N concentration in potato petioles (dry weight basis) and nitrate concentration in petiole sap - Becker,MN.

Treatment			Date			
			July 15		August 5	
			dry weight Petiole-N	sap Horiba	dry weight Petiole-N	sap Horiba
	N total	N timing	ppm NO_3-N			
1.	165	(25,70,70)[1]	4011	510	573	223
2.	205	(25,90,90)	9139	1070	2032	368
3.	245	(25,110,110)	13259	1425	4583	588
4.	165	(65,50,50)	990	278	611	298
5.	205	(65,70,70)	7734	923	3163	413
6.	245	(65,90,90)	13372	1425	4412	523
Significance			**	**	++	*
BLSD (0.05)			3811	269	3931	238
Contrasts						
Lin Rate N (1, 2, 3)			**	**	*	**
Quad Rate N (1, 2, 3)			NS	NS	NS	NS
Lin Rate N (4, 5, 6)			**	**	*	*
Quad Rate N (4, 5, 6)			NS	NS	NS	NS
Main Effects						
N rate						
165			2501	394	592	260
205			8437	996	2598	390
245			13315	1425	4498	555
Significance			**	**	*	**
Contrasts						
Lin Rate N (1&4,2&5,3&6)			**	**	**	**
Quad Rate N (1&4,2&5,3&6)			NS	NS	NS	NS
N timing						
25 planting			8803	1002	2396	392
65 planting			7365	875	2729	411
Significance			NS	NS	NS	NS
Interaction						
N rate*N timing			NS	NS	NS	NS

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

EVALUATION OF "MEISTER" CONTROLLED RELEASE FERTILIZER FOR IRRIGATED POTATO PRODUCTION - 1996[1]

Carl J. Rosen and Dave Birong[2]

ABSTRACT: The effect of Meister controlled release nitrogen fertilizer on yield and quality of irrigated Russet Burbank potatoes was determined in a field study conducted at the Sand Plain Research Farm in Becker. Five urea treatments (125, 165, 205, 245, and 285 lb N/A) split applied at planting, emergence, and hilling were compared to Meister nitrogen fertilizer applied at the same rates, but all applied in a band at planting. Two post-hilling treatments were also evaluated where 165 lb N was split applied as urea followed by 80 lb N/A post-hilling as urea-ammonium nitrate ands 165 lb N/A was banded as Meister followed by 80 lb N/A post-hilling as urea-ammonium nitrate. At equivalent N rates, yields with the controlled release fertilizer were significantly higher than those with the urea fertilizer. On average, hollow heart incidence was lower with the controlled release fertilizer than with urea. Post-hilling nitrogen applications did not significantly affect yield but did tend to reduce hollow heart incidence. Greater N recovery in the tubers was obtained with the Meister fertilizer compared to urea. Petiole nitrate-N was higher with urea treatments early in the season, but was lower toward the end of the season compared to the controlled release nitrogen fertilizer source.

Controlled release fertilizers have been used in crop production to varying degrees for many years. These types of fertilizers can potentially be useful for nitrogen management since high rates of quick release fertilizer such as urea, ammonium sulfate, or ammonium nitrate are susceptible to leaching. Some of the drawbacks of the traditional controlled release fertilizers such as sulfur coated urea are the slow and unpredictable release rates. Some studies with sulfur coated urea have shown significant quantities remaining after the growing season. Meister (Chisso Ashai Co., Tokyo) is the trade name of controlled release nitrogen fertilizers that are made of urea granules coated with polyolefin resin and talc. They have an analysis of 40-0-0. The talc addition is used to control moisture permeability and the rate of dissolution, thus allowing the development of products with varying release rates. The release of N from the polyolefin coated fertilizer is primarily determined by soil temperature with less influence due to soil moisture. Most of the nitrogen taken up by the potato crop occurs between 20 and 60 days after emergence (about 40 to 80 days after planting). It is critical, therefore, to have N available for uptake during this time period. Nitrogen available too early in the season may be subject to losses due to leaching rains and lack of an established root system to take up the N. Fertilizer developed to release N during the period of maximum uptake may be an efficient method of applying N fertilizer to improve yield and minimize nitrate losses. The overall objective of this study was to determine the effects of a Meister controlled release N fertilizer on potato yield, quality, and N use efficiency under irrigated conditions in Minnesota.

Materials and Methods

The experiment was conducted at the Sand Plain Research Farm in Becker, Minnesota on a Hubbard sandy loam following a previous crop of rye. Selected soil chemical properties in the 0-6" depth were as follows: pH, 6.5; organic matter, 2.1%; Bray P1, 51 ppm; and NH_4OAc K, 142 ppm. An average of 11 lb nitrate-N was available in the top 2 ft prior to planting. Russet Burbank was used as the test cultivar. Prior to planting, 200 lbs/A 0-0-22 and 200 lbs/A 0-0-60 were broadcast and incorporated. At planting, phosphate (11-48-0) and potash fertilizer (0-0-60 and 0-0-22) were banded 3 inches to the side and 2 inches below each tuber to supply 110 lb P_2O_5/A, 200 lb K_2O/A, 20 lb Mg/A, and 34 lb S/A. Six N treatments and two N sources were evaluated. The N sources were urea (46-0-0) as the quick release fertilizer and Meister controlled release fertilizer. The Meister fertilizer (40-0-0) was a mixture of 70 day release (75%) and a 50 day release (25%) granules. Five of the six N treatments for both N sources were: 125, 165, 205, 245, 285 lb N/A. At planting, 25 lb N/A of this N rate was banded as MAP for all treatments. For urea, the remaining N was applied in two applications split equally between emergence and hilling. For the Meister N source, the total N rates applied were the same as for the urea treatments except that all N was banded at planting, which included the 25 lb N/A as MAP, as well as the controlled release fertilizer. Two additional treatments included the 165 lb N/A rate as described above for both N sources plus two 40 lb N/A post-hilling splits as urea-ammonium nitrate to give a total of 245 lb N/A for each N source.

Treatments were replicated 4 times in a randomized complete block design. Spacing was 10" in the row and 36" between rows. Each plot was 4 rows wide and 20 feet in length. Russet Burbank cut "A" size seed potatoes were planted on April 22, 1996. Admire was applied in furrow for Colorado potato beetle control to all plots. For the urea treatments, emergence N was applied on May 23 and hilling N was applied on June 11. Petioles were sampled at two week intervals starting June 20. Half of the petioles collected were crushed to express the sap for quick nitrate determination, and the remainder were dried for conventional nitrate determination. Vines were killed September 9 and tubers were harvested September 16. 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

Yield and quality: Tuber and vine yield as affected by both urea and controlled release fertilizers is presented in Table 1. Increasing rate of N as urea from 120 lb N/A to 280 lb N/A had no effect on total yield, but increased yield of tubers greater than 6 oz. Yield of undersized tubers (< 6 oz) decreased with increasing N rate. Tuber size seemed to be optimized at the 285 lb N/A rate. At equivalent N rates, post-hilling N had no effect on total yield, but tended to increase the yield of tubers in the greater than 12 oz category and knobby tubers. Urea treatments had no effect on specific gravity or hollow heart incidence. Vine yield increased with increasing N rate.

[1]Funding for this research was provided by Helena Chemical Co. and the Area 2 Potato Research Council.
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Increasing the rate of N as controlled release fertilizer had no effect on total yield but as with urea, the yield of tubers larger than 6 oz increased. Similarly, the yield of tubers less than 6 oz decreased with increasing N rate. The optimum N rate for controlled release fertilizer was 205 lb N/A. At equivalent N rates, post-hilling N as urea-ammonium nitrate with banded controlled released fertilizer at planting had no effect on total yield but did increase yield of tubers in the 3-6 oz category. Vine yield increased with increasing N rate. Controlled release N treatments had no effect on specific gravity or hollow heart incidence.

At equivalent N rates, total tuber yields with controlled release fertilizer were higher than those with urea. Compared to urea, the controlled release fertilizer also tended to increase yield in the greater than 12 oz and 3-6 oz categories. Hollow heart incidence also tended to be lower with controlled release fertilizer.

Nitrogen content, nitrogen concentration, and dry matter in vines and tubers: Total dry matter production at harvest was not significantly affected by N treatment or N source (Table 2). Dry matter production of vines at harvest increased with increasing N rate. Dry matter production of tubers was slightly higher with Meister fertilizer compared to urea. Nitrogen concentrations in vines and tubers increased with increasing N rates for both N sources with greater concentrations with Meister fertilizer compared to urea. Nitrogen content of vines increased with increasing N rate, but was not affected by N source. In contrast N content of tubers increased with increasing N rate and was also higher with Meister fertilizer compared to urea. Total N recovered in the vines plus tubers at harvest increased with increasing N rates with higher recovery obtained with the Meister source compared to urea. The N recovered in the Meister treatments was 16 to 50 lb N/A higher that recovered by the urea treatments. These results suggest an improved N use efficiency with the controlled release fertilizer compared to urea. At equivalent N rates, post-hilling N applications had little effect on dry matter production or N content of vines and tubers.

Petiole nitrate-N: Petiole nitrate-N on a sap and dry weight basis is presented in Table 3. Within each N source, petiole nitrate-N increased with increasing N rate at all sampling dates. The effect of N source on petiole nitrate-N depended on sampling date and N rate. Early in the season, petiole nitrate-N was generally higher with urea treatments, with greatest differences between urea and Meister occurring at the lower N rates ($\leq$ 205 lb N/A). By July 25, petiole nitrate-N was lower in all urea treatments compared to the Meister treatments. These results are consistent with the release rates of the fertilizer sources. That is the urea, a quick release source induced high petiole nitrate-N concentrations early in the season followed by a rather fast drop in concentrations by midseason. In contrast, the Meister N source resulted in lower petiole nitrate-N levels early in the season followed by a much slower rate of decline.

The positive yield responses obtained with the Meister fertilizer are encouraging. This new type of controlled release fertilizer may be an option that can be used to minimize leaching of nitrate during irrigated potato production. Before definitive conclusions can be made, further studies are needed to evaluate the effect of this fertilizer on yield and nitrate leaching in subsequent years.

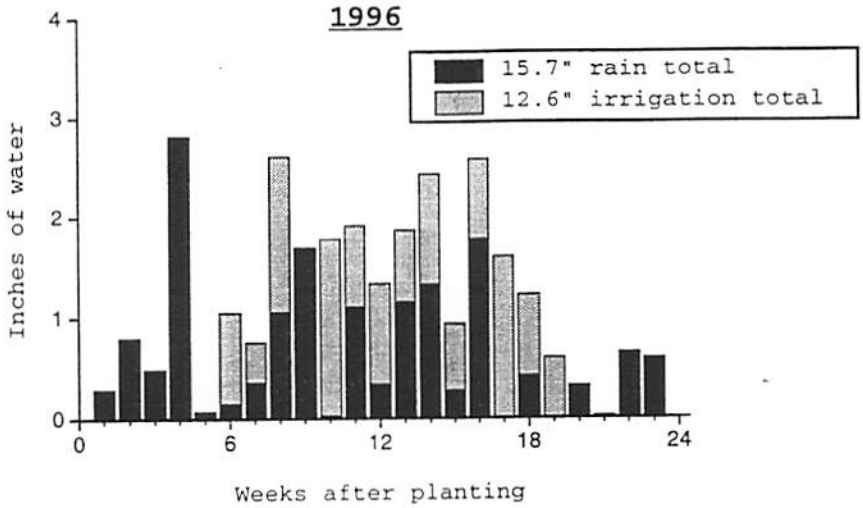

Figure 1. Rainfall and irrigation at Becker, MN during the 1996 growing season.

Table 1. Effect of nitrogen treatments on vine yield, and tuber yield and quality - Becker, MN.

Treatment				Fresh weight						Specific	Hollow
N Source	N Trmt	N timing	Vine	Knobs	<3 oz	3-6 oz	6-12 oz	>12 oz	Total	Gravity	Heart-%
Urea - Quick Release			Tons/A	cwt/A							incidence
1.	125	(25,50,50)[1]	3.69	15.5	74.5	186.3	209.1	42.3	527.7	1.0875	26.4
2.	165	(25,70,70)	6.31	14.5	82.1	178.1	189.7	52.8	517.2	1.0895	34.8
3.	205	(25,90,90)	6.82	14.5	61.9	157.2	215.0	91.0	539.6	1.0917	25.0
4.	245	(25,110,110)	8.40	8.8	63.8	171.9	215.9	68.1	528.5	1.0908	22.5
5.	285	(25,130,130)	11.81	28.0	61.7	152.1	232.7	93.3	567.8	1.0907	30.8
6.	245	(25,70,70)+80[2]	9.10	24.8	59.0	152.7	200.7	96.7	533.9	1.0901	8.3
Meister - Controlled Release											
7.	125	(125,0,0)[1]	3.01	19.0	88.7	219.5	197.3	50.1	574.6	1.0921	16.7
8.	165	(165,0,0)	6.16	30.6	67.6	187.1	213.6	69.0	567.9	1.0911	15.3
9.	205	(205,0,0)	7.61	16.7	69.8	175.0	231.8	90.9	584.2	1.0919	23.2
10.	245	(245,0,0)	8.44	26.2	65.7	156.6	222.4	105.8	576.7	1.0899	19.4
11.	285	(285,0,0)	9.60	24.0	61.4	149.5	236.5	110.1	581.5	1.0907	15.3
12.	245	(165,0,0)+80[2]	7.95	18.7	69.5	183.7	215.9	86.7	574.5	1.0896	15.5
Significance			**	NS	**	**	NS	**	NS	NS	++
BLSD (0.05)			2.02	--	15.8	35.2	--	35.4	--	--	20.4
Main Effects											
Fert Trmt											
125			3.35	17.3	81.6	202.9	203.2	46.2	551.2	1.0898	21.5
165			6.23	22.5	74.9	182.6	201.6	60.9	542.5	1.0903	25.1
205			7.21	15.6	65.8	166.1	223.4	90.9	561.8	1.0918	24.1
245			8.42	18.8	64.9	163.2	219.6	89.7	556.2	1.0903	20.7
285			10.70	26.0	61.5	150.8	234.6	101.7	574.6	1.0907	23.0
165+80[2]			8.52	21.7	64.3	168.2	208.3	91.7	554.2	1.0898	11.9
Significance			**	NS	**	**	++	**	NS	NS	NS
BLSD (0.05)			1.38	--	10.3	22.9	29.3	22.9	--	--	--
Fert Source											
Urea			7.66	18.1	67.3	166.1	210.3	74.3	536.1	1.0900	24.7
Meister			7.13	22.5	70.5	178.6	219.6	85.5	576.7	1.0909	17.6
Significance			NS	NS	NS	++	NS	++	**	NS	*
Interaction											
Fert Trmt*Fert Source			NS	NS	++	NS	NS	NS	NS	NS	NS
Contrasts											
Lin Rate Urea (1, 2, 3, 4, 5)			**	NS	**	*	*	**	NS	NS	NS
Quad Rate Urea (1, 2, 3, 4, 5)			NS	NS	NS	NS	NS	NS	NS	NS	NS
Post-hilling Urea (4) vs (6)			NS	++	NS	NS	NS	++	NS	NS	NS
Lin Rate Meister (7, 8, 9, 10, 11)			**	NS	**	**	*	**	NS	NS	NS
Quad Rate Meister (7, 8, 9, 10, 11)			++	NS	NS	NS	NS	NS	NS	NS	NS
Post-hilling Meister (10) vs (12)			NS	NS	NS	++	NS	NS	NS	NS	NS
Urea (1-6) vs Meister (7-12)			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 1. Effect of nitrogen treatments on vine yield, tuber yield, and tuber quality - Becker, MN.

Treatment			Fresh weight							Specific	Hollow
N Source	N Trmt	N timing	Vine	Knobs	<3 oz	3-6 oz	6-12 oz	>12 oz	Total	Gravity	Heart-%
Urea - Quick Release			Tons/A	cwt/A							incidence
1.	125	(25,50,50)[1]	3.69	15.5	74.5	186.3	209.1	42.3	527.7	1.0875	26.4
2.	165	(25,70,70)	6.31	14.5	82.1	178.1	189.7	52.8	517.2	1.0895	34.8
3.	205	(25,90,90)	6.82	14.5	61.9	157.2	215.0	91.0	539.6	1.0917	25.0
4.	245	(25,110,110)	8.40	8.8	63.8	171.9	215.9	68.1	528.5	1.0908	22.5
5.	285	(25,130,130)	11.81	28.0	61.7	152.1	232.7	93.3	567.8	1.0907	30.8
6.	245	(25,70,70)+80[2]	9.10	24.8	59.0	152.7	200.7	96.7	533.9	1.0901	8.3
Meister - Controlled Release											
7.	125	(125,0,0)[1]	3.01	19.0	88.7	219.5	197.3	50.1	574.6	1.0921	16.7
8.	165	(165,0,0)	6.16	30.6	67.6	187.1	213.6	69.0	567.9	1.0911	15.3
9.	205	(205,0,0)	7.61	16.7	69.8	175.0	231.8	90.9	584.2	1.0919	23.2
10.	245	(245,0,0)	8.44	26.2	65.7	156.6	222.4	105.8	576.7	1.0899	19.4
11.	285	(285,0,0)	9.60	24.0	61.4	149.5	236.5	110.1	581.5	1.0907	15.3
12.	245	(165,0,0)+80[2]	7.95	18.7	69.5	183.7	215.9	86.7	574.5	1.0896	15.5
Significance			**	NS	**	**	NS	**	NS	NS	++
BLSD (0.05)			2.02	--	15.8	35.2	--	35.4	--	--	20.4
Main Effects											
Fert Trmt											
125			3.35	17.3	81.6	202.9	203.2	46.2	551.2	1.0898	21.5
165			6.23	22.5	74.9	182.6	201.6	60.9	542.5	1.0903	25.1
205			7.21	15.6	65.8	166.1	223.4	90.9	561.8	1.0918	24.1
245			8.42	18.8	64.9	163.2	219.6	89.7	556.2	1.0903	20.7
285			10.70	26.0	61.5	150.8	234.6	101.7	574.6	1.0907	23.0
165+80[2]			8.52	21.7	64.3	168.2	208.3	91.7	554.2	1.0898	11.9
Significance			**	NS	**	**	++	**	NS	NS	NS
BLSD (0.05)			1.38	--	10.3	22.9	29.3	22.9	--	--	--
Fert Source											
Urea			7.66	18.1	67.3	166.1	210.3	74.3	536.1	1.0900	24.7
Meister			7.13	22.5	70.5	178.6	219.6	85.5	576.7	1.0909	17.6
Significance			NS	NS	NS	++	NS	++	**	NS	*
Interaction											
Fert Trmt*Fert Source			NS	NS	++	NS	NS	NS	NS	NS	NS
Contrasts											
Lin Rate Urea (1, 2, 3, 4, 5)			**	NS	**	*	*	**	NS	NS	NS
Quad Rate Urea (1, 2, 3, 4, 5)			NS	NS	NS	NS	NS	NS	NS	NS	NS
Post-hilling Urea (4) vs (6)			NS	++	NS	NS	NS	++	NS	NS	NS
Lin Rate Meister (7, 8, 9, 10, 11)			**	NS	**	**	*	**	NS	NS	NS
Quad Rate Meister (7, 8, 9, 10, 11)			++	NS	NS	NS	NS	NS	NS	NS	NS
Post-hilling Meister (10) vs (12)			NS	NS	NS	++	NS	NS	NS	NS	NS
Urea (1-6) vs Meister (7-12)			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 2. Effect of nitrogen treatments on nitrogen content, nitrogen concentration, and dry matter production of vines and tubers - Becker, MN.

Treatment			Nitrogen content			N concentration		Dry matter		
			Vine	Tuber	Total	Vine	Tuber	Vine	Tuber	Total
N Source	N Trmt	N timing	------- lbs/A --------			---- % N ----		------ Tons/A ------		
1.	125	(25,50,50)[1]	14.1	123.5	137.6	0.92	0.96	0.77	6.42	7.19
2.	165	(25,70,70)	21.4	139.2	160.6	1.18	1.13	0.94	6.15	7.09
3.	205	(25,90,90)	21.3	139.4	160.7	1.34	1.11	0.79	6.33	7.12
4.	245	(25,110,110)	34.1	148.4	182.5	1.49	1.23	1.21	6.45	7.66
5.	285	(25,130,130)	35.5	170.2	205.7	1.51	1.32	1.18	6.49	7.67
6.	245	(25,70,70)+80[2]	40.1	152.6	192.7	1.85	1.19	1.08	6.42	7.50
Meister - Controlled Release										
7.	125	(125,0,0)[1]	15.2	138.3	153.5	1.08	1.03	0.70	6.70	7.40
8.	165	(165,0,0)	23.1	157.9	181.0	1.33	1.25	0.87	6.38	7.25
9.	205	(205,0,0)	28.1	182.3	210.4	1.62	1.35	0.87	6.78	7.65
10.	245	(245,0,0)	41.6	175.9	217.5	1.88	1.28	1.11	6.91	8.02
11.	285	(285,0,0)	43.0	194.2	237.2	2.02	1.47	1.10	6.60	7.70
12.	245	(165,0,0)+80[2]	33.8	172.3	206.1	1.74	1.30	0.97	6.64	7.61
Significance			**	**	**	**	**	*	NS	NS
BLSD (0.05)			10.3	20.0	21.1	0.43	0.17	0.35	--	--
Main Effects										
Fert Trmt										
125			14.6	130.9	145.5	1.00	1.00	0.74	6.56	7.30
165			22.2	148.5	170.7	1.26	1.19	0.90	6.26	7.16
205			24.7	160.8	185.5	1.48	1.23	0.83	6.56	7.39
245			37.8	162.2	200.0	1.68	1.25	1.15	6.71	7.86
285			39.3	182.2	221.5	1.77	1.40	1.14	6.55	7.69
165+80[2]			37.0	162.4	199.4	1.79	1.24	1.02	6.53	7.55
Significance			**	**	**	**	**	**	NS	NS
BLSD (0.05)			7.0	13.9	14.7	0.29	0.11	0.21	--	--
Fert Source										
Urea			27.8	145.5	173.3	1.38	1.16	0.99	6.37	7.36
Meister			30.8	170.1	200.9	1.61	1.28	0.94	6.67	7.61
Significance			NS	**	**	*	**	NS	++	NS
Interaction										
Fert Trmt*Fert Source			NS	NS	NS	NS	NS	NS	NS	NS
Contrasts										
Lin Rate Urea (1, 2, 3, 4, 5)			**	**	**	**	**	**	NS	NS
Quad Rate Urea (1, 2, 3, 4, 5)			NS	NS	NS	NS	NS	NS	NS	NS
Post-hilling Urea (4) vs (6)			NS	NS	NS	++	NS	NS	NS	NS
Lin Rate Meister (7, 8, 9, 10, 11)			**	**	**	**	**	**	NS	NS
Quad Rate Meister (7, 8, 9, 10, 11)			NS	NS	NS	NS	NS	NS	NS	NS
Post-hilling Meister (10) vs (12)			NS	NS	NS	NS	NS	NS	NS	NS
Urea (1-6) vs Meister (7-12)			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 3. Effect of nitrogen treatments on Russet Burbank nitrate-N concentration in potato petioles (dry weight basis) and nitrate concentration in petiole sap - Becker, MN.

Treatment			Date					
			June 20		July 1		July 15	
N Source	N Trmt	N timing	dry weight Petiole-N	sap Horiba	dry weight Petiole-N	sap Horiba	dry weight Petiole-N	sap Horiba
			ppm NO_3-N					
Urea - Quick Release								
1.	125	(25,50,50)[1]	23578	1725	12216	1325	3490	695
2.	165	(25,70,70)	24507	1750	17697	1725	4174	858
3.	205	(25,90,90)	25364	1825	21966	1850	6215	1085
4.	245	(25,110,110)	23631	1750	24661	1925	13008	1525
5.	285	(25,130,130)	25106	1800	26293	1975	15153	1700
6.	245	(25,70,70)+80[2]	24323	1775	23350	1975	17885	1925
Meister - Controlled Release								
7.	125	(125,0,0)[1]	17271	1400	8355	1100	796	413
8.	165	(165,0,0)	19623	1575	12770	1375	4524	862
9.	205	(205,0,0)	20612	1625	14307	1550	6967	1200
10.	245	(245,0,0)	23851	1700	17501	1725	8006	1275
11.	285	(285,0,0)	24204	1775	20965	1850	14708	1725
12.	245	(165,0,0)+80[2]	17902	1500	11614	1225	11794	1500
Significance			**	**	**	**	**	**
BLSD (0.05)			2159	91	1948	95	3707	262
Main Effects								
Fert Trmt								
125			20425	1563	10286	1213	2143	554
165			22065	1663	15233	1550	4349	860
205			22988	1725	18137	1700	6591	1143
245			23741	1725	21081	1825	10507	1400
285			24655	1788	23629	1913	14931	1713
165+80[2]			21113	1638	17482	1600	14840	1713
Significance			**	**	**	**	*	*
BLSD (0.05)			1576	65	1375	67	2570	182
Fert Source								
Urea			24418	1771	21031	1796	9987	1298
Meister			20577	1596	14252	1471	7799	1163
Significance			**	**	**	**	**	**
Interaction								
Fert Trmt*Fert Source			**	**	**	**	++	++
Contrasts								
Lin Rate Urea (1, 2, 3, 4, 5)			NS	NS	**	**	**	**
Quad Rate Urea (1, 2, 3, 4, 5)			NS	NS	**	**	NS	NS
Post-hilling Urea (4) vs (6)			NS	NS	NS	NS	*	**
Lin Rate Meister (7, 8, 9, 10, 11)			**	**	**	**	**	**
Quad Rate Meister (7, 8, 9, 10, 11)			NS	NS	NS	*	NS	NS
Post-hilling Meister (10) vs (12)			**	**	**	**	++	NS
Urea (1-6) vs Meister (7-12)			**	**	**	**	*	*

[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 3 cont. Effect of nitrogen treatments on Russet Burbank nitrate-N concentration in potato petioles (dry weight basis) and nitrate concentration in petiole sap - Becker MN.

Treatment			Date			
			July 25		August 9	
N Source	N Trmt	N timing	dry weight Petiole-N	sap Horiba	dry weight Petiole-N	sap Horiba
			ppm NO_3-N			
Urea - Quick Release						
1.	125	(25,50,50)[1]	614	305	489	158
2.	165	(25,70,70)	1381	498	840	193
3.	205	(25,90,90)	3516	773	2046	235
4.	245	(25,110,110)	6509	1023	3662	405
5.	285	(25,130,130)	9266	1250	5106	660
6.	245	(25,70,70)+80[2]	13606	1575	5747	650
Meister - Controlled Release						
7.	125	(125,0,0)[1]	1229	370	108	188
8.	165	(165,0,0)	2319	683	1653	225
9.	205	(205,0,0)	7235	1090	3279	465
10.	245	(245,0,0)	8614	1295	4889	748
11.	285	(285,0,0)	12372	1625	8504	1023
12.	245	(165,0,0)+80[2]	13923	1650	7656	950
Significance			**	**	**	**
BLSD (0.05)			2683	249	2442	235
Main Effect						
Fert Trmt						
125			922	338	298	173
165			1850	590	1247	209
205			5375	931	2663	350
245			7562	1159	4275	576
285			10819	1438	6805	841
165+80[2]			13765	1613	6701	800
Significance			**	**	*	**
BLSD (0.05)			1872	174	1672	163
Fert Source						
Urea			5816	904	2982	383
Meister			7615	1119	4348	600
Significance			**	**	**	**
Interaction						
Fert Trmt*Fert Source			NS	NS	NS	NS
Contrasts						
Lin Rate Urea (1, 2, 3, 4, 5)			**	**	**	**
Quad Rate Urea (1, 2, 3, 4, 5)			NS	NS	NS	++
Post-hilling Urea (4) vs (6)			**	**	++	++
Lin Rate Meister (7, 8, 9, 10, 11)			**	**	**	**
Quad Rate Meister (7, 8, 9, 10, 11)			NS	NS	NS	NS
Post-hilling Meister (10) vs (12)			**	*	*	++
Urea (1-6) vs Meister (7-12)			**	**	*	**

[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.