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Soil Series #145

ACKNOWLEDGMENTS

This 1999 edition of the soils "bluebook" compiles data collected and analyzed throughout Minnesota. Information is contributed by personnel of the University of Minnesota College of Agricultural, Food, and Environmental Sciences; by soil scientists at the Minnesota Agricultural Experiment Station branches at the University of Minnesota Research and Outreach Centers, and at the Sand Plain Research Farm at Becker and the Central Lakes Agricultural Center in Staples; 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, and the University of Minnesota College of Natural Resources also contribute.

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Climate Summary – 1998

Pete Boulay
State Climatology Office
DNR Waters

1998 was one of the warmest years on record

1998 will go down as the 3rd warmest year since 1891. The warmest year was 1931. The winter of 1997-1998 was one of the warmest on record. "Meteorological winter" is often defined by climatologists as the months of December, January, and February. Minnesota experienced unusually mild temperatures in each of these months. The statewide average temperature for December, 1997 was 23.6 degrees F, which is 10.8 degrees above normal. January's average temperature was a mild 14.0, above normal by 7.1 degrees. The month of February was extraordinarily warm, averaging 28.0 degrees, exceeding the normal by 14.9 degrees. The temperature for the 1997-1998 meteorological winter (December - February) averaged 21.9 statewide, which makes places it second only to 1877-1878. The winter of 1877-1878 is far and away the warmest Minnesota winter of the post-settlement era.

As the result of the warm temperatures and light snowfall, many areas of Minnesota reported little or no snow cover by late February. Northern Minnesota communities like International Falls and Hibbing reported a trace of snow on the ground in late February. Historically, late February is the point of the winter season when the maximum snow depth is reached.

Spring Severe Weather

1998 was also a stormy year with 57 tornadoes. This total puts 1998 at the top of the list for the number of tornadoes recorded in one year. Spring and early summer were very active for severe weather. March had a record-setting number of tornadoes with 13. All of these occurred on the 29th. A series of strong tornadoes hit south central Minnesota. A 1.25 mile-wide damage path was carved through the city of St. Peter in extreme eastern Nicollet County. Debris from St. Peter was found some 50 miles to the northeast in Apple Valley, which is located in northwestern Dakota County. Other towns devastated by these tornadoes included Comfrey and Hanska in Brown County. Total damage from the March tornadoes was over $200 million dollars.

May was an especially active month for severe weather. In addition to the strong straight line winds, tornadoes, hail and heavy rainfall, the storm system on Friday, May 15 brought with it record setting dewpoint temperatures and record setting warm minimum temperatures. Several communities, including the Twin Cities, reported dew points of 70 degrees F or greater, breaking the old record.

Dry weather gives way to summer rains

Much of Minnesota suffered through extraordinarily warm temperatures Monday, May 18th. The thermometer reached 100 degrees in Redwood Falls. A 100-degree temperature in May is quite rare. The last time that the temperature reached 100 degrees earlier than June, was April 21, 1980 when some communities in west central and northwest Minnesota reached the century mark.

Fears of a spring drought tapered off a bit after a series of heavy rainstorms moved over southern Minnesota. Very heavy rains fell across a large portion of southeastern Minnesota during the week ending June 28. Multi-day totals exceeding eight inches were reported in Scott, Rice and Goodhue Counties. A location near Zumbrota in Goodhue County reported 10.03 inches of precipitation over the period.

Very heavy rains also fell across much of Minnesota during the afternoon and evening of July 14. The heaviest of the rains fell in Ottertail County in west central Minnesota and Cass County in north central Minnesota. More than five inches of rain fell in portions of these counties. For many locations throughout the state, rainfall rates were roughly two inches per hour, leading to urban and small stream flooding. Damaging hail was also reported in many locations.

Autumn and Early Winter

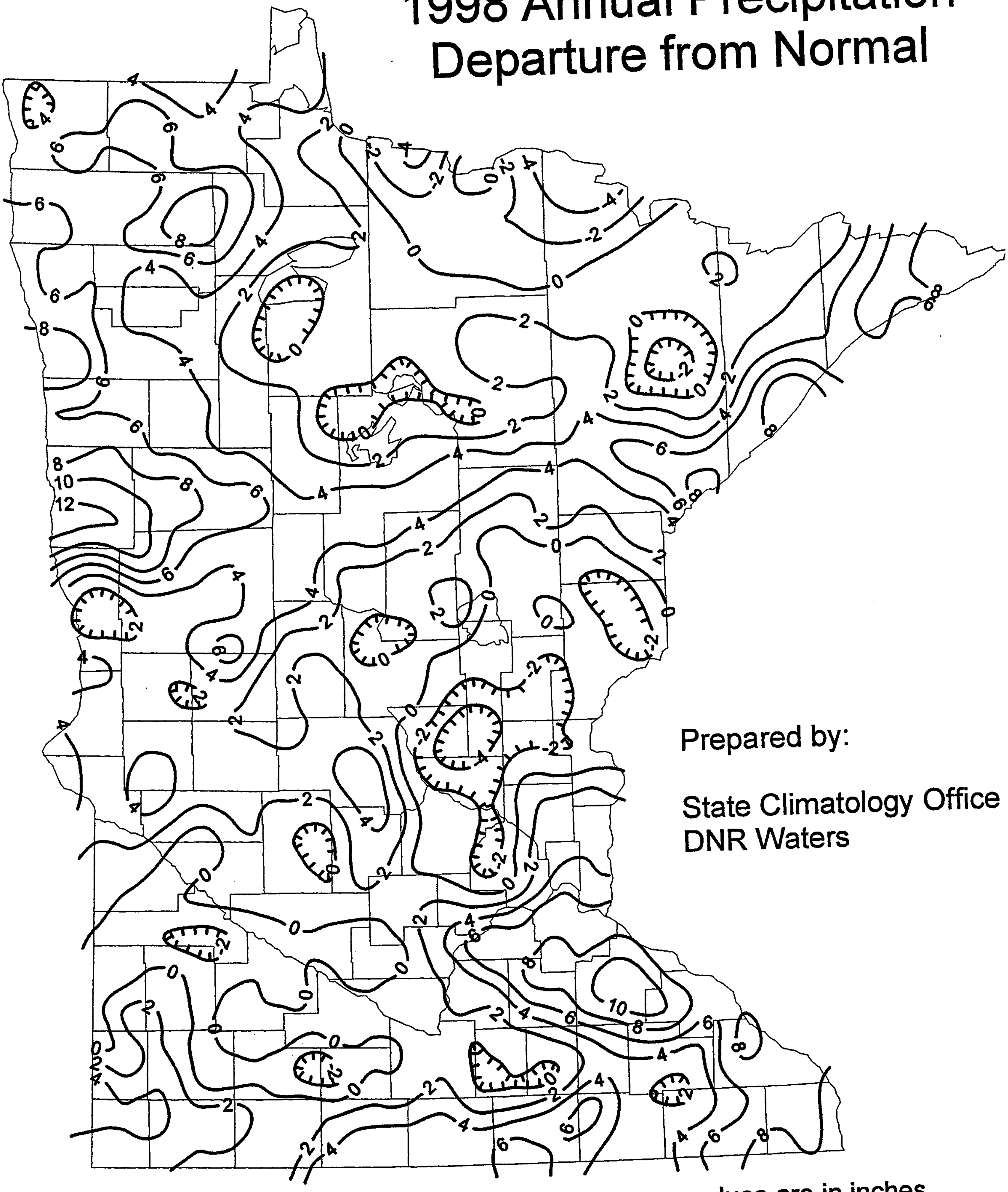
Summer continued right into autumn with warmer than normal temperatures. September 1998 was the 4th warmest since 1895 taken as an aggregate average from all reporting locations in Minnesota. Fergus Falls and Canby had the warmest Septembers on record. The warm conditions continued right into December. The statewide average temperature was 2.6 degrees above normal in October and 3.6 degrees above normal in November. In the first week of December, Minnesota was about 19.3 Degrees above normal. The warm autumn was a continuation of warm temperatures experienced throughout much of 1998. An interesting artifact of this warmth was the number of days without below zero temperatures in many southern Minnesota communities.

Despite a rather tranquil autumn, there was one winter storm that stood out. On November 10, a "Land Hurricane" swept across the state. Winds gusted to 64 mph at St. Cloud. Winds also gusted in the 50mph to 60mph over other parts of central and southern Minnesota. The all-time lowest barometric pressure record was broken. The 28.43 reading at Austin and Albert Lea broke the old record of 28.55 that was set in Duluth on January 11, 1975. Some heavy snow fell with this storm too, with Canby in Yellow Medicine County receiving 13.5 inches of snow. 4 to 8 inches fell across west central Minnesota. 1998 ended with a return to normal winter-like temperatures in late December to remind everyone that this is still Minnesota after all.

Overall, it was a moist year across Minnesota. The northeast and southwest sections of the state were very dry during the growing season. However, autumn rains made up for the deficiency. By the end of the year parts of southeast

Minnesota and northwest Minnesota had as much as 10 inches above the normal annual precipitation. There were only a few isolated areas of the state that had slightly less than a normal precipitation year.

1998 Annual Precipitation Departure from Normal

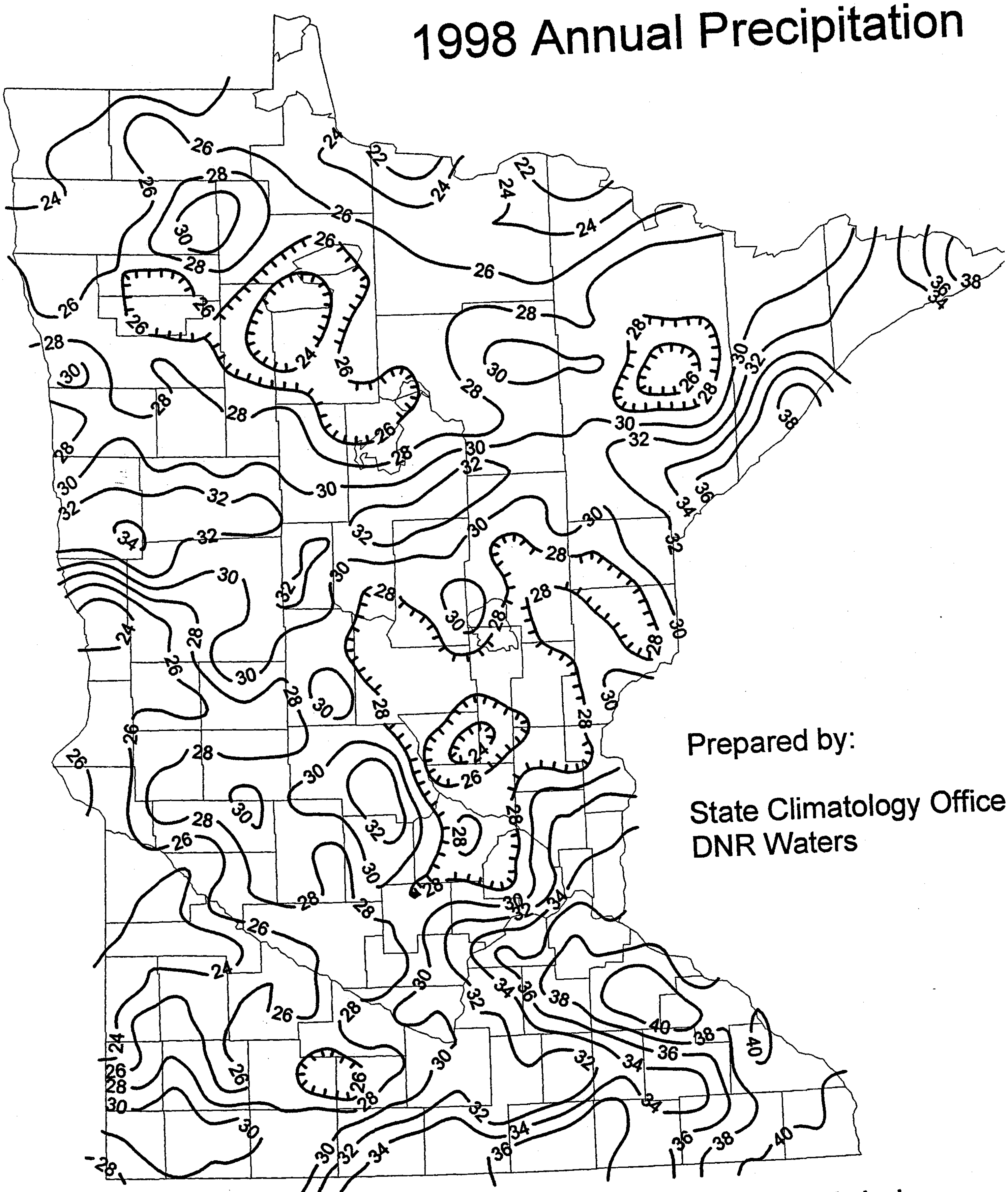


Prepared by:

State Climatology Office
DNR Waters

values are in inches

1998 Annual Precipitation



Prepared by:

State Climatology Office
DNR Waters

values are in inches

Response of Russet Norkotah Clonal Selections to Nitrogen Fertilization: 1998[1]

Francis Zvomuya, Carl Rosen, and J. Creighton Miller Jr.[2]

Abstract. This study examined the influence of nitrogen fertilization on the yield and quality of Russet Norkotah clonal selections on a Hubbard loamy sand at the Sand Plain Research Farm at Becker, MN. The clones, NK112, NK223 and NK278 (selected for vigor in the Texas breeding program), and standard Russet Norkotah were grown under irrigated conditions and received total nitrogen (N) levels of 25, 100, 200, or 300 lb/A. Total and large (>6 oz.) tuber yield increased significantly ($P = 0.01$) with rate of N. Total tuber yield of the clonal selections was not significantly different than the standard cultivar ($P=0.1$). Significant clone effects were observed in total dry mass (TDM) and vine dry mass. TDM of the clones was greater than TDM of standard Russet Norkotah. Tuber dry mass was slightly higher in the clonal selections but the difference was not statistically significant. TDM increased significantly with N rate, as did vine and tuber dry mass. However, the partitioning of dry matter shifted in favor of vines as N rate increased from 25 to 300 lb/A. Petiole nitrate-N concentration was highest in the standard cultivar both early and late in the season. Standard Russet Norkotah had lower specific gravity than the clones. The incidence of internal defects in standard Russet Norkotah was not significantly different from that in the clones. Total N uptake was 13 to 21 lb N/A greater in the clones than the standard cultivar, but most of the increase was due to a greater vine dry mass of the clonal selections.

Russet Norkotah potato was released in 1987 by North Dakota State University and is widely grown in Minnesota for the fresh market. This cultivar requires higher N inputs than many other cultivars because of its low vine vigor and early vine maturity. Because of low specific gravity, the tubers are not suitable for processing. The Texas A&M potato breeding program initiated a study several years ago to select Russet Norkotah clones for vine vigor. Three clones have been identified that consistently show greater vine growth and tuber yield than the standard cultivar in western variety trials. Other attributes of these selections have not been studied or evaluated to any great extent.

Profitable and environmentally sound potato production depends on the ability of the crop to make efficient use of N. Thus the ideal cultivar would be one that produces high yields with low N inputs. Because of environmental concerns related to nitrate leaching, research efforts in many areas are being placed on developing cultivars that have high N use efficiency in addition to other desirable agronomic attributes. The objective of this study was to compare the N use efficiency of Russet Norkotah clonal selections from the Texas breeding program to that of the standard Russet Norkotah. This study specifically examines whether the increased vine vigor of the clonal selections is associated with a corresponding improvement in N utilization.

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[1]This study was funded by the Area 2 Potato Growers.

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Materials and Methods

The study was conducted in 1998 on a Hubbard loamy sand at the Sand Plain Research Farm at Becker. Selected soil properties prior to planting were: pH, 6.8, organic matter, 1.6%; Bray P1, 30 ppm; ammonium acetate K, Mg, and Ca, 108 ppm, 136 ppm, and 743 ppm; S, 4 ppm; B, 0.3 ppm; Zn, 0.5 ppm. Preplant nitrate-N (0-2') was 8 lb/A. Four N rates (25, 100, 200 and 300 lb/A) were tested on the standard Russet Norkotah and three clonal selections from the Texas A&M breeding program (NK112, NK223, and NK278). Treatments were replicated 4 times in a split plot design with N rate as the main plot and clone as the sub plot. Each sub plot was three rows wide and 15 feet in length. Spacing was 10" in the row and 36" between rows. K_2O (200 lb/A) was applied broadcast (April 6) and the rest of the starter fertilizer was applied at furrow opening (April 16) in a double band 3 inches to the side and 2 inches below the tuber to supply 25 lb N/A, 110 lb P_2O_5/A, 20 lb Mg/A, and 34 lb S/A. Hand cut 2-3 oz seed pieces of the clones were planted on April 16. Furrows were covered after application of the insecticide Admire. Except for the 25 lb N/A rate, N treatments received additional N as ammonium nitrate applied in two equal split applications at emergence (May 11) and at hilling (May 26) to give total rates of 100, 200, and 300 lb N/A. Nitrate (NO_3^-) concentration was determined on June 6 and July 21 in petioles from the most recently matured leaf, which is usually the fourth leaf from the top. Vines were killed on August 10 and the middle row of each plot was harvested on August 19. Tubers were weighed and graded by size. Internal defects and specific gravity were determined on tuber samples from each plot. Vines were killed on August 10 and the middle row of each plot was harvested on August 19. Tubers were weighed and graded by size. Internal defects and specific gravity were determined on tuber samples from each plot. Vines and tubers were sampled for dry matter and nitrogen determinations.

Results

Yield and quality of the clones and standard cultivar are presented in Tables 1 to 4. Vines of the standard cultivar began to die down at the end of July. Vines of the clonal selections began to die down about the same time but remained green for about one week longer. Total and large (>6oz) tuber yield increased with rate of N. Total yield was highest with NK 112 and lowest with standard Russet Norkotah, but the differences were not statistically significant. Specific gravity was higher for the clones than the standard cultivar raising the possibility that the clones may be suitable for processing. Hollow heart was not affected by clone. N rate had inconsistent effects on hollow heart. Significant differences were observed in total dry mass (TDM) and vine dry mass where the clones outperformed the standard cultivar (Tables 5 to 8). TDM and tuber and vine dry mass increased significantly with N rate. The higher rates of N resulted in an increase in the proportion of TDM partitioned to the vines.

Petiole NO_3^--N concentrations of the clones are presented in tables 9 to 12. At equivalent N rate, standard Russet Norkotah, followed by NK 112, had the highest NO_3^--N concentration both early (June 8) and late (July 21) in the growing season. For all cultivars, petiole NO_3^--N concentration generally increased with rate of N. However, late in the season, the first N rate increment (100 lb/A) tended to decrease the NO_3^--N concentration, and to a greater extent in the clones than the standard cultivar.

Total N uptake increased significantly (P = 0.01) with N rate and was higher (P = 0.05) in clones than in the standard cultivar (Tables 13-16). Tuber N concentration and uptake were similar among the clones and standard cultivar, but they increased significantly (P = 0.01) with N rate. Standard Russet Norkotah had the highest N concentration and lowest total N in the vines.

Conclusions

The Russet Norkotah selections from the Texas breeding program responded to N in a manner similar to the standard cultivar. N uptake by the clonal selections was slightly higher than the standard cultivar but this effect was due to a higher N content in the clonal vines. N uptake by tubers was similar among all genotypes. Specific gravity of the clonal selections was significantly higher than the standard cultivar and may allow use of these selections as a potato for early processing.

Table 1. Russet Norkotah clone x N rate effect on yield and quality of tubers at Becker, MN: 1998.

Clone	N, lb/A	Tuber Yield, cwt/A						%>6 oz.	Specific	% w/ Hollow
		<3 oz	3-6 oz	6-12 oz	>12 oz	Knobs	Total		gravity	Heart
NK	25	43.3	137.8	131.5	10.1	4.1	326.7	42.4	1.0740	1.0
	100	40.6	118.7	202.3	67.0	15.8	444.3	60.7	1.0699	1.0
	200	38.4	115.7	236.6	80.6	7.9	479.2	66.0	1.0700	1.0
	300	52.0	102.1	222.4	141.3	15.3	533.1	67.8	1.0699	0
NK 112	25	55.3	147.8	118.7	32.1	13.9	367.8	40.8	1.0736	0
	100	41.9	110.8	216.2	84.4	10.1	463.4	65.0	1.0738	2.0
	200	51.7	117.9	214.0	98.8	14.2	496.6	62.7	1.0732	0
	300	39.2	105.1	211.8	147.6	10.4	514.0	69.8	1.0751	2.0
NK 223	25	54.2	102.1	182.4	27.0	8.7	374.3	54.9	1.0763	1.0
	100	47.4	101.0	171.8	84.4	31.6	436.1	58.9	1.0744	3.1
	200	45.2	91.8	175.9	106.7	46.6	466.1	59.8	1.0735	0
	300	39.8	110.0	209.1	150.0	32.9	541.8	65.9	1.0749	4.0
NK 278	25	44.1	147.0	150.8	16.3	4.6	362.9	45.9	1.0731	0
	100	43.3	99.9	191.1	77.9	16.3	428.5	62.8	1.0749	5.0
	200	34.6	93.9	235.0	111.1	15.0	489.5	70.8	1.0752	2.0
	300	37.0	71.9	232.0	147.3	31.3	519.5	72.4	1.0743	2.0

Table 2. Yield and quality of Russet Norkotah clones at Becker, MN: 1998.

Clone	Tuber Yield, cwt/A						%>6 oz.	Specific	% w/ Hollow
	<3 oz	3-6 oz	6-12 oz	>12 oz	Knobs	Total		gravity	Heart
NK	43.6	118.6	198.2	74.7	10.8	445.8	59.2	1.0709	0.8
NK 112	47.0	120.4	190.2	90.7	12.1	460.4	59.6	1.0739	1.0
NK 223	46.6	101.2	184.8	92.0	30.0	454.6	59.9	1.0748	2.0
NK 278	39.8	103.2	202.2	88.1	16.8	450.1	63.0	1.0744	2.2

Table 3. Nitrogen rate effects on yield and quality of tubers at Becker, MN: 1998.

N rate,	Tuber Yield, cwt/A						%>6 oz.	Specific	% w/ hollow
lb/A	<3 oz	3-6 oz	6-12 oz	>12 oz	Knobs	Total		gravity	heart
25	49.2	133.7	145.9	21.4	7.8	357.9	46.0	1.0743	0.5
100	43.3	107.6	195.3	78.4	18.4	443.1	61.9	1.0733	2.8
200	42.5	104.8	215.4	99.3	20.9	482.8	64.8	1.0730	0.8
300	42.0	97.3	218.8	146.5	22.5	527.1	69.0	1.0735	2.0

Table 4. Clone, N rate, and interaction effects on yield and quality of tubers at Becker, MN: 1998.
(++ = significant at 10%; * = significant at 5%; ** = significant at 1%; ns = not significant)

Factor	Tuber Yield						%>6 oz.	Specific	% w/ hollow
	<3 oz	3-6 oz	6-12 oz	>12 oz	Knobs	Total		gravity	heart
Clone	ns	++	ns	ns	**	ns	ns	**	ns
N rate	ns	**	**	**	**	**	**	ns	++
Clone X N rate	ns	ns	ns	ns	++	ns	ns	ns	ns

Table 5. Russet Norkotah clone x N rate effects on dry matter yield, Becker, MN: 1998.

Clone	N, lb/A	Tuber Dry Mass, lb/A	Vine Dry Mass, lb/A	Total DM lb/A	Tuber DM % of total
NK	25	5792.9	125.8	5918.5	97.9
	100	7496.1	218.5	7714.5	97.2
	200	8595.1	449.5	9044.8	95.0
	300	9246.8	803.5	10050.3	92.0
NK 112	25	6421.5	545.5	6967.0	92.3
	100	8653.3	453.5	9106.8	95.0
	200	8380.3	806.5	9186.8	91.4
	300	9231.6	1558.3	10790.0	85.6
NK 223	25	6829.4	518.5	7348.0	92.8
	100	7894.8	606.0	8500.8	92.9
	200	8174.2	1060.8	9234.8	88.5
	300	9867.4	2152.5	12019.8	81.7
NK 278	25	6605.4	338.8	6944.3	95.2
	100	7895.1	516.0	8411.0	93.7
	200	8744.4	802.5	9546.8	91.6
	300	9419.3	1843.0	11262.3	83.5

Table 6. Dry matter yield of Russet Norkotah clones at Becker, MN: 1998.

Clone	Tuber Dry Mass, lb/A	Vine Dry Mass, lb/A	Total DM, lb/A	Tuber DM, % of total
NK	7782.7	399.3	8182.0	95.5
NK112	8171.7	840.9	9012.6	91.1
NK223	8191.4	1084.4	9275.8	89.0
NK278	8166.0	875.1	9041.1	91.0

Table 7. Nitrogen rate effects on dry matter yield of Russet Norkotah clones at Becker, MN: 1998.

N rate, lb/A	Tuber Dry Mass lb/A	Vine Dry Mass lb/A	Total DM lb/A	Tuber DM % of total
25	6412.3	382.1	6794.4	94.5
100	7984.8	448.5	8433.3	94.7
200	8473.5	779.8	9253.3	91.6
300	9441.3	1589.3	11030.6	85.7

Table 8. Clone, N rate, and interaction effects on dry matter yield of Russet Norkotah clones at Becker, MN: 1998. (++ = significant at 10%; * = significant at 5%; ** = significant at 1%; ns = not significant)

Factor	Tuber Dry Mass, lb/A	Vine Dry Mass, lb/A	Total DM, lb/A	Tuber DM, % of total
Clone	ns	**	**	**
N rate	**	**	**	**
Clone X N rate	ns	++	ns	ns

Table 9. Russet Norkotah clone x N rate effects on petiole nitrate concentration, Becker, MN: 1998.

Clone	N, lb/A	Petiole NO_3^- concentration	
		June 6	July 21
NK	25	1850	1394
	100	13558	1323
	200	19405	5976
	300	22783	11593
NK 112	25	1991	1250
	100	12077	414
	200	18862	3186
	300	22616	10180
NK 223	25	1644	906
	100	12026	641
	200	17945	3085
	300	20569	7354
NK 278	25	1770	1273
	100	10536	394
	200	17515	2492
	300	20847	7873

Table 10. Clone effects on petiole NO_3^- concentration of Russet Norkotah clones at Becker, MN: 1998.

Clone	June 8	July 21
NK	14399	5071
NK112	13886	3757
NK223	13046	2997
NK278	12667	3008

Table 11. Nitrogen rate effects on petiole NO_3^- concentration of Russet Norkotah clones at Becker, MN: 1998.

N rate, lb/A	June 8	July 21
25	1814	1206
100	12049	693
200	18432	3685
300	21704	9250

Table 12. Clone, N rate, and interaction effects on petiole NO_3^- concentration of Russet Norkotah clones at Becker, MN: 1998. (++ = significant at 10%; * = significant at 5%; ** = significant at 1%; ns = not significant)

Factor	June 8	July 21
Clone	**	**
N rate	**	**
Clone X N rate	ns	*

Table 13. Russet Norkotah clone x N rate effects on N content, Becker, MN: 1998.

		Tuber N		Vine N		Total N
Clone	N, lb/A	%	lb/A	%	lb/A	lb/A
NK	25	1.14	66.3	2.90	3.6	69.9
	100	1.38	102.9	3.29	6.5	109.4
	200	1.49	129.1	2.96	13.3	142.5
	300	1.73	159.5	2.70	21.4	180.9
NK 112	25	1.13	72.5	2.79	14.9	87.4
	100	1.20	103.3	2.20	9.9	113.2
	200	1.67	141.0	2.61	21.4	162.3
	300	1.63	151.0	2.60	41.6	192.5
NK 223	25	0.96	65.0	2.73	14.1	79.1
	100	1.27	99.7	2.38	13.8	113.5
	200	1.77	143.7	2.32	25.1	168.7
	300	1.80	172.6	2.56	54.0	226.6
NK 278	25	1.06	70.1	3.16	10.7	80.8
	100	1.29	98.4	2.05	10.7	107.3
	200	1.70	147.1	2.06	16.6	163.7
	300	1.59	148.4	2.70	49.4	197.8

Table 14. N content of Russet Norkotah clones at Becker, MN: 1998.

Clone	Tuber N		Vines		Total N
	%	lb/A	%	lb/A	lb/A
NK	1.44	114.4	2.96	11.2	125.6
NK112	1.41	116.9	2.55	21.9	138.8
NK223	1.45	120.2	2.50	26.7	147.0
NK278	1.41	116.0	2.52	22.6	139.4

Table 15. Nitrogen rate effects on N content of Russet Norkotah clones at Becker, MN: 1998.

	Tuber N		Vines		Total N
N rate, lb/A	%	lb/A	%	lb/A	lb/A
25	1.07	68.5	2.90	10.8	79.3
100	1.28	101.1	2.51	10.2	111.1
200	1.66	140.2	2.49	19.1	159.3
300	1.69	157.9	2.64	41.6	199.4

Table 16. Clone, N rate, and interaction effects on N content of Russet Norkotah clones at Becker, MN: 1998. (++ = significant at 10%; * = significant at 5%; ** = significant at 1%; ns = not significant)

	Tuber N		Vines		Total N
Factor	%	lb/A	%	lb/A	lb/A
Clone	ns	ns	*	**	*
N rate	**	**	++	**	**
Clone X N rate	ns	ns	ns	++	ns

Effect of Nitrogen Management on Yield and Quality of Russet Burbank and NewLeaf Russet Burbank Potatoes - 1998[1]

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Abstract. This study conducted to determine the effects of nitrogen timing on the yield and quality of Russet Burbank and New Leaf Russet Burbank potatoes on a Hubbard loamy sand at the Sand Plain Research Farm at Becker, MN. The two varieties were grown under irrigated conditions and received a total nitrogen application of 250 lb/A. Four N application timings were evaluated. The rates (lb N/A) at planting, emergence, hilling and posthilling were as follows: 1) 30, 110, 110, 0; 2) 30, 78, 79, 63; 3) 30, 47, 48, 125; and 4) 30, 16, 16, 188. Posthilling applications were divided into five equal applications at about two week intervals starting on June 4. Variety by N management interaction was not significant for tuber grade, total yield, or specific gravity. Russet Burbank had higher total yield than NewLeaf; however, a higher proportion of the total yield was comprised of #1 and a lower proportion of #2 tubers for NewLeaf compared to Russet Burbank. Delayed N application (increasing posthilling N rate) increased total tuber yield; however, some negative effects of delayed N were also apparent. Increasing posthilling N rate tended to decrease then increase undersized (<4oz) tubers. Delayed N application also increased #2 and decreased #1 tuber yields. Specific gravity was not affected by variety but tended to decrease with increasing posthilling N rate. Hollow heart incidence tended to be greater in NewLeaf compared to Russet Burbank and decreased with increasing rate of posthilling N application Under the conditions of this study, NewLeaf response to nitrogen management was similar to that of Russet Burbank.

NewLeaf Russet Burbank potato is a genetically transformed Bt Russet Burbank potato resistant to Colorado potato beetle. The transformed potato was developed by NatureMark Potatoes (a Monsanto Company) and released in 1995. While visually not distinguishable from standard Russet Burbank, results from field trials over the last few years have shown subtle differences in growth and possibly response to nitrogen fertilization. In some trials, NewLeaf tended to die down earlier and had a greater response to early applications of N than Russet Burbank. However, more research is needed to determine the conditions responsible for differential responses of these two potato clones. Therefore, the objective of this study was to the effects of nitrogen management on the yield and quality of Russet Burbank and New Leaf Russet Burbank potatoes under irrigation.

Materials and Methods

The study was conducted in 1998 on a Hubbard loamy sand at the Sand Plain Research Farm at Becker. The previous crop was rye. Selected soil properties prior to planting were: pH, 6.8, organic matter, 1.6%; Bray P1, 30 ppm; ammonium acetate K, Mg, and Ca, 108 ppm, 136 ppm, and 743 ppm; S, 4 ppm; B, 0.3 ppm; Zn, 0.5 ppm. Preplant nitrate-N (0-2') was 8 lb/A. Russet Burbank and NewLeaf Russet Burbank received a total nitrogen application of 250 lb/A. Four treatments comprised of various N application timings were evaluated. The N rates (lb N/A) at planting, emergence, hilling, and posthilling were as follows: 1) 30, 110, 110, 0; 2) 30, 78, 79, 63; 3) 30, 47, 48, 125; and 4) 30, 16, 16, 188. Treatments were

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replicated 4 times in a split plot design with N rate as the main plot and variety as the sub plot. Each subplot was seven rows wide and 30 feet in length. Two weeks prior to planting, 200 lbs 0-0-60 and 200 lbs 0-0-22 were broadcast applied and incorporated. Starter fertilizer was applied at furrow opening (April 17, 1998) in a double band 3 inches to the side and 2 inches below the tuber to supply 30 lb N/A, 130 lb P_2O_5/A, 240 lb K_2O/A, 24 lb Mg/A, and 41 lb S/A. Following furrow opening, cut "A" seed was planted by hand at 12 inch spacing within rows and 36 inch between rows. Furrows were covered after application of the insecticide Admire. Nitrogen applications as urea were applied at emergence on May 13 and at hilling on May 27. Posthilling N as urea ammonium nitrate was applied in the granular form by hand as a broadcast application over the designated plots and then irrigated in to give total posthilling rates of 0, 63, 125, and 187 lb N/A. Each rate was split into five equal amounts and applied on the following dates: June 4, June 16, July 1, July 16, and July 28. Petiole samples from the most recently matured leaf were collected on June 1, June 15, June 30, July 17, July 28, and August 12 for nitrate determinations. Petioles collected on June 1, June 30 and July 28 were also analyzed for other elements by ICP. Four plants from row 6 (a non-harvest row) were sampled on June 1, June 16, July 1, and July 20. Vine and tuber dry weights were recorded as well as tuber number. Vines were killed on Sept. 9 and rows 3 and 4 of each plot were harvested on Sept 19. Prior to killing the vines a four plant sample was collected to determine vine fresh weight. Tubers were weighed and graded by size. Internal defects and specific gravity were determined on tuber samples from each plot. Tubers were weighed and graded by size. Internal defects and specific gravity were determined on tuber samples from each plot. Vines and tubers were sampled for dry matter and nitrogen determinations.

Results

Weather. Rainfall during the 1998 growing season totaled 13.5 inches. Two leaching events (>2 in. rainfall/day) occurred during the 9th and 12th week after planting. Temperature was above average for April and May, below average for June and about average for July and August.

Seasonal growth measurements. The effect of N management on tuber set, stem number, and dry matter production of roots, vines, and tubers during the growing season is presented in Tables 1 to 5. No consistent effects due to variety or N timing on tuber set were observed on the first three sampling dates. On the June 20 sampling date, tuber set was slightly higher with Russet Burbank compared to NewLeaf and with delayed N applications. However, at harvest the trends due to variety was reversed and the N timing effect was not consistent. Few conclusions pertaining to tuber set can be made from this data suggesting the need for further studies. Stem number was not affected by variety or N management. Dry matter production of tubers tended to be lower in NewLeaf compared Russet Burbank when sampled early in the season and at harvest. Vine dry matter was not affected by variety or N management but on the first sampling date, vine fresh weight tended to be lower in NewLeaf compared to Russet Burbank and with delayed N application. Root dry matter was slightly lower in NewLeaf compared to Russet Burbank on the first sampling date.

Tuber Yield and Quality. Graded tuber yield and specific gravity for both varieties as affected by N management are presented in Table 6. Variety by N timing interaction was not significant for tuber grade, total yield or specific gravity. Yield of 4-10 oz tubers was higher for Russet Burbank compared to NewLeaf, but the 12-14 oz grade was highest for NewLeaf. Russet Burbank had higher total yield than NewLeaf. Similar trends emerged when only marketable yield was evaluated (Table 7). On a marketable yield basis, the interaction between variety and N management was not significant. NewLeaf had a slightly higher percentage of larger tubers than Russet Burbank (Table 7). Tuber shape was significantly affected variety. A higher proportion of the total yield was comprised of #1 and a lower proportion of #2 tubers for NewLeaf compared to Russet Burbank. Delayed N application (increasing posthilling N rate) increased total tuber yield; however, some negative effects of delayed N were also apparent. Delayed N application tended to decrease then increase undersized (<4oz) tubers. Delayed N application also increased #2 and decreased #1 tuber yields.

Specific gravity was not affected by variety but tended to decrease with increasing posthilling N rate (Table 6). Hollow heart incidence tended to be greater in NewLeaf compared to Russet Burbank and decreased with increasing rate of posthilling N application (Table 8). The interaction between variety and N management was not significant.

Petiole Nutrient Concentrations: Petiole nitrate levels through the season are presented in Table 9. On four of the six dates sampled, NewLeaf had higher petiole nitrate levels than Russet Burbank. On the first three sampling dates petiole nitrate decreased with delay in posthilling N application. On the fourth sampling date (June 17) N management did not affect petiole, nitrate levels. However, at the last two sampling dates, petiole nitrate levels increased with increasing posthilling N application.

Concentrations of other petiole nutrients sampled on June 1, June 30 and July 28 are presented in Tables 10, 11, and 12 respectively. On the June 1 sampling date, Russet Burbank petiole K levels were higher than those of NewLeaf. Petiole P, K, Fe and Zn tended to increase with a delay in N application. On June 30, Petiole K levels were higher and Mg, Mn, and B levels lower in Russet Burbank compared to those in NewLeaf. Petiole Mg and Mn decreased with increasing rate of posthilling N application. On July 28, Petiole P, Cu and B levels were higher in NewLeaf than in Russet Burbank. Petiole Mg levels increased with increasing posthilling N application.

Nitrogen Concentrations and Uptake: Concentrations of N in roots, vines, and tubers as well as total N uptake through the growing season are presented in Tables 13 to 17. Delayed N application resulted in lower N concentrations in vines on the first three sampling dates, but higher N in vines on the last two sampling dates. Tuber N concentrations were lower when N application was delayed on the first four sampling dates, but by the final harvest, no difference in tuber N concentrations due to N management were apparent. Root N concentrations as affected by N management followed similar trends similar to that of the tubers. Root, vine, and tuber N levels were not consistently affected by variety; however, at harvest, higher vine and tuber N levels were found in Russet Burbank compared to NewLeaf.

Total N uptake was not affected by variety on any of the sampling dates. N management as expected, had significant effects. Delayed application resulted in lower N uptake through June, but no differences in N uptake due to N management were found from July on. For the first three sampling dates (June 1, 15, and July1), 70-90% of the N was in the vines. By July 20, about 50% of the N was in vines and 50% in tubers. By harvest, 95% of the N was in the tubers. Of interest is that only 60-70% of the total N had been taken up by July 20. For Russet Burbank, in many other seasons 80-90% of the N would have been taken up by this date. During this growing season, significant N uptake apparently occurred during tuber bulking.

Summary: The interaction between N management and variety was, for the most part, not significant. This indicates that under the conditions of this study, NewLeaf response to N management was similar to that of Russet Burbank. Russet Burbank tended to have higher total yield than NewLeaf, but NewLeaf tended to have a higher yield of #1 tubers. Delayed N application tended to increase total yield and decrease incidence of hollow heart of both varieties but also tended to decrease specific gravity and yield of #1 potatoes. NewLeaf tended to have a higher incidence of hollow heart than Russet Burbank. Nitrogen uptake by both varieties was similar.

Table 1. Effect of N management on New Leaf and Russet Burbank tuber and stem number, and fresh and dry mass. Sampled 6/1/98.

Treatments		Growth Measurement, 6/1/98							
Variety	*N rate, lb N/A	Tuber # /Plant	Stem # /plant	Dry matter tuber, lb/A	Dry matter vine, lb/A	Dry matter root, lb/A	Total Dry Matter lb/A	Fresh wt Tuber cwt/A	Fresh wt Vine Ton/A
R.B.	0	19.7	3.6	65	1004	140	1211	6.2	6.7
R.B.	63	20.5	4.2	62	1000	131	1194	6.0	7.0
R.B.	125	18.1	3.6	53	952	127	1133	5.5	6.0
R.B.	188	16.0	3.3	61	882	122	1066	5.8	5.8
N.L.	0	13.6	3.8	40	843	113	997	4.1	5.5
N.L.	63	14.6	3.6	29	916	122	1068	3.3	5.8
N.L.	125	19.1	3.6	77	943	108	1130	9.0	5.7
N.L.	188	16.8	3.3	64	912	122	1099	6.2	5.5
Statistics									
Main Effects									
Variety		NS	NS	NS	NS	++	NS	NS	**
N rate		NS	NS	NS	NS	NS	NS	NS	NS
Linear N		NS	++	NS	NS	NS	NS	NS	++
Quad N		NS	NS	NS	NS	NS	NS	NS	NS
Interaction									
Variety x N rate		NS	NS	NS	++	NS	NS	NS	NS

*N rate = post hill N rate, all treatments received 250 lb N/A

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

Table 2. Effect of nitrogen management on New Leaf and Russet Burbank tuber number, stem number, and fresh and dry mass. Sampled 6/15/98.

Treatments		Growth Measurement 6/15/98							
Variety	*N rate, lb N/A	Tuber # /Plant	Stem # /plant	Dry matter tuber, lb/A	Dry matter vine, lb/A	Dry matter root, lb/A	Total Dry Matter lb/A	Fresh wt Tuber cwt/A	Fresh wt Vine Ton/A
R.B.	0	17.2	3.0	1468	1955	186	3610	95.5	12.3
R.B.	63	19.8	3.4	2319	2184	213	4716	147.6	13.9
R.B.	125	18.8	3.4	1950	1788	186	3925	118.1	11.1
R.B.	188	22.5	3.2	1776	2214	186	4176	112.3	10.5
N.L.	0	21.1	3.5	1625	2232	199	4057	110.4	13.3
N.L.	63	17.9	3.6	1310	1954	181	3446	84.8	11.2
N.L.	125	17.8	3.1	1579	1799	181	3560	102.5	11.2
N.L.	188	16.6	2.6	1501	1753	158	3414	98.1	9.6
Statistics									
Main Effects									
Variety		NS	NS	**	NS	NS	++	*	NS
N rate		NS	NS	NS	NS	NS	NS	NS	**
Linear N		NS	NS	NS	NS	NS	NS	NS	**
Quad N		NS	NS	NS	NS	NS	NS	NS	NS
Interaction									
Variety x N rate		++	NS	++	++	NS	NS	++	*

*N rate = posthill N rate, all treatments received 250 lb N/A

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

Table 3. Effect of nitrogen management on New Leaf and Russet Burbank tuber number, stem number, and fresh and dry mass. Sampled 7/1/98.

Treatments		Growth Measurement 7/1/98							
Variety	*N rate, lb N/A	Tuber # /Plant	Stem # /plant	Dry matter tuber, lb/A	Dry matter vine, lb/A	Dry matter root, lb/A	Total Dry Matter lb/A	Fresh wt Tuber cwt/A	Fresh wt Vine Ton/A
R.B.	0	18.5	3.5	4171	2938	721	7830	232.5	17.2
R.B.	63	18.0	3.7	4462	2595	226	7285	238.5	16.4
R.B.	125	16.5	3.3	4327	3667	195	8190	244.8	14.5
R.B.	188	20.4	3.8	5042	2920	240	8204	266.8	15.6
N.L.	0	15.9	3.1	4140	2990	934	8065	227.3	16.2
N.L.	63	18.6	3.3	5124	3512	199	8837	275.8	17.3
N.L.	125	18.6	4.0	3990	2894	231	7115	214.5	14.0
N.L.	188	20.1	3.8	4650	2741	258	7650	242.3	13.9
Statistics									
Main Effects									
Variety		NS	NS	NS	NS	**	NS	NS	NS
N rate		NS	NS	NS	NS	**	NS	NS	NS
Linear N		NS	NS	NS	NS	**	NS	NS	++
Quad N		NS	NS	NS	NS	**	NS	NS	NS
Interaction									
Variety x N rate		NS	NS	NS	NS	NS	NS	NS	NS

*N rate = post hill N rate, all treatments received 250 lb N/A

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

Table 4. Effect of nitrogen management on New Leaf and Russet Burbank tuber number, stem number, and fresh and dry mass. Sampled 7/20/98.

Treatments		Growth Measurement 7/20/98							
Variety	*N rate, lb N/A	Tuber # /Plant	Stem # /plant	Dry matter tuber, lb/A	Dry matter vine, lb/A	Dry matter root, lb/A	Total Dry Matter lb/A	Fresh wt Tuber cwt/A	Fresh wt Vine Ton/A
R.B.	0	16.1	3.5	7233	3274	231	10739	413.3	13.7
R.B.	63	18.0	3.8	7449	2849	231	10529	425.6	13.4
R.B.	125	19.6	3.1	7831	3059	217	11109	447.5	14.0
R.B.	188	21.6	3.5	7982	2787	226	10997	456.1	13.6
N.L.	0	15.9	3.1	7298	3529	231	11036	417.0	15.0
N.L.	63	17.2	3.3	6318	2686	190	9195	361.0	12.1
N.L.	125	17.3	3.5	7397	3353	231	10982	422.7	15.0
N.L.	188	18.0	4.0	7436	3313	263	11013	424.9	15.5
Statistics									
Main Effects									
	Variety	++	NS	NS	NS	NS	NS	NS	NS
	N rate	*	NS	NS	NS	NS	NS	NS	NS
	Linear N	**	NS	NS	NS	++	NS	NS	NS
	Quad N	NS	NS	NS	NS	NS	NS	NS	NS
Interaction									
	Variety x N rate	NS	NS	NS	NS	++	NS	NS	NS

*N rate = post hill N rate, all treatments received 250 lb. N/A
NS= Nonsignificant; ++, *, ** = significant at 10%, 5%, and 1% respectively.

Table 5. Effect of nitrogen management on New Leaf and Russet Burbank tuber number, stem number, and fresh and dry mass – final harvest. Sampled 9/9/98.

Treatments		Growth Measurements - Final harvest 9/9/98						
Variety	*N rate, lb N/A	Tuber # /Plant	Dry matter tuber, lb/A	Dry matter vine, lb/A	Dry matter root, lb/A	Total Dry Matter lb/A	Fresh wt Tuber cwt/A	Fresh wt Vine Ton/A
R.B.	0	15.1	12234	1055	95	13385	625.7	2.9
R.B.	63	12.6	11766	970	108	12846	613.1	2.3
R.B.	125	13.3	12425	1524	136	14085	648.3	5.1
R.B.	188	14.3	13304	854	104	14263	702.0	2.3
N.L.	0	15.3	11319	998	49	12368	576.7	1.3
N.L.	63	14.8	11989	970	49	12921	593.8	1.4
N.L.	125	14.1	11982	1304	81	13368	604.9	2.0
N.L.	188	18.1	12415	1581	113	14110	634.6	4.1
Statistics								
Main Effects								
	Variety	++	++	NS	NS	NS	**	NS
	N rate	NS	*	NS	NS	++	**	NS
	Linear N	NS	**	NS	NS	**	**	NS
	Quad N	*	NS	NS	NS	NS	*	++
Interaction								
	Variety x N rate	NS	NS	++	NS	NS	NS	++

*N rate = post hill N rate, all treatments received 250 lb N/A
NS= Nonsignificant; ++, *, ** = significant at 10%, 5%, and 1% respectively.

Table 6. Effect of N management on New Leaf and Russet Burbank tuber yield and quality – based on total yield.

Treatments		Tuber yield, cwt/A							> 4 oz		%	Specific
Variety	*N rate, lb N/A	<4 oz	4 - 6 oz	6-10 oz	10-12 oz	12-14 oz	>14 oz	Total	#2	#1	> 6 oz	Gravity
R.B.	0	146.6	192.3	179.4	50.1	29.3	27.8	625.7	210.7	268.3	45.8	1.0779
R.B.	63	134.9	194.2	172.9	45.4	33.6	31.8	613.1	251.5	226.6	46.3	1.0776
R.B.	125	130.2	198.8	187.9	54.9	30.9	45.5	648.3	273.4	244.6	49.1	1.0774
R.B.	188	158.3	227.9	195.8	52.8	30.4	36.5	702.0	324.8	218.8	45.1	1.0746
N.L.	0	130.2	172.5	163.0	41.3	25.8	43.6	576.7	133.7	312.6	47.5	1.0768
N.L.	63	136.1	162.8	161.0	42.9	45.1	45.6	593.8	194.5	263.1	49.6	1.0750
N.L.	125	133.6	177.8	160.1	51.9	42.4	38.8	604.9	191.0	280.2	48.5	1.0756
N.L.	188	158.0	173.0	161.9	49.8	44.4	47.2	634.6	250.7	225.8	47.9	1.0741
Statistics												
Main Effects												
	Variety	NS	* *	*	NS	*	NS	* *	* *	++	NS	NS
	N rate	++	NS	NS	NS	NS	NS	* *	* *	*	NS	NS
	Linear N	++	++	NS	NS	NS	NS	* *	* *	* *	NS	++
	Quad N	*	NS	NS	NS	NS	NS	*	NS	NS	NS	NS
Interaction												
	Variety x N rate	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

*N rate = post hill N rate, all treatments received 250 lb N/A
NS= Non significant; ++, *, ** = significant at 10%, 5% and 1% respectively.

Table 7. Effect of N management on New Leaf and Russet Burbank marketable (> 4 oz) tuber yield and grade.

Treatments		Marketable tuber grade and yield						
Variety	*N rate, lb N/A	% 4 - 6 oz	% 6-10 oz	% 10-12 oz	% 12-14oz	% >14 oz	% >6 oz	Total cwt./A
R.B.	0	40.1	37.5	10.4	6.1	5.9	59.9	479.0
R.B.	63	40.6	36.1	9.5	7.0	6.7	59.4	478.1
R.B.	125	38.5	36.2	10.6	6.0	8.7	61.5	518.1
R.B.	188	42.0	36.0	9.7	5.6	6.7	58.0	543.6
N.L.	0	38.6	36.5	9.3	5.8	9.9	61.4	446.5
N.L.	63	35.6	35.2	9.4	9.9	10.0	64.4	457.8
N.L.	125	37.7	34.0	11.1	9.0	8.2	62.3	471.3
N.L.	188	36.3	33.8	10.5	9.4	10.1	63.7	476.6
Statistics								
Main Effects								
	Variety	++	NS	NS	**	*	++	**
	N rate	NS	NS	NS	NS	NS	NS	**
	Linear N	NS	NS	NS	NS	NS	NS	**
	Quad N	NS	NS	NS	NS	NS	NS	NS
Interaction								
	Variety x N rate	NS	NS	NS	NS	NS	NS	NS

*N rate = post hill N rate, all treatments received 250 lb. N/A
NS= Nonsignificant; ++, *, ** = significant at 10%, 5%, and 1% respectively.

Table 8. Effect of N management on hollow heart incidence in New Leaf and Russet Burbank potatoes.

Treatments		% With Hollow Heart				
Variety	*N rate, lb N/A	6-10 oz	10-12oz	12-14oz	>14 oz	Total
R.B.	0	8.3	27.0	43.7	73.0	38.0
R.B.	63	10.4	25.0	43.7	78.6	39.4
R.B.	125	4.1	16.6	25.0	46.6	23.1
R.B.	188	10.4	11.3	2.0	43.3	16.7
N.L.	0	27.0	35.4	54.7	87.2	51.1
N.L.	63	26.6	42.0	62.9	70.0	50.5
N.L.	125	26.7	40.3	45.8	75.4	47.0
N.L.	188	16.6	22.9	35.0	67.5	35.5
Statistics						
Main Effects						
Variety		* *	* *	* *	*	* *
N rate		NS	*	* *	++	* *
Linear N		NS	* *	* *	* *	* *
Quad N		NS	*	**	NS	NS
Interaction						
Variety x N rate		NS	NS	NS	NS	NS

*N rate = post hill N rate, all treatments received 250 lb N/A
NS= Nonsignificant; ++, *, ** = significant at 10%, 5% and 1% respectively

Table 9. Effect of N management on New Leaf and Russet Burbank petiole NO3-N concentrations.

Treatments		Petiole NO3-N					
Variety	*N rate, lb N/A	Sampling dates					
		6/1/98	6/15/98	6/30/98	7/17/98	7/28/98	8/12/98
R.B.	0	22294	21991	9528	2008	893	184
R.B.	63	21759	19663	8657	4128	2353	1153
R.B.	125	20949	15343	4534	2368	5691	1662
R.B.	188	16309	12036	4746	3214	6582	4279
N.L.	0	23302	22962	10144	3369	877	587
N.L.	63	23575	20774	9621	3654	2452	1446
N.L.	125	21074	18027	5645	2904	4144	2888
N.L.	188	19814	13302	6439	3924	7205	4936
Statistics							
Main Effects							
Variety		*	* *	++	NS	NS	*
N rate		**	++	**	NS	**	**
Linear N		**	**	**	NS	**	**
Quad N		*	NS	NS	NS	NS	*
Interaction							
Variety x N rate		NS	NS	NS	NS	NS	NS

*N rate = post hill N rate, all treatments received 250 lb. N/A
NS= Non significant; ++, *, ** = significant at 10%, 5% and 1% respectively.

Table 10. Effect of nitrogen management on petiole nutrient concentrations in New Leaf and Russet Burbank potato varieties sampled 6/1/98.

Treatments		Petiole nutrient levels								
Variety	*N rate, lb N/A	P %	K %	Ca %	Mg %	Mn ppm	Fe ppm	Zn ppm	Cu ppm	B ppm
R.B.	0	0.48	10.87	0.82	0.48	41	109	43	7	37
R.B.	63	0.50	11.04	0.80	0.46	40	111	46	7	35
R.B.	125	0.47	11.66	0.95	0.52	46	127	45	8	35
R.B.	188	0.55	11.69	0.81	0.44	44	117	51	8	37
N.L.	0	0.44	10.68	0.88	0.50	46	100	43	6	37
N.L.	63	0.46	10.17	0.76	0.47	43	111	45	7	35
N.L.	125	0.53	10.77	0.78	0.49	43	110	52	7	39
N.L.	188	0.52	11.48	0.85	0.49	47	122	50	7	39
Statistics										
Main Effects										
Variety		NS	**	NS	NS	NS	NS	NS	NS	NS
N rate		NS	**	NS	NS	NS	NS	NS	NS	NS
Linear N		++	**	NS	NS	NS	++	*	NS	NS
Quad N		NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction										
Variety x N rate		NS	NS	NS	NS	NS	NS	NS	NS	NS

*N rate = post hill N rate, all treatments received 250 lb. N/A

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

Table 11. Effect of nitrogen management on petiole nutrient concentrations in New Leaf and Russet Burbank potato varieties sampled 6/30/98.

Treatments		Petiole nutrient concentrations								
Variety	*N rate, lb N/A	P %	K %	Ca %	Mg %	Mn ppm	Fe ppm	Zn ppm	Cu ppm	B ppm
R.B.	0	0.33	9.78	0.69	0.46	45	58	38	5	64
R.B.	63	0.32	9.84	0.70	0.46	39	60	42	5	62
R.B.	125	0.29	9.94	0.74	0.40	34	59	45	4	65
R.B.	188	0.30	9.56	0.73	0.37	35	64	41	5	66
N.L.	0	0.30	9.52	0.80	0.55	57	62	40	5	82
N.L.	63	0.35	9.43	0.74	0.51	43	60	40	5	73
N.L.	125	0.34	9.68	0.73	0.42	39	59	37	5	67
N.L.	188	0.30	9.24	0.75	0.39	36	61	43	5	64
Statistics										
Main Effects										
Variety		NS	**	NS	*	**	NS	NS	NS	++
N rate		NS	NS	NS	**	**	NS	NS	NS	NS
Linear N		NS	NS	NS	**	**	NS	NS	NS	NS
Quad N		NS	NS	NS	NS	*	NS	NS	NS	NS
Interaction										
Variety x N rate		NS	NS	NS	NS	NS	NS	NS	NS	NS

*N rate = post hill N rate, all treatments received 250 lb. N/A

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

Table 12. Effect of nitrogen management on petiole nutrient concentrations in New Leaf and Russet Burbank potato varieties sampled 7/28/98.

Treatments		Petiole nutrient levels								
Variety	*N rate, lb N/A	P %	K %	Ca %	Mg %	Mn ppm	Fe ppm	Zn ppm	Cu ppm	B ppm
R.B.	0	0.22	9.25	1.01	0.46	52	54	27	4	46
R.B.	63	0.23	9.35	1.01	0.56	48	53	35	4	46
R.B.	125	0.21	8.51	1.00	0.58	41	49	30	3	43
R.B.	188	0.21	9.02	1.07	0.66	50	52	25	4	45
N.L.	0	0.25	9.74	1.06	0.49	58	48	25	4	49
N.L.	63	0.22	9.43	1.01	0.56	50	49	25	4	48
N.L.	125	0.25	10.01	1.20	0.67	53	64	29	5	53
N.L.	188	0.23	9.35	1.10	0.69	47	54	35	5	47
Statistics										
Main Effects										
Variety		*	NS	NS	NS	NS	NS	NS	*	++
N rate		NS	NS	NS	++	NS	NS	NS	NS	NS
Linear N		NS	NS	NS	**	NS	NS	NS	NS	NS
Quad N		NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction										
Variety x N rate		NS	NS	NS	NS	NS	NS	NS	NS	NS

*N rate = post hill N rate, all treatments received 250 lb. N/A

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

Table 13. Effect of nitrogen management on tissue nitrogen concentrations and nitrogen uptake – sampled 6/1/98.

Treatments								
Variety	*N rate, lb N/A	%N			N uptake lb/A			
		Roots	Vines	Tubers	Roots	Vines	Tubers	Total
R.B.	0	2.87	5.42	2.95	4.0	54.5	1.9	60.4
R.B.	63	3.00	5.23	3.07	3.9	52.3	1.9	58.2
R.B.	125	2.69	4.96	2.71	3.4	47.2	1.4	52.0
R.B.	188	2.55	4.71	2.64	3.0	41.2	1.5	45.8
N.L.	0	2.94	5.38	3.10	3.3	45.3	1.2	49.9
N.L.	63	2.96	5.38	3.24	3.6	49.3	0.9	53.8
N.L.	125	3.30	5.03	2.97	3.6	47.1	2.3	52.9
N.L.	188	2.61	4.75	2.88	3.2	43.3	1.8	48.4
Statistics								
Main Effects								
Variety		NS	NS	**	NS	NS	NS	NS
N rate		++	**	**	NS	*	NS	++
Linear N		++	**	**	++	**	NS	*
Quad N		*	NS	++	NS	NS	NS	NS
Interaction								
Variety x N rate		NS	NS	NS	NS	NS	NS	NS

*N rate = post hill N rate, all treatments received 250 lb. N/A

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

Table 14. Effect of nitrogen management on tissue nitrogen concentrations and nitrogen uptake – sampled 6/15/98.

Treatments								
Variety	*N rate, lb N/A	%N			N uptake lb/A			
		Roots	Vines	Tubers	Roots	Vines	Tubers	Totals
R.B.	0	2.63	4.79	2.06	4.9	94.0	29.5	128.4
R.B.	63	2.15	4.56	1.84	4.6	99.4	42.9	146.9
R.B.	125	1.82	4.09	1.56	3.3	73.0	30.7	107.0
R.B.	188	2.04	4.26	1.53	3.6	101.0	27.2	131.9
N.L.	0	2.21	4.94	1.97	4.4	110.5	31.8	146.8
N.L.	63	2.30	4.65	1.85	4.2	90.5	24.3	119.0
N.L.	125	2.07	4.31	1.84	3.8	77.6	29.1	110.6
N.L.	188	2.04	4.08	1.56	3.2	72.1	23.1	98.4
Statistics								
Main Effects								
Variety		NS	NS	NS	NS	NS	*	NS
N rate		**	**	**	**	NS	NS	NS
Linear N		++	**	**	**	NS	++	++
Quad N		*	NS	NS	NS	NS	NS	NS
Interaction								
Variety x N rate		*	NS	++	NS	NS	*	NS

*N rate = post hill N rate, all treatments received 250 lb. N/A
NS= Non significant: ++, *, ** = significant at 10%, 5% and 1% respectively.

Table 15. Effect of nitrogen management on tissue nitrogen concentrations and nitrogen uptake – sampled 7/1/98.

Treatments								
Variety	*N rate, lb N/A	%N			N uptake lb/A			
		Roots	Vines	Tubers	Roots	Vines	Tubers	Totals
R.B.	0	1.58	3.67	1.42	3.6	108.7	59.1	171.5
R.B.	63	1.52	3.35	1.37	3.5	87.7	62.3	153.5
R.B.	125	1.50	3.10	1.22	2.9	111.9	52.9	167.8
R.B.	188	1.42	3.29	1.28	3.3	96.3	64.5	164.1
N.L.	0	1.84	3.56	1.40	4.4	105.8	56.6	166.8
N.L.	63	1.84	3.37	1.26	3.7	118.5	64.5	186.8
N.L.	125	1.57	2.85	1.37	3.6	82.4	53.9	140.0
N.L.	188	1.41	3.10	1.21	3.6	84.1	56.3	144.1
Statistics								
Main Effects								
Variety		*	NS	NS	+	NS	NS	NS
N rate		*	++	NS	NS	NS	NS	NS
Linear N		**	*	++	+	NS	NS	NS
Quad N		NS	NS	NS	NS	NS	NS	NS
Interaction								
Variety x N rate		NS	NS	NS	NS	NS	NS	NS

*N rate = post hill N rate, all treatments received 250 lb. N/A
NS= Non significant; ++, *, ** = significant at 10%, 5% and 1% respectively.

Table 16. Effect of nitrogen management on tissue nitrogen concentrations and nitrogen uptake – sampled 7/20/98.

Treatments								
Variety	*N rate, lb N/A	%N			N uptake lb/A			
		Roots	Vines	Tubers	Roots	Vines	Tubers	Totals
R.B.	0	1.70	2.29	1.17	4.1	75.3	84.5	157.4
R.B.	63	1.61	2.79	1.22	3.7	79.2	90.7	187.4
R.B.	125	1.67	2.60	1.11	3.5	80.4	87.1	171.3
R.B.	188	1.56	2.66	1.09	3.7	74.2	91.6	170.2
N.L.	0	1.57	2.57	1.11	3.5	91.8	80.9	170.6
N.L.	63	1.91	2.80	1.15	3.8	77.6	72.8	157.8
N.L.	125	1.92	2.55	1.24	4.2	86.4	91.5	177.7
N.L.	188	1.69	3.22	1.10	4.5	107.1	81.9	191.7
Statistics								
Main Effects								
	Variety	NS	*	NS	NS	NS	NS	NS
	N rate	NS	**	NS	NS	NS	NS	NS
	Linear N	NS	**	**	NS	NS	NS	NS
	Quad N	NS	NS	NS	NS	NS	NS	NS
Interaction								
Variety x N rate		NS	++	NS	NS	NS	NS	NS

*N rate = post hill N rate, all treatments received 250 lb. N/A
NS= Non significant; ++, *, ** = significant at 10%, 5% and 1% respectively.

Table 17. Effect of nitrogen management on tissue nitrogen concentrations and nitrogen uptake – sampled 9/9/98.

Treatments								
Variety	*N rate, lb N/A	%N			N uptake lb/A			
		Roots	Vines	Tubers	Roots	Vines	Tubers	Totals
R.B.	0	1.54	1.52	1.67	1.4	15.4	243.3	260.2
R.B.	63	1.64	1.88	1.67	1.7	18.4	201.6	221.9
R.B.	125	1.77	1.72	1.60	2.5	26.2	230.5	259.4
R.B.	188	1.53	2.21	1.84	1.6	17.7	252.9	272.3
N.L.	0	1.52	1.18	1.44	0.8	12.1	202.4	215.4
N.L.	63	1.82	1.25	1.63	1.1	10.1	225.8	237.1
N.L.	125	1.71	1.42	1.50	1.3	19.9	197.7	218.9
N.L.	188	1.48	2.00	1.51	1.7	32.2	231.0	265.8
Statistics								
Main Effects								
	Variety	NS	*	++	NS	NS	NS	NS
	N rate	NS	*	NS	NS	*	NS	NS
	Linear N	NS	**	NS	NS	**	NS	NS
	Quad N	*	NS	NS	NS	NS	NS	NS
Interaction								
Variety x N rate		NS	NS	NS	NS	+	NS	NS

*N rate = post hill N rate, all treatments received 250 lb. N/A
NS= Non significant; ++, *, ** = significant at 10%, 5% and 1% respectively.

Evaluation of Polyolefin-Coated Urea Fertilizers for Irrigated Potato Production in Minnesota[1]: 1998 Results

Francis Zvomuya and Carl Rosen[2]

Abstract. A field study was conducted in 1998 to evaluate the effect of polyolefin-coated urea fertilizers (Meister, Chisso Co., Japan) on yield and quality, applied N recovery, and nitrate (NO_3^-) leaching under potato production on a Hubbard loamy sand at Becker, Minnesota. The coated fertilizers were M5 and M7, which release 80% of their N in 50 and 70 days, respectively, in water at 25°C, and a 1:1 mixture of M5 and M7. The study compared two soluble urea treatments (125 and 250 lb N/A) split applied at planting, emergence, and hilling, versus the same nitrogen (N) rates of coated urea fertilizers applied in a double band at planting. An additional urea treatment at 250 lb N/A had 62 lb of the 250 lb N/A applied in two split applications after hilling. A 0 N fertilizer control was also included. ^{15}N-labeled M7 and urea were applied to portions of appropriate plots in order to determine N recovery by the crop. NO_3^- leaching was estimated from soil solution collected using suction cup samplers installed at 4-ft. depth within and between potato rows. The N sources gave similar total and large (>6 oz) tuber yields in the season characterized by low leaching. At equivalent N rate, Meister fertilizers gave higher total and tuber N uptake than urea. When 250 lb N/ha was applied, NO_3^- concentrations measured in solutions extracted within the row at 4-ft. depth were higher with urea than Meister fertilizers. At the lower rate in the row, and at both rates between the rows, NO_3^- concentrations in the extracted solutions tended to be higher with M5. Recovery of applied N was generally higher with Meister fertilizers than urea.

Potato production requires high inputs of nitrogen in order to increase productivity and profit. Since this shallow-rooted crop in the Upper Midwest is often grown on coarse-textured soils under irrigation and unpredictable rainfall, leaching of nitrate can potentially result in contamination of groundwater. The problem is exacerbated by the use of soluble fertilizers such as urea and ammonium nitrate.

Controlled or slow release nitrogen fertilizers have been available for many years in a wide variety of formulations; however, yield responses obtained by various researchers with these fertilizers have been inconsistent. In part, this inconsistency has been due to unpredictable release rates often leading to high rates of the fertilizer either being available too early or late during the growing season. A new formulation of polymer coated urea manufactured by Chisso Corp. called Meister fertilizer now makes the release more predictable with most of the release rate dependent on soil temperature and to some extent soil moisture. As soil temperature increases, so does root and shoot growth, as well as nitrogen demand. The idea behind using these controlled release fertilizers is that nitrogen release rate is more closely matched with plant demand, allowing better

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nitrogen use efficiency and potentially less nitrate leaching. Use of these fertilizers may potentially have the following advantages: lower rates of N required, all N could be applied at planting, hilling could be done at an earlier stage reducing root pruning, few if any fertigation applications would have to be used. The main disadvantage of these fertilizers is the cost: 5 to 8 times the cost of urea. In part this high cost is due to the fact that the fertilizer has to be imported. Future plans are to manufacture the fertilizer in the US, which could reduce the costs. At the present time however, it is essential to determine what the break-even cost of the fertilizer would be given the potential for increased yield, lower N rates, and fewer sidedress applications.

The overall objective of this study was to compare the effects of quick-release urea and polyolefin-coated urea-N (Meister) sources on N recovery and leaching, and yield and quality of irrigated Russet Burbank potatoes grown on a loamy sand soil.

Methods and Materials

The study was conducted at the Sand Plain Research Farm in Becker, MN, on a Hubbard loamy sand. The potato crop was planted in a field previously cropped with winter rye (*Secale cereale* L.). Selected soil chemical properties prior to planting were (0-6"): pH, 6.6; organic matter, 1.7; Bray 1 P, 35 ppm; ammonium acetate K, Mg, and Ca, 107 ppm, 134 ppm, and 640 ppm; S, 2 ppm; B, 0.3 ppm; Zn, 0.8 ppm. Preplant nitrate-N (0-2') was 9 lb /A. Russet Burbank, a long season variety maturing in about 120 days, was used as the test cultivar.

Prior to planting, 200 lb/A potassium chloride (0-0-60) and 200 lb/A potassium-magnesium sulfate (0-0-22) were broadcast and incorporated. At planting (April 21), triple superphosphate (0-46-0) and additional potash fertilizer (0-0-60 and 0-0-22) were banded 2.5 in. to the side and 2 in. below each seed piece to supply 110 lb P_2O_5/A, 200 lb K_2O/A, 25 lb Mg/A, and 40 lb S/A. Spacing was 10 in. in the row and 3 ft. between rows. Each experimental plot consisted of six, 20 ft. long rows. Irrigation water requirements to supplement rainfall were scheduled according to the checkbook method.

One quick-release and three controlled release (Meister) urea sources were applied at the rates of 125 and 250 lb N/A. The controlled-release sources were M-5, M-7, and a 1:1 mixture of M-5 and M-7. A control treatment receiving no N was included in each replication. All Meister fertilizers were added in a single banded application at planting. Quick-release urea was applied as a split-application receiving an initial 25 lb N/A in the band at planting, with the remainder added in two equal sidedress applications at emergence and hilling. An additional quick-release urea treatment at 250 lb N/A received 25 lb N/A at planting and 163 lb/A split between emergence and hilling. The remaining 62 lb N/A was applied as a 1:1 mixture of urea and ammonium nitrate N in two equal 31 lb N/A post-hilling applications. The study was arranged as a randomized complete block design of 10 treatments with 4 replications.

Urea and M7 treatments received ^{15}N-enriched fertilizer in order to determine N use efficiency. The ^{15}N was hand-applied in a double band in a 5-ft. section of a non-harvest row within the experimental plots. Urea containing 5 atom % ^{15}N, and M7 containing 3 atom % ^{15}N were used in the ^{15}N study. Prior to plot harvesting, the middle 4 plants from the ^{15}N treated plot sections were hand-harvested and tubers were counted. Tubers and shoots were weighed before and after drying, and ground samples were analyzed for ^{15}N and total N content.

In-situ field incubation was undertaken in order to estimate the amount of N released from M5 and M7. Eight plastic mesh-bags containing 3 g of fertilizer and 5 g of soil from the experimental field were buried in portions of the corresponding treatments at planting. One mesh bag from each source was retrieved every 2 to 3 weeks for determination of total N. The amount of N released was estimated from the difference between the initial N content of the source and the N content at sampling. The N released was plotted against the number of days after planting in order to determine the rate of release.

Nitrate leaching was determined from soil solutions collected using suction cup samplers installed at 4-ft. depth both in the row and between the row. A suction of 40 kPa was applied to each sampler using a hand pump. Water samples were collected at least once every week for measurement of NO_3^- concentration.

Petiole samples were collected at three growth stages for conventional NO_3^- determination in order to determine the effect of source and rate of N on plant N status. Petioles from the fourth leaf from the top, which is usually the most recently matured leaf, were sampled. Twenty petioles per sampling date were collected from each experimental plot.

Prior to harvesting, vines were chopped (September 10) from 10-ft. sections of the 2 middle (harvest) rows for determination of fresh and dry weight, and N content. Tubers were mechanically harvested (September 17) from the harvest rows of each plot after all vines had been chopped. The tubers were sorted and weighed according to size and shape. A sample of 25 tubers was taken from each plot for determination of moisture content, N concentration, specific gravity, and internal defects.

Immediately after harvest, soil samples were taken from the top 2 ft. for determination of KCl-extractable residual N.

Results

Tuber yield and quality as affected by N source and rate are presented in Tables 1 and 2. All treatments receiving N produced similar total tuber yield. The yield of large tubers (>6 oz) increased with N rate but did not differ among the N sources at equivalent N rates. The relatively low % > 6 oz tubers in all treatments was due to an unusually high tuber set. Lack of an N response to the controlled release in 1998 was likely due to the fact that leaching rainfalls were minimal.

The highest percent of number 2 (misshapen) tubers was obtained with M5, although the difference among sources at equivalent N rate was not significant at P=0.05 (Table 1). For a given source, doubling the N rate resulted in an increase in the percent of number 2 tubers, but this was only significant (P=0.05) for M5. Specific gravity was highest with urea at 250 lb N/A, whereas tubers fertilized with urea at 125 lb N/A had the lowest specific gravity of all treatments receiving N. Hollow heart incidence was lowest in the controls and highest in tubers receiving 250 lb urea N/A.

For a given N source, tuber, vine, and total dry matter yield (TDM) increased with increasing N rate (Table 3). At equivalent N rate, tuber and vine dry matter yields were not significantly different among sources. Total dry matter yield was similar among the N sources at 125 lb N/A and the 250 lb N/A post-hill urea treatment. At the higher N rate, TDM was higher for the M5 and urea treatments compared to post-hill treatment.

All N treatments increased tuber, vine, and total N uptake compared to the control, but differences in vine N concentration were minimal (Table 3). Doubling the rate of N from 125 to 250 lb/A significantly increased tuber and total N uptake for all sources, and vine N uptake only for M5 and the 1:1 M5/M7 mixture. At equivalent N rates, total and tuber N uptake and tuber N concentrations tended to be higher with the controlled release sources than urea, although the differences were not significant at P=5%.

Table 4 shows petiole NO_3^--N concentrations at different growth stages during the season. On the first (June 8) and second (July 7) sampling dates, M7 gave the lowest petiole NO_3^--N concentrations of all sources at equivalent N rate. M5, either alone or mixed with M7 gave similar or higher petiole NO_3^--N levels than any other source at equivalent N rate on all sampling dates. At 250 lb N/A, petiole NO_3^--N concentrations were lowest with the urea treatment late in the season (August 3).

Weekly rainfall and irrigation amounts during the 1998 growing season are presented in Figure 1. No major leaching events (>2 in. rainfall/day) occurred during the season. Figure 2 shows soil moisture content measured at the depth of the fertilizer band. Volumetric water content at field capacity is about 0.14. Nitrate-N concentrations measured in soil solutions extracted at 4-ft. depth are shown in Figure 3. At 250 lb N/A, NO_3^--N concentrations measured in suction tubes placed in the row (in-row solutions) were higher with soluble than controlled-release urea sources (Figure 3b). In all other situations, the concentrations were highest with M5 both alone (Figure 3a, c, and d) and in combination with M7 (Figure 3a and c). Higher concentrations were measured in in-row than inter-row soil solutions (Figure 3a and b vs. 3c and d). Nitrate-N concentrations in solutions from in-row tubes increased with rate of urea N, but controlled-release N rate had minimal effect, except on the final sampling date when M5 gave a higher peak at the higher rate (Figure 3a vs. 3b). Solutions from inter-row tubes had similar NO_3^--N concentrations at both N rates for a given source, except for M5 which gave a higher final concentration (Figure 3c and 3d).

Rates of dissolution of Meister fertilizers are plotted in Figure 4. Low temperatures in June (Figure 5) resulted in a corresponding decrease in N release during the same period. Cumulative N release by the end of the cropping season (149 days after planting) was 61 and 76% for M7 and M5, respectively.

Table 5 shows inorganic N concentration and content in the top 2 ft. of soil immediately after the crop had been harvested. There were no significant differences in residual N among the treatments. However, total residual N tended to be higher with Meister fertilizers, with the exception of the lower rate of M5, either alone or mixed with M7, which gave lower values at equivalent N rate. Doubling the rate of N increased residual N content only with M5 and the M5/M7 mixture.

Nitrogen derived from fertilizer (N_{dff}), N uptake, and N use efficiency (NUE), as measured by the ^{15}N isotope method, are presented in Tables 6 to 9. M7 gave higher NUE and tuber N uptake than urea. Doubling the rate of N resulted in higher N uptake by vines, and N_{dff} in both vines and tubers, but marginally lower NUE and tuber N uptake.

Nitrogen use efficiency calculated using the difference method (NUE_{diff}) was similar among all treatments receiving N (Table 3), although there was a tendency for higher values with M5 and M7 than equivalent rates of urea. When M7 and urea were compared in a separate statistical analysis, M7 gave higher NUE_{diff} values, although the differences were not significant (P>5%). Mean NUE_{diff} for M7 and urea were, respectively, 39 and 32% at 125 lb N/A, and 38 and 36% at 250 lb N/A.

Conclusions

Results from this study are not as consistent as in previous years where both potato yields and N uptake increased with controlled release Meister fertilizers. In part, the lack of a response in 1998 was due to the lack of leaching rainfall during the growing season. Vine growth also seemed to stop about mid-July even though adequate N was applied. A greater than normal incidence of vine rot occurred at the end of July, which may have inhibited response to late season release of N from M7 and the post-hill urea applications. Reduced N uptake by the plant resulted in high residual N amounts in the soil at the end of the season. Nevertheless, recovery of applied N was higher with Meister fertilizers than urea. Ideally, this study should be repeated with an irrigation treatment to ensure that leaching will occur.

Table 1. Effect of nitrogen source and rate on tuber yield and quality.

N source	N rate lb/A	Fresh Weight, cwt/A <3 oz	3-6 oz	6-12 oz	>12 oz	Total	Percent >6 oz	Hollow Heart, %	Specific gravity
Control	0	184.54	212.95	50.59	0.79	448.87	11.12	2.0	1.0728
Urea[1]	125	137.31	206.91	148.01	16.83	509.06	31.62	10.0	1.0737
Urea[1]	250	120.19	219.38	179.19	45.84	564.60	40.17	20.0	1.0792
M-5	125	131.97	227.70	155.43	19.40	534.50	32.65	13.0	1.0752
M-5	250	110.68	215.42	203.46	47.02	576.58	43.56	13.0	1.0775
M-7	125	141.17	242.25	137.12	9.01	529.55	27.57	7.0	1.0755
M-7	250	148.50	187.61	193.55	43.86	573.51	41.10	16.0	1.0784
M-5/7	125	128.01	230.67	147.21	8.51	514.40	30.07	8.0	1.0752
M-5/7	250	113.36	192.06	182.36	45.74	533.51	42.30	12.0	1.0770
Posthill urea[2]	250	146.32	164.44	189.39	36.83	536.98	42.14	14.0	1.0784
Significance		*	ns	***	***	*	***	**	**
LSD (0.05)		43.09	-	43.37	25.67	75.41	7.78	7.87	0.0041

[1] 25 lb N/A applied at planting, and the remainder split between emergence and hilling.
[2] 25 lb N/A applied at planting, 163 lb/A as ammonium nitrate and urea (1/1) split between emergence and hilling, and 31 lb/A as ammonium nitrate and urea (1/1) added in 2 applications after hilling
All the other treatments were added in a single application at planting.
ns = not significant ; *, **, *** = Significant at 5%, 1% and 0.1%, respectively.

Table 2. Effect of nitrogen source and rate on tuber yield and quality.

N Source	N rate lb/A	Fresh Weight, cwt/A <3 oz	3-6 oz #1	3-6 oz #2	6-12 oz #1	6-12 oz #2	>12 oz #1	>12 oz #2	Total >3 oz #1	Total >3 oz #2	>6 oz. % #1	>6 oz. % #2
Control	0	185	185	27.72	19.01	31.58	0.79	0	205	59.30	4.44	6.68
Urea[1]	125	137	173	33.56	76.43	71.58	11.09	6.95	261	111	16.97	14.65
Urea[1]	250	120	177	42.17	101	77.42	34.25	3.49	313	131	24.34	15.83
M-5	125	132	197	30.69	93.46	61.97	13.56	4.16	304	98.51	19.93	12.72
M-5	250	111	157	58.01	87.02	116	31.09	7.42	276	190	20.63	22.92
M-7	125	141	203	39.11	64.35	72.77	7.52	2.97	275	113	13.48	14.09
M-7	250	149	146	41.78	94.84	98.70	28.81	13.51	269	156	21.32	19.78
M-5/7	125	128	197	33.86	74.84	72.37	7.82	1.39	279	107	15.93	14.14
M-5/7	250	113	150	41.68	89.20	93.16	35.64	11.04	275	145	23.50	18.79
Posthill urea[2]	250	146	132	32.18	84.05	105	25.15	3.91	241	149	20.26	21.88
Significance		*	*	ns	**	**	**	*	**	**	ns	**
LSD (5%)		43.09	49.89	-	32.09	46.74	18.77	11.66	48.39	67.85	-	11.32

[1] 25 lb N/A applied at planting, and the remainder split between emergence and hilling.
[2] 25 lb N/A applied at planting, 163 lb/A as ammonium nitrate and urea (1/1) split between emergence and hilling, and 31 lb/A as ammonium nitrate and urea (1/1) added in 2 applications after hilling
All the other treatments were added in a single application at planting.
ns = not significant ; *, **, *** = Significant at 5%, 1% and 0.1%, respectively.

Table 3. Effect of nitrogen source and rate on N content, N concentration and dry matter production of vines and tubers at Becker, MN, 1998

Nitrogen		Tubers			Vines			TDM	Total N	NUE_{diff}
Source	lb/A	DM, lb/A	% N	N, lb/A	DM, lb/A	% N	N, lb/A	lb/A	lb/A	%
Control	0	8100	0.87	71.27	366	2.03	6.85	8466	78.12	-
Urea[1]	125	9639	1.12	107.76	531	1.81	10.70	10169	118.46	32.3
Urea[1]	250	11162	1.29	142.73	1144	1.78	24.25	12306	167.30	35.7
M-5	125	9515	1.16	110.27	672	1.46	9.94	10187	120.21	33.7
M-5	250	11221	1.39	156.26	1573	1.92	31.61	12794	187.88	43.9
M-7	125	10165	1.13	114.62	762	1.57	12.60	10927	127.22	39.3
M-7	250	10701	1.41	150.24	1239	1.90	23.83	11940	174.07	38.4
M-5/7	125	9810	1.17	113.27	622	1.48	10.06	10432	123.33	36.2
M-5/7	250	10281	1.34	137.43	1428	2.10	31.14	11709	168.57	36.2
Posthill urea[2]	250	9697	1.35	131.15	1239	1.83	23.97	10936	155.11	30.8
Significance		**	***	***	**	ns	**	***	***	ns
LSD (0.05)		1536	0.15	20.55	626	-	17.42	1498	25.61	-

[1] 25 lb N/A applied at planting, and the remainder split between emergence and hilling.
[2] 25 lb N/A applied at planting, 163 lb/A as ammonium nitrate and urea (1/1) split between emergence and hilling, and 31 lb/A as ammonium nitrate and urea (1/1) added in 2 applications after hilling
All the other treatments were added in a single application at planting.
ns = not significant ; *, **, *** = Significant at 5%, 1% and 0.1%, respectively.

Table 4. Effect of nitrogen source and rate on NO_3^--N concentration in potato petioles (dry weight basis).

N source	N rate	NO_3^- concentration (mg/kg) by sampling date		
	lb/A	June 8	July 7	August 3
Control	0	10315	396	1020
Urea[1]	125	22089	6912	639
Urea[1]	250	21683	21054	4406
M-5	125	20213	6255	1554
M-5	250	20799	24342	9703
M-7	125	17536	4129	1322
M-7	250	19644	16088	5795
M-5/7	125	19990	4935	1099
M-5/7	250	20463	18622	9220
Posthill urea[2]	250	21852	17207	2535
Significance		***	***	***
LSD (0.05)		2015	3338	1818

[1] 25 lb N/A applied at planting, and the remainder split between emergence and hilling.
[2] 25 lb N/A applied at planting, 163 lb/A as ammonium nitrate and urea (1/1) split between emergence and hilling, and 31 lb/A as ammonium nitrate and urea (1/1) added in 2 applications after hilling
All the other treatments were added in a single application at planting.
ns = not significant ; *, **, *** = Significant at 5%, 1% and 0.1%, respectively.

Table 5. Effect of nitrogen source and rate on residual N in the soil (0-2 ft.).

N source	N rate lb/A	N concentration, ppm NH_4^+-N	NO_3^--N	Total inorg. N	Total inorg. N lb/A
Control	0	0.75	3.18	3.92	33.40
Urea[1]	125	0.72	4.60	5.32	45.28
Urea[1]	250	0.50	4.67	5.17	44.07
M-5	125	0.56	4.48	5.04	42.95
M-5	250	1.88	6.94	8.83	75.18
M-7	125	0.53	6.20	6.72	57.25
M-7	250	0.56	5.49	6.05	51.57
M-5/7	125	0.60	4.47	5.07	43.21
M-5/7	250	0.69	6.06	6.76	57.55
Posthill urea[2]	250	0.56	5.24	5.80	49.38
Significance		ns	ns	ns	ns
LSD (0.05)		-	-	-	-

[1] 25 lb N/A applied at planting, and the remainder split between emergence and hilling.
[2] 25 lb N/A applied at planting, 163 lb/A as ammonium nitrate and urea (1/1) split between emergence and hilling, and 31 lb/A as ammonium nitrate and urea (1/1) added in 2 applications after hilling
All the other treatments were added in a single application at planting.
ns = not significant ; *, **, *** = Significant at 5%, 1% and 0.1%, respectively.

Table 6. Effect of nitrogen source and rate on fertilizer N uptake and use efficiency (NUE) determined using ^{15}N.

N source	N rate lb/A	Tubers Ndff, %	Tubers Fertilizer N uptake, %	Vines Ndff, %	Vines Fertilizer N uptake, %	NUE %
Urea[1]	125	40	33.72	31	2.57	36.28
	250	52	29.63	46	3.91	33.53
M-7	125	44	40.55	32	3.13	43.68
	250	56	33.41	49	4.58	38.00

[1] 25 lb N/A applied at planting, and the remainder split between emergence and hilling.

Table 7. Effect of nitrogen source on fertilizer N uptake and use efficiency (NUE) determined using ^{15}N.

N source	Tubers Ndff, %	Tubers Fertilizer.N uptake, %	Vines Ndff, %	Vines Fertilizer N uptake, %	NUE %
Urea[1]	46	31.68	38	3.24	34.91
M-7	50	36.98	40	3.86	40.84

[1] 25 lb N/A applied at planting, and the remainder split between emergence and hilling. \

Table 8. Effect of nitrogen rate on fertilizer N uptake and use efficiency (NUE) determined using ^{15}N.

N rate lb/A	Tubers		Vines		NUE %
	Ndff, %	Fertilizer.N uptake, %	Ndff, %	Fertilizer N uptake, %	
125	42	37.14	31	2.85	39.98
250	54	31.52	48	4.24	35.77

Table 9. Nitrogen source, rate, and interaction effects on fertilizer N uptake and use efficiency (NUE) determined using ^{15}N.

N source	Tubers		Vines		NUE %
	Ndff, %	Fertilizer N uptake, %	Ndff, %	Fertilizer N uptake, %	
N source	ns	++	ns	ns	++
N rate	**	*	***	ns	ns
Source x Rate	ns	ns	ns	ns	ns

ns = not significant ; ++, *, **, *** = Significant at 10%, 5%, 1% and 0.1%, respectively.

Russet Burbank and Red Norland Potato Response to Fulcrum -1998[1]

Carl Rosen, Matt McNearney, and Francis Zvomuya[2]

Abstract: The effects of Fulcrum, a molasses based foliar product, were evaluated on irrigated Russet Burbank and early harvest Red Norland potatoes were evaluated in field studies. Total and marketable yield of Russet Burbank potatoes increased with Fulcrum application. Rate and timing had minimal effects on yield. In contrast, Fulcrum depressed total yield of early harvest Red Norland potatoes. Yields may have been depressed due to a delay in maturity.

Fulcrum is a molasses based foliar applied product developed to enhance crop yields. Precise mechanisms for the mode of action are not clearly understood, but research trials over the past few years have frequently shown statistical increases in yield for a variety of crops including potato. Studies in Minnesota during 1997 showed that overall effects of Fulcrum on potato yield were dependent on cultivar. Greatest yield increases were obtained with Russet Burbank, a long season cultivar. Response by Norland, a short season cultivar, to Fulcrum was not statistically significant. Shepody , a mid season cultivar, response to Fulcrum was intermediate. The overall objective of the 1998 research was to determine Fulcrum foliar application timing and rate effects on tuber yield and quality of Red Norland and Russet Burbank potatoes.

Materials and Methods

The Red Norland study was conducted as an on-farm trial in Clear Lake, Minnesota. The soil is a Hubbard sandy loam with 1-2% organic matter, Bray P of 95, and ammonium acetate K of 120. The previous crop was soybean. The previous fall, 300 lbs 0-0-60/A were applied. Red Norland cut "A" size potatoes were planted on April 8, 1998 at a spacing of 36 inches between the row and 11 inches within the row. At planting, 850 lbs of 8-16-16 were applied as a band below the seed piece.

Seven treatments were evaluated:

1) Control - No Fulcrum applied
2) Fulcrum applied at 3 gal/A applied at the prehook stage ($\leq$4 inches tall), followed by another 3 gal/A application 7 to 15 days after the first application - banded
3) 3 gal/A prehook + 3 gal/A tuberization broadcast
4) 0 gal/A prehook + 6 gal/A tuberization broadcast
5) 6 gal/A prehook + 0 gal/A tuberization broadcast
6) 0 gal/A prehook + 12 gal/A tuberization broadcast
7) 12 gal/A prehook + 0 gal/A tuberization broadcast

[1]Funding for this study was provided by Cargill.
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The prehook application was made on May 13 and the tuberization application was made on May 25. Ammonium nitrate was applied as a sidedress at the rate of 100 lb N/A on May 11. All treatments were replicated 5 times in a randomized complete block design. Irrigation and weed and pest control followed standard commercial practices. Each plot was six rows wide and 30 ft in length. One week after the second Fulcrum application, five plants per plot were removed and tubers were counted and weighed to determine initial tuber set. Petiole samples were collected on June 9 and June 23 and analyzed for nitrate. One day before vine kill, five additional plants per plot were removed to determine final tuber set. The most uniform 20 ft section of row in each plot was flagged and then vines were killed on July 1. Tubers were dug by hand on July 13 then weighed and sorted according to diameter.

The Russet Burbank experiment was conducted at the Sand Plain Research Farm at Becker, MN on a Hubbard loamy sand soil with 1-2% organic matter. Selected soil chemical properties prior to planting were: pH, 6.4; Bray P, 42 ppm; and ammonium acetate K, 120 ppm. The previous crop was rye. Two weeks prior to planting, 200 lbs 0-0-60 and 200 lbs 0-0-22 were broadcast applied and incorporated.

Cut "A" seed was planted at 10 inch spacing within rows and 36 inch between rows on April 14, 1998. At planting, 680 lbs 3-17-30 were applied in a band 3 inches to the side and 2 inches below the seed piece.

Six treatments were evaluated:

1) Control - No Fulcrum applied
2) Fulcrum applied at 3 gal/A applied at the prehook stage ($\leq$4 inches tall), followed by another 3 gal/A application 7 to 15 days after the first application - <u>banded</u>
3) 3 gal/A prehook + 3 gal/A tuberization <u>broadcast</u>
4) 0 gal/A prehook + 6 gal/A tuberization <u>broadcast</u>
5) 0 gal/A prehook + 12 gal/A tuberization <u>broadcast</u>
6) 12 gal/A prehook + 0 gal/A tuberization <u>broadcast</u>

The prehook application was made on May 13 and the tuberization application was made on May 26. Ammonium nitrate was applied as a sidedress at the rate of 105 lb N/A on May 13 (emergence) and May 26 (hilling). All treatments were replicated 6 times in a randomized complete block design. Irrigation and weed and pest control followed standard commercial practices. Each plot was four rows wide and 20 ft in length. One week after the second Fulcrum application, four plants were removed and tubers were counted and weighed to determine initial tuber set. Petiole samples were collected on June 8, July 7, and July 21 and analyzed for nitrate. One day before vine kill (Sept. 1), five plants were removed to determine final tuber set. The middle two rows of each plot were mechanically harvested on Sept 8. Total yield, graded yield, tuber specific gravity, and internal disorders were recorded at final harvest.

Results

Norland: Yield and quality of Norland tubers are presented in Table 1. Fulcrum application decreased total yield, especially of the larger sized tubers. Differences among the various Fulcrum treatments were not significant. Fulcrum did not statistically affect initial or final set (Tables 2 and 3). These results suggest that Fulcum delayed maturity of the early harvest Red Norland crop. Petiole nitrate-N concentrations were not significantly affected by Fulcrum application (Table 4).

Russet Burbank: Total and marketable yield significantly increased with Fulcrum application compared to the control (Table 5). Size distribution of the tubers was not affected by Fulcrum suggesting that the yield increase was due to and increase in tuber yield in all size categories (Table 6). The overall low percentage of > 6 oz tubers in all treatments was due to an unusually high tuber set. Fulcrum application did not consistently affect initial or final tuber set (Tables 7 and 8). Effects of Fulcrum on hollow heart incidence and specific gravity were not significant; although brown center incidence increased slightly with Fulcrum application (Table 9). Petiole nitrate-N concentrations were not significantly affected by Fulcrum application on June 8 and July 7, but on July 21 petiole nitrate concentrations were significantly lower in the control treatment compared to the Fulcrum treatments (Table 10). These results suggest that Fulcrum in some cases will affect nitrogen nutrition of the plant during the tuber bulking stage.

Discussion

The 1998 season was characterized as a warm spring, which was conducive for an early harvest. Fulcrum application on Red Norland potatoes appears to have a negative effect on early yield in years that are favorable for an early harvest. Further research on Red Norland is necessary to determine effects of Fulcrum on Red Norland yield on later harvest dates. In addition, since Fulcrum appeared to affect nitrogen nutrition of Russet Burbank potatoes, a study determining whether nitrogen nutrition affects Fulcrum response would seem warranted.

Table 1. Fulcrum Effects on Red Norland Yield - Clear Lake, 1998.

Treatment hooking	Treatment tuberization	< 1½"	1½-1⅞"	1⅞"-2¼"	2¼-2½"	2½-3"	>3"	Total
—— gallons/A ——		cwt/A						
0	0	5	22	55	69	127	79	356
3 band	3 band	6	21	67	74	101	48	317
3 broad	3 broad	7	25	77	83	95	19	306
0	6 broad	5	18	59	71	96	55	304
6 broad	0	5	21	78	100	91	25	325
0	12 broad	5	21	65	81	89	46	308
12 broad	0	4	24	87	76	105	33	331
Contrasts:								
Control vs Fulcrum		NS	NS	NS	NS	**	**	**
Band vs Broad		NS	NS	NS	NS	NS	NS	NS
6 vs 12		NS	NS	NS	NS	NS	NS	NS
Early vs Late		NS	NS	++	++	NS	++	NS

NS, **, ++ = not significant, significant at the 5% or 10% level, respectively.

Table 2. Effect of Fulcrum on Red Norland Tuber Initiation - Clear Lake -- Sampled June 2, 1998.

Treatment hooking	Treatment tuberization	# hooks/plant	# tubers/plant
—— gallons/A ——			
0	0	8.0	9.1
3 band	3 band	4.5	9.1
3 broad	3 broad	6.8	5.7
0	6 broad	4.4	8.3
6 broad	0	9.8	7.3
0	12 broad	6.2	9.9
12 broad	0	6.2	8.1
Contrasts:			
Control vs Fulcrum		NS	NS
Band vs Broad		NS	NS
6 vs 12		NS	NS
Early vs Late		++	NS

NS, ++ = not significant, significant at the 5% or 10% level, respectively.

Table 3. Effect of Fulcrum on Final Tuber Set - Red Norland, Clear Lake – July 1998.

Treatment		<1"	1-2"	>2"	Total
		——— tuber number per plant ———			
hooking	tuberization				
—— gallons/A ——					
0	0	2.5	3.3	6.0	11.8
3 band	3 band	1.9	3.8	7.5	13.2
3 broad	3 broad	2.0	3.9	6.8	12.7
0	6 broad	2.0	2.8	5.2	10.0
6 broad	0	3.1	4.0	7.3	14.5
0	12 broad	2.0	3.2	6.6	11.8
12 broad	0	2.5	4.2	5.7	12.5
Contrasts:					
Control vs Fulcrum		NS	NS	NS	NS
Band vs Broad		NS	NS	NS	NS
6 vs 12		NS	NS	*	++
Early vs Late		NS	NS	NS	NS

NS, *, ++ = not significant, significant at the 5% or 10% level, respectively.

Table 4. Effect of Fulcrum on petiole nitrate-N concentrations - Red Norland - Clear Lake 1998.

Treatment		June 9, 1998	June 23, 1998
hooking	tuberization	---------- ppm Nitrate-N ----------	
—— gallons/A ——			
0	0	18683	16303
3 band	3 band	19208	16224
3 broad	3 broad	18012	15062
0	6 broad	18986	16352
6 broad	0	14953	12558
0	12 broad	17364	13547
12 broad	0	17740	13207
Contrasts:			
Control vs Fulcrum		NS	NS
Band vs Broad		NS	NS
6 vs 12		NS	NS
Early vs Late		NS	NS

NS, ++ = not significant, significant at the 5% or 10% level, respectively.

Table 5. Russet Burbank Response to Fulcrum - Becker 1998.

Treatment		Knobs	< 3 oz	Yield 3-6 oz	6-12 oz	>12 oz	Total yield	Total Marketable (> 3 oz)
		cwt/A						
hooking	tuberization							
gallons/A								
0	0	19	126	237	133	22	538	411
3 band	3 band	33	118	246	146	17	559	441
3 broad	3 broad	29	111	237	134	36	547	436
0	6 broad	32	122	222	153	30	560	438
0	12 broad	20	130	239	151	34	575	445
12 broad	0	20	120	226	157	30	553	433
Contrasts:								
Control vs. Fulcrum		NS	NS	NS	NS	NS	*	++
Band vs. Broad		NS	NS	NS	NS	*	NS	NS
Early vs. late		NS	NS	NS	NS	NS	NS	NS

NS, *, ++ = not significant, significant at the 5% or 10% level, respectively.

Table 6. Fulcrum effects on Russet Burbank tuber size distribution (based on total marketable) - Becker, 1998.

Treatment		Knobs	3-6 oz	6-12 oz	>12 oz	>6
		%				
hooking	tuberization					
gallons/A						
0	0	4.6	57.7	32.4	5.4	37.7
3 band	3 band	7.5	55.8	33.1	3.9	37.0
3 broad	3 broad	6.7	54.4	30.7	8.3	39.0
0	6 broad	7.3	50.7	34.9	6.8	41.8
0	12 broad	4.5	53.7	33.9	7.6	41.6
12 broad	0	4.6	52.2	36.3	6.9	43.2
Contrasts:						
Control vs. Fulcrum		NS	NS	NS	NS	NS
Band vs. Broad		NS	NS	NS	*	NS
Early vs. late		NS	NS	NS	NS	NS

NS, *, ++ = not significant, significant at the 5% or 10% level, respectively.

Table 7. Fulcrum effects on specific gravity, hollow heart, and brown center - Russet Burbank, Becker, 1998.

Treatment		Specific Gravity	Hollow Heart	Brown Center
			%	%
hooking	tuberization			
—— gallons/A ——				
0	0	1.082	11.5	6.7
3 band	3 band	1.081	6.7	10.7
3 broad	3 broad	1.080	8.0	12.5
0	6 broad	1.081	12.7	15.9
0	12 broad	1.082	9.7	15.8
12 broad	0	1.082	11.3	11.9
Contrasts:				
Control vs. Fulcrum		NS	NS	*
Band vs. Broad		NS	NS	NS
Early vs. late		NS	NS	NS

NS, *, ++ = not significant, significant at the 5% or 10% level, respectively.

Table 8. Fulcrum effects on Russet Burbank tuber initiation,- Becker, sampled June 2, 1998.

Treatment		Hooks per plant	Tuber number per plant
hooking	tuberization		
—— gallons/A ——			
0	0	3.0	16.6
3 band	3 band	3.1	16.9
3 broad	3 broad	4.0	15.9
0	6 broad	3.3	18.3
0	12 broad	3.6	19.0
12 broad	0	4.0	16.8
Contrasts:			
Control vs. Fulcrum		NS	NS
Band vs. Broad		NS	NS
Early vs. late		NS	NS

NS, *, ++ = not significant, significant at the 5% or 10% level, respectively.

Table 9. Effect of Fulcrum on final tuber set - Russet Burbank, Becker, September 6, 1998.

Treatment		Knobs	< 3 oz	3-6 oz	6-12 oz	>12 oz	Total
		—— Tuber number per plant ——					
hooking	tuberization						
—— gallons/A ——							
0	0	0.3	7.0	6.3	2.3	0.1	15.9
3 band	3 band	0.1	5.3	7.2	2.2	0.1	15.0
3 broad	3 broad	0.4	4.9	4.8	2.0	0.5	12.6
0	6 broad	0.2	7.5	7.2	1.7	0.0	16.6
0	12 broad	0.6	6.1	8.2	2.4	0.1	17.4
12 broad	0	0.1	6.6	8.9	2.2	0.1	17.6
Contrasts:							
Control vs. Fulcrum		NS	NS	NS	NS	NS	NS
Band vs. Broad		NS	NS	*	NS	*	NS
Early vs. late		NS	NS	NS	NS	NS	NS

NS, *, ++ = not significant, significant at the 5% or 10% level, respectively.

Table 10. Fulcrum effects on petiole nitrate-N concentrations - Russet Burbank, Becker, 1998.

Treatment		June 8, 1998	July 7, 1998	July 21, 1998
		---- ppm Nitrate-N ----		
hooking	tuberization			
—— gallons/A ——				
0	0	17938	11676	5942
3 band	3 band	17003	12867	7315
3 broad	3 broad	15843	12174	6720
0	6 broad	17287	12510	8041
0	12 broad	17232	13220	6465
12 broad	0	18137	12340	6837
Contrasts:				
Control vs. Fulcrum		NS	NS	++
Band vs. Broad		NS	NS	NS
Early vs. late		NS	NS	NS

NS, *, ++ = not significant, significant at the 5% or 10% level, respectively.

EVALUATION OF CARDBOARD SLUDGE AS A SOIL AMENDMENT FOR CROP PRODUCTION[1]

Carl Rosen, Tom Halbach, Matt McNearney, and Glenn Titrud [2]

Abstract: The effects of land application of cardboard sludge on corn and potato yields were evaluated in a field study at the Sand Plain Research Farm in Becker in 1997 and 1998. The sludge had a moisture content of 87-89% and a near neutral pH. The total nitrogen content was 5-7% with a C/N ratio of 7, indicating a high availability of nitrogen. Soluble salts were in a range that would not be considered harmful to crop plants. Trace elements were in a range that would categorize the sludge as exceptional quality based on Minnesota Pollution Control Agency and U.S. Environmental Protection Agency standards. Boron levels ranged from 160 to 173 ppm. In 1997, treatments were sludge applied at 0, 17, and 34 dry tons per acre and nitrogen fertilizer applied at 0, 98, and 208 lb N/A as ammonium nitrate in two equal split applications (4-6 leaf and 10-12 leaf). Without sludge application, corn grain yields increased with N fertilizer up to 110 lb N/A. With sludge application, corn grain yields were not affected by N fertilizer suggesting that total N requirements of corn could be met by the sludge application. Corn grain yields with a sludge rate of 17 tons/A were the same as those with sludge applied at 34 tons/A suggesting that the 17 ton/A application supplied adequate N to meet crop needs. Overall grain yields were higher with sludge application than without, indicating that more than just an N response was occurring. Residual soil nitrate increased substantially with increasing sludge rate, indicating that the sludge at the rates applied provided N in excess of crop needs. The high rates of sludge were applied in 1997 because the analysis provided was based on N concentrations before urea was added to the digestion process. After the sludge was applied, the analysis was found to be ten times higher than expected. In 1998, residual effects of the 1997 sludge application were evaluated on potato yields and a new experiment with corn was established using more realistic sludge application rates: 1.75 and 3.5 dry tons/A - based on 100% and 50% of the total N being available, respectively. Without added sludge, total potato yield and tuber size increased with added N fertilizer. In contrast, with sludge, added N fertilizer tended to decrease total yield. Increasing sludge rate tended to increase tuber size. These results suggest that residual effects of high rates of sludge are apparent the second year after application. Even though this high rate of application is not practical and may be deleterious to the environment, the results show that if N fertilizer is managed properly, high rates of sludge are not detrimental to potato yields. Using more realistic N sludge application rates, corn yield increased with increasing sludge application. Based on N uptake measurements and residual soil nitrate levels, the amount of N mineralized from the sludge organic fraction the year of application was about 30%. In summary, the cardboard sludge generated by the City of Becker can be beneficially used as a safe and effective amendment for crop production provided that agronomic application rates based on N mineralization are used.

Introduction

Cardboard sludge, a by-product of a cardboard recycling facility, is produced in the City of Becker and has been used primarily as a landfill cover. Increasing landfill costs as well as transportation costs have prompted interest in using the sludge as a soil amendment for crop production.

[1]This study was funded by the City of Becker.

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The sludge contains some beneficial nutrients and would also increase soil organic matter. Soils in the region are generally low in organic matter and would therefore benefit from application of sludge. Research and demonstrations are needed to define agronomically and environmentally acceptable rates of application. Too high an application may result in nitrate leaching and/or stunting of crop growth. If the material is found beneficial for crop production, landfill costs would be eliminated and transportation costs could be reduced substantially since most farmer's fields are closer to Becker than the landfill. The overall objective of this research was to evaluate the effects of land application of Becker cardboard sludge on corn yield and nitrogen uptake by the crop. If beneficial effects can be measured, then a second objective is to determine agronomically acceptable rates for land application.

Materials and Methods

The study was conducted in 1997 and 1998 at the Sand Plain Research Farm at Becker on a Hubbard loamy sand soil. The effect of the sludge on corn yield was evaluated in 1997. Residual effects were evaluated on potato yields in 1998 and because of some initial analytical problems a second corn study was also conducted. Specific details for each year are as follows:

1997 - Corn: Nine treatments with 3 sludge rates and 3 N fertilizer rates were evaluated. Based on preliminary analysis, the sludge was found to contain about 0.5 % N. A 20 ton application would provide 200 lbs of N and a 40 ton application would provide 400 lbs of N. Not all of this N would be available the first year. Residual release would occur for one or two years after application. However, after application it was found that the sludge actually contained about 5% N - 10 times the expected level. The reason for the discrepancy is that urea is used during the processing of the sludge. The original sample analyzed was taken before the urea was used. Therefore the sludge rates applied represent a worst case scenario and agronomic rates would probably be much less than those used for the study. Samples of sludge applied to each treatment were collected for chemical analysis (Table 1). Because of the problems associated with the initial analysis, additional samples were collected over a three month period to determine variability in the sludge composition (Table 2).

The nine treatments were replicated 3 times in a 3x3 factorial, split plot design with N rate as the main plot and sludge application as the subplot. The previous crop was rye. Treatments were sludge applied at 0, 17, and 34 dry tons per acre and nitrogen applied at 0, 98, and 208 lb N/A as ammonium nitrate in two equal split applications (4-6 leaf - June 4 and 10-12 leaf - June 20). The sludge was weighed with load cells to within 20 lbs and applied to each plot on May 6, 1997 with a front end loader. Rakes were used to spread the sludge uniformly over the plot. The entire experimental area was then moldboard plowed to a depth of 10 inches to incorporate the sludge.

Each plot consisted of 6 rows, 25 feet in length. Spacing between rows was 30 inches with a seeded population of 32,000 plants per acre. The middle two rows were used as harvest rows. Corn (Pioneer hybrid 3730) was planted on May 7, 1997 along with 150 lbs/A of a 8-10-30 starter fertilizer. Sidedress nitrogen fertilizer was incorporated with tillage or irrigation. Ear leaf samples were collected at silking on July 31. Soil samples (0-1 ft) were collected at mid-season to determine how the sludge affected soil moisture content and at harvest to determine residual nitrate-N. The corn was harvested during the last week in September. Samples were collected for dry matter and nitrogen determination.

1998 - potatoes: Potatoes (Russet Burbank) were planted April 14, 1998 in the same plot the corn was in during the 1997 season to evaluate residual effects of the 1997 sludge applications. Plot size and statistical set up were the same as in 1997. Spacing was 3 feet between rows and 10 inches within rows. A 4-17-29 starter fertilizer at the rate of 150 lbs/A was banded at planting. Nitrogen as ammonium nitrate was applied to designated plots at emergence (May 13) and hilling (May 27). Petiole samples were collected on June 26 for nitrate determinations. Vines were killed on Sept. 9 and a subsample collected from 20 ft of row for dry matter determinations and N uptake. Tubers were harvested form the middle two rows on Sept. 16. The tubers were sorted according to size and a subsample was taken for dry matter determination specific gravity and internal disorders.

1998 - corn: Six treatments with 2 sludge rates and 4 N fertilizer rates were evaluated. The six treatments were replicated 3 times in a randomized complete block design. The previous crop was rye. Sludge treatments were 1.75 and 3.5 dry tons per acre with no fertilizer N application except the starter. These rates were selected based on 100% and 50% of the total N being available, respectively. Based on 6.0% total N content, the low rate would supply about 210 lb total N/A and the high rate would supply 420 lb total N/A. The four N treatments were 0, 75, 150 and 225 lb N/A as ammonium nitrate in two equal split applications (4-6 leaf - May 27 and 10-12 leaf - June 11). The sludge was weighed with load cells to within 20 lbs and applied to each plot on April 28, 1999 with weighed 5 gallon buckets. Rakes were used to spread the sludge uniformly over the plot. The entire experimental area was then moldboard plowed to a depth of 10 inches to incorporate the sludge.

Each plot consisted of 6 rows, 25 feet in length. Spacing between rows was 30 inches with a seeded population of 32,000 plants per acre. The middle two rows were used as harvest rows. Corn (Pioneer hybrid 3730) was planted on May 1, 1998 along with 150 lbs/A of a 8-10-30 starter fertilizer. Sidedress nitrogen fertilizer was incorporated with tillage or irrigation. Ear leaf samples were collected at silking on July 23. Soil samples (0-2 ft) were collected at harvest to determine residual nitrate-N. The corn was harvested during the last week in September. Samples were collected for dry matter and nitrogen determination.

Results

Sludge Chemical Characterization. Chemical analysis of the sludge applied to the plots in 1997 is presented in Table 1. The sludge had a moisture content of about 87% and a near neutral pH. The nitrogen content was about 5% with a C/N ratio of 7, indicating a high potential for nitrogen availability. Nitrate and ammonium were determined in KCl extracts on moist samples. Extractable nitrate in 1997 was negligible. In contrast, extractable ammonium when expressed on a dry weight basis was significant and would account for about 2 lbs of available N per dry ton. Soluble salts were in a range that would not be considered harmful to crop plants. Trace elements were in a range that would categorize the sludge as exceptional quality based on MPCA and USEPA standards. Boron levels ranged from 160 to 173 ppm, which could present problems to sensitive plants such as soybeans if applied at high rates (greater than 20 dry tons per acre).

Variability in sludge composition over the summer months is presented in Table 2. Total N concentrations were slightly higher in the summer sludge compared to the sludge applied in the spring. Boron concentrations were within the same range as those found in the spring sludge. Except for ammonium, overall variability was less than10% for the parameters tested.

Similar results for the sludge were obtained in 1998 for the microwave digest (data not presented). However, nitrogen concentrations were somewhat different in 1998 compared to 1997. Total N averaged 6.7% (about 20% higher than in 1997), extractable ammonium-N averaged 21 ppm on a dry weight basis (much lower then in 1997) and extractable nitrate-N averaged 270 ppm on a dry weight basis (much higher than in 1997). Because of this variability, frequent analysis of the sludge is essential to determine available N loading potential.

Corn Yields - 1997. Grain and stover yield as well as mid-season soil moisture content and residual soil nitrate are presented in Table 3. Without sludge application, corn grain yields increased with N fertilizer up to 110 lb N/A. With sludge application, corn grain yields were not affected by N fertilizer suggesting that total N requirements of corn could be met by the sludge application. Corn grain yields at sludge rates of 17 tons/A were the same as those at 34 tons/A suggesting that no more than 17 tons/A are necessary for crop production. Overall grain yields were higher with sludge application than without, indicating that more than just an N response was occurring. Stover yield increased with N fertilizer when sludge was not applied. As with grain yield, stover yield was not affected by N fertilizer when applied at either sludge rate. Soil moisture increased significantly with increasing sludge rate. Part of the yield increase may have been due to an early season increase in soil moisture before irrigation started. Residual soil nitrate increased substantially with increasing sludge rate, indicating that the sludge at the rates applied provided nitrogen in excess of crop needs. Increasing nitrogen rate had inconsistent effects on residual soil nitrate.

Corn Nitrogen Uptake - 1997. Nitrogen uptake by the crop as well as ear leaf nitrogen concentrations at silking and stover, cob and kernel nitrogen concentrations at harvest are presented in Table 4. Nitrogen concentrations in the ear leaf at silking increased with increasing N rate and sludge rate; however, at harvest only increasing sludge rate increased tissue nitrogen concentrations. Based on crop N uptake, sludge applied at 17 dry tons per acre supplied about 130 lbs N/A to the corn crop (7.6 lb N/ dry ton) while the 34 ton sludge rate supplied about 150 lbs N/A (4.4 lb N/ dry ton). Increasing N rate increased N uptake in the absence of sludge, but had no effect when sludge was applied. The sludge rates used in this study could supply all the N needs without additional N fertilizer.

Potato Yields - 1998: Residual effects of cardboard sludge on potato yield and size distribution are presented in Table 5. Without added sludge, total yield and tuber size increased with added N fertilizer. In contrast, with sludge, added N fertilizer tended to decrease total yield. Increasing sludge rate tended to increase tuber size. These results suggest that residual effects of high rates of sludge are apparent the second year after application. Under the conditions of this study, all the N requirements for potato could have been met from the sludge application in 1997. Even though this high rate of application is not practical, the results show that if N fertilizer is managed properly, high rates of sludge are not detrimental to potato yields.

Potato Nitrogen Uptake - 1998: Nitrogen uptake by the potato crop as well as petiole nitrate-N concentrations during tuber bulking and vine and tuber nitrogen concentrations at harvest are presented in Table 6. Nitrate-N concentrations in the petiole, and vine and tuber N concentrations increased with increasing N rate and sludge rate. Based on crop N uptake, sludge applied at 17 dry tons per acre supplied about 130 lbs N/A (7.6 lb N/ dry ton) to the corn crop while the 34 ton sludge rate supplied about 170 lbs N/A (5 lbs N/ dry ton). These availabilities are very similar to the availabilities found with corn the year of application. Increasing N rate increased N uptake in the absence of sludge, but had minimal effects when sludge was applied. The residual N in the cardboard sludge used in this study could supply all the N needs without additional N fertilizer.

Corn Yields - 1998: Grain and stover yield as well as residual soil nitrate folowing the 1998 growing season are presented in Table 7. Without sludge application, corn grain yields increased with increasing rates of N fertilizer up to 225 lb N/A. Even though high rates of N were applied, grain yields were much lower than in 1997. The yields from areas that received only starter fertilizer were over 3 time greater in 1997 compared to 1998. The precise reasons for the difference between the two years is not known. With sludge application at a rate equivalent to 210 lbs total N/A yields were the same as N fertilizer at about the same N rate. These results were also unexpected since some of the N in the sludge should have been tied up in organic matter and not as available as the fertilizer N. Possibly leaching occurred and the soluble N from the ammonium nitrate leached out while the slower release form the sludge reduced leaching losses. Corn yields were highest with sludge applied at rates assuming 50% N availability. These results suggest that, for unknown reasons, N was limiting corn yields in this study. Stover yield increased with N fertilizer when sludge was not applied. Residual soil nitrate increased slightly with increasing sludge rate, but were much lower than those when levels recorded in 1997 when higher sludge rates were used.

Corn Nitrogen Uptake - 1998. Nitrogen uptake by the crop as well as ear leaf nitrogen concentrations at silking and stover, cob and kernel nitrogen concentrations at harvest are presented in Table 8. Nitrogen concentrations in the ear leaf at silking increased with increasing N rate and sludge rate; however, except for the high rate of sludge, all other treatments resulted in ear leaf concentrations below the sufficiency level of 2.5% , suggesting N deficiency. These results are consistent with the lower yields obtained with the N fertilizer and low sludge rate treatments. Based on crop N uptake, sludge applied at 1.75 dry tons per acre supplied about 60 lbs N/A to the corn crop (34 lb N/ dry ton) while the 3.5 ton sludge rate supplied about 109 lbs N/A (31 lb N/ dry ton). To meet the N needs of a corn crop the first year about 3 to 4 dry tons of sludge would be needed. Unfortunately, residual N availability from the sludge was not determined in this study.

Estimation of Nitrogen Mineralization from the Organic Fraction (based on 1998 corn study):

Sludge characteristics:
Moisture: 88.6
Total N - 6.7% (dw basis)
Inorganic N - 280 ppm (dw basis) = 0.028%
Organic N = Total N-Inorganic N = 6.7-0.028=6.67% = 0.0667lb/lb

<u>1.75 dry ton rate</u>
Total N applied = 1.75 tons/A x 2000 lb/ton x 0.0667 lb/lb = 235 lb N/A
Inorganic N applied = 1.75 tons/Ax2000lbs/tonx0.00028 lb/lb= 1 lb N/A
Organic N applied = 235 lb N/A - 1lb N/A = 234 lb N/A

Total N in crop (1.75 ton rate) - control = 88 lb N/A -28 lb N/A = 60 lb N/A
Residual Nitrate in soils (0-2 ft) from sludge = 10 lb N/A
Total N from sludge (assuming no leaching) = Total N in crop + residual soil nitrate = 60 lb N/A + 10 lb N/A = 70 lb N/A

Organic N = total N from sludge - inorganic N = 70 lb N/A - 1 lb N/A = 69 lb N/A

% availability of the organic fraction the year of application =
(69 ÷ 234) 100 = 29%

<u>3.5 dry ton rate</u>

Total N applied = 3.5 tons/A x 2000 lb/ton x 0.067 lb/lb = 469 lb N/A
Inorganic N applied = 3.3 tons/Ax2000lbs/tonx0.00028 lb/lb = 2 lb N/A
Organic N applied = 469 lb N/A - 2 lb N/A = 467 lb N/A

Total N in crop (3.5 ton rate) - control = 137 lb N/A -28 lb N/A = 109 lb N/A
Residual Nitrate in soils (0-2 ft) from sludge = 38 lb N/A
Total N from sludge (assuming no leaching) = Total N in crop + residual soil nitrate = 109 lb N/A + 38 lb N/A = 147 lb N/A

Organic N = total N from sludge - inorganic N = 147 lb N/A - 2 lb N/A = 145 lb N/A

% availability of the organic fraction the year of application = (145 ÷ 467) 100 = 31%

Approximate N availability from the organic fraction of the sludge = 30%
Based on the 1998 sample (6.7% N). Each dry ton (8 fresh tons) of sludge contains about 40 lbs available N from the organic fraction and less than 1 lb of inorganic N.

Unfortunately, second and third year credit for the sludge is not available, but based on biosolids research, an availability of 12% of the organic N applied would be expected for the first year carry over and 5% would be expected for the second year carry over.

Conclusions and Recommendations

The cardboard sludge processed by the City of Becker meets all criteria for clean sludge based on trace element standards established by the USEPA and MPCA for biosolids. Salts and boron are relatively low and would not cause any problems when applied at agronomic rates. The sludge appears to be an excellent source of nitrogen for corn and potato production. Rates applied above the agronomic rates may result in high levels of residual soil nitrate, which would be susceptible to leaching on sandy soils. Based on the results of this study, a nitrogen availability index for the organic fraction is about 30% for the year of application.

Table 1. Selected chemical properties of cardboard sludge applied to the experimental plots. Becker, MN, 1997.

Property	Mean	Standard deviation	Range
Moisture, %	87.7	0.5	86.8-88.4
pH	7.2	0.1	7.2-7.3
Soluble salts, mmhos/cm	2.4	0.2	2.2-2.6
Dry weight basis			
Organic C, %	38.7	0.9	37.1-39.8
Total N, %	5.28	0.25	5.02-5.61
C/N	7.4	0.2	7.1-7.6
Nitrate-N, ppm	<8	----	----
Ammonium-N, ppm	1214	469	761-2030
Chloride, ppm	807	67	718-896
Nitric Acid Microwave Digest - (EPA 3051)			
Calcium, %	1.80	0.03	1.75-1.83
Aluminum, %	1.45	0.11	1.23-1.57
Phosphorus, %	1.18	0.04	1.10-1.25
Sulfur, %	1.04	0.03	1.00-1.08
Potassium, %	0.34	0.04	0.30-0.42
Sodium, %	0.30	0.01	0.28-0.32
Magnesium, %	0.28	0.01	0.26-0.28
Iron, %	0.20	0.02	0.18-0.23
Silicon, %	0.12	0.01	0.11-0.14
Manganese, ppm	371	27	326-396
Zinc, ppm	193	9	186-207
Boron, ppm	167	5	160-173
Barium, ppm	133	4	126-137
Copper, ppm	63	1	61-65
Lead, ppm	17	1	16-18
Chromium, ppm	17	1	16-17
Nickel, ppm	14	2	12-19
Molybdenum, ppm	5.1	0.3	4.8-5.5
Cobalt, ppm	2.6	0.2	2.4-2.6
Cadmium, ppm	1.4	0.2	1.1-1.6
Arsenic, ppm	<3.3	----	-----

Table 2. Selected chemical properties of cardboard sludge collected over a three month period (July - September) during 1997. Mean of nine samples.

Property	Mean	Standard deviation	Range
Moisture, %	89.1	0.5	88.5-90.0
Organic carbon, % dw	38.1	1.0	36.6-39.9
Total nitrogen, % dw	6.38	0.28	5.85-6.68
C/N	6.0	0.2	5.7-6.3
Nitrate-N, ppm dw	0.3	0.0	----
Ammonium-N, ppm dw	1136	300	809-1345
Boron, ppm dw	173	13	155-182

Table 3. Effect of cardboard sludge on corn yields and selected soil properties. Becker, MN 1997.

Treatment					
Sludge Rate	N Rate	Grain Yield	Stover Yield	Mid-Season Soil Moisture	Residual Soil Nitrate
T/A	lb/A	bu/A	dry tons/A	%	ppm
0	0	123	2.61	6.6	1.16
0	110	181	3.32	6.8	2.11
0	220	183	3.42	6.9	3.48
17	0	212	4.28	10.7	35.08
17	110	193	3.91	11.4	30.26
17	220	212	3.95	9.5	15.45
34	0	198	4.00	11.8	34.08
34	110	206	4.17	13.9	51.36
34	220	198	4.06	15.1	36.06
Significance		**	**	**	**
BLSD (0.10)		19	0.47	3.4	20.83
Main Effects					
N rate					
0		178	3.63	9.7	23.44
110		194	3.80	10.7	27.91
220		198	3.81	10.5	18.33
Significance		*	NS	NS	NS
BLSD (0.10)		12	--	--	--
Linear		**	NS	NS	NS
Quadratic		NS	NS	NS	NS
Sludge rate					
0		162	3.11	6.8	2.25
17		206	4.05	10.5	26.93
34		201	4.08	13.6	40.50
Significance		**	**	**	**
BLSD (0.10)		11	0.26	1.8	10.94
Linear		**	**	**	**
Quadratic		**	**	NS	NS
Interaction					
N x Sludge		**	*	NS	NS

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

Table 4. Effect of cardboard sludge on corn nitrogen content and concentration. Becker, MN 1997.

Treatment		Nitrogen content				Nitrogen concentration			
Sludge Rate	N Rate	Stover	Cob	Kernel	Total	Ear leaf	Stover	Cob	Kernel
T/A	lb/A	---------- lb/A ----------				---------- % N ----------			
0	0	23.6	1.5	70.4	95.5	1.60	0.48	0.20	1.02
0	110	32.3	2.5	103.3	138.1	2.20	0.49	0.24	1.01
0	220	51.2	2.9	116.0	170.1	2.44	0.70	0.25	1.13
17	0	59.2	5.1	160.8	225.1	2.65	0.70	0.35	1.35
17	110	74.6	3.4	151.1	229.1	2.55	0.91	0.29	1.40
17	220	57.0	4.3	156.1	217.4	2.92	0.72	0.32	1.31
34	0	67.8	4.0	172.5	244.3	2.72	0.85	0.32	1.55
34	110	59.1	5.1	157.1	221.3	2.76	0.70	0.37	1.34
34	220	71.9	4.3	160.5	236.7	2.63	0.88	0.31	1.45
Significance		**	**	**	**	**	*	NS	**
BLSD (0.10)		21.5	1.6	33.9	36.7	0.32	0.27	--	0.26
Main Effects									
N rate									
0		53.5	3.6	134.6	191.7	2.32	0.70	0.29	1.31
110		52.9	3.7	137.2	193.8	2.50	0.67	0.30	1.25
220		61.0	3.8	144.2	209.0	2.67	0.77	0.30	1.30
Significance		NS	NS	NS	NS	*	NS	NS	NS
BLSD (0.10)		--	--	--	--	0.19	--	--	--
Linear		++	NS	NS	++	**	NS	NS	NS
Quadratic		NS	NS	NS	NS	NS	NS	NS	NS
Sludge rate									
0		32.5	2.3	96.6	131.4	2.08	0.52	0.23	1.05
17		62.2	4.3	156.0	222.5	2.71	0.76	0.32	1.35
34		65.6	4.5	163.4	233.5	2.70	0.80	0.33	1.45
Significance		**	**	**	**	**	*	*	**
BLSD (0.10)		11.1	0.8	18.2	19.5	0.18	0.14	0.06	0.13
Linear		**	**	**	**	**	*	*	**
Quadratic		++	*	*	**	**	NS	NS	NS
Interaction									
N x Sludge		++	NS	NS	*	*	NS	NS	NS

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

Table 5. Residual effects of cardboard sludge on potato yields - Becker, 1998.

Treatments		culls	< 3 oz	3-6 oz	6-12 oz	>12 oz	total	% > 6 oz
Sludge	Fertilizer Rate	cwt/A						
T/A	lb N/A							
0	0	34	106	119	17	0	276	5
0	110	30	97	211	76	4	419	19
0	220	37	74	198	168	23	499	38
17	0	44	90	250	137	10	531	28
17	110	60	88	199	143	19	508	32
17	220	90	80	170	138	25	503	32
34	0	84	84	141	155	41	505	39
34	110	82	99	147	129	33	490	33
34	220	70	73	142	133	34	452	37
Main Effects								
	N rate							
	0	54	94	170	103	17	438	27
	110	58	95	186	116	18	473	30
	220	66	76	170	147	27	485	30
	Significance	NS	*	NS	**	++	NS	**
	Linear	-	*	-	**	*	++	**
	Quadratic	-	++	-	NS	NS	-	NS
	Sludge rate							
	0	34	93	176	87	9	398	21
	17	65	86	206	140	18	515	31
	34	79	85	143	143	36	483	36
	Significance	*	NS	**	**	**	**	**
	Linear	*	-	*	**	**	**	**
	Quadratic	NS	-	**	*	NS	**	NS
Interaction								
N rate x sludge rate		NS	NS	**	**		NS	****

NS = Non-significant, ++, *, ** = significant at 10%, 5%, and 1%, respectively.

Table 6. Residual effects of cardboard sludge on potato N uptake, petiole NO_3-N, and vine and tuber N concentrations.

Treatment		Nitrogen Content			Nitrogen Concentration		
Sludge	Fertilizer Rate	Vines	Tubers	Total	Petiole	Vines	Tubers
T/A	lb N/A	lb N/A			ppm NO_3-N	% N	
0	0	3.5	63.8	67	175	1.16	1.18
0	110	8.4	115.2	123.6	10051	1.51	1.44
0	220	14.7	163.6	178.3	16419	1.30	1.60
17	0	29.5	167.0	196.5	14914	2.17	1.57
17	110	41.7	171.8	213.5	20058	2.35	1.65
17	220	55.5	173.3	228.8	23071	2.62	1.63
34	0	60.0	179.4	239.4	23211	2.58	1.70
34	110	78.4	165.2	243.6	23498	3.01	1.62
34	220	61.8	158.9	220.7	24075	3.03	1.73
Main Effects							
	N rate						
	0	31.0	136.7	168.0	14341	1.97	1.49
	110	42.8	150.7	193.6	17869	2.29	1.58
	220	44.0	165.2	209.2	21189	2.32	1.65
	Significance	NS	*	*	**	NS	++
	Linear	++	**	**	**	++	*
	Quadratic	NS	NS	NS	NS	NS	NS
	Sludge rate						
	0	8.8	114.2	123.0	9970	1.33	1.41
	17	42.2	170.7	212.9	19348	2.39	1.62
	34	66.7	167.8	234.5	23544	2.87	1.70
	Significance	**	**	**	**	**	**
	Linear	**	**	**	**	**	**
	Quadratic	NS	**	**	*	++	NS
Interaction							
N rate x sludge rate		NS	**	*	*	NS	NS

NS = Non-significant, ++, *, ** = significant at 10%, 5%, and 1%, respectively.

Table 7. Effect of cardboard sludge on corn yields and residual soil nitrate-N (0-2ft). Becker, MN 1998.

Treatment				
Sludge Rate	N Rate	Grain Yield	Stover Yield	Residual Soil Nitrate
T/A	lb/A	bu/A	dry tons/A	ppm
0	10	40	1.17	1.43
0	75	67	1.89	1.46
0	150	107	2.23	1.43
0	225	118	2.32	1.51
1.75	0	119	2.87	2.67
3.50	0	155	2.48	6.15
Significance		**	**	*
BLSD (0.10)		21	0.44	2.54

Table 8. Effect of cardboard sludge on corn nitrogen content and concentration. Becker, MN 1998.

Treatment		Nitrogen content				Nitrogen concentration			
Sludge Rate	N Rate	Stover	Cob	Kernel	Total	Ear leaf	Stover	Cob	Kernel
		lb/A				% N			
0	0	7.7	0.7	19.8	28.3	1.05	0.33	0.90	1.04
0	75	11.7	1.0	34.9	47.6	1.45	0.30	0.87	1.12
0	150	12.8	1.0	58.6	72.4	2.18	0.28	0.59	1.16
0	225	15.1	1.2	61.5	77.8	2.07	0.32	0.66	1.10
1.75	0	22.1	1.2	64.9	88.3	1.83	0.38	0.74	1.15
3.50	0	20.6	1.5	114.7	136.8	2.55	0.41	0.56	1.55
Significance		**	**	**	**	**	*	*	*
BLSD (0.10)		4.9	0.3	24.0	36.7	0.30	0.07	0.17	0.24

NITROGEN FERTILITY MANAGEMENT - 1998

L.D. Klossner, P.M. Porter and G.L. Malzer[1]

ABSTRACT

The N-Fertility Management study at the Southwest Research and Outreach Center at 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). It is a modification of the continuous corn study initiated in 1960 on tiled Normania loam soil. The study was modified in 1994 to include additional N rates, a corn-soybean rotation, and anhydrous ammonia. The first year of results that included corn yields both in continuous corn and corn-soybean rotations was in 1995. Soil moisture levels were above the 32-year average during the fall of 1997and below normal in the spring of 1998. Continuous corn yields were similar regardless of the form of nitrogen application, and greatest at 160 lb N/A. Sidedress applications of anhydrous ammonia and urea nitrogen significantly increased yields at the 40 lb N/A rate. Soybeans showed no significant yield effect from the previous year's nitrogen treatments.

METHODS AND MATERIALS

The N-Fertility Management study is a modification of the continuous corn study initiated in 1960 at the Southwest Research and Outreach Center on tiled Normania loam soil. The study is a randomized complete block, split plot design with four replications during corn years. Main plots (20'x57.5') consist of crop rotation (continuous corn and corn-soybean) and subplots (20'x28.75') 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 divided into 6 inch increments for the first 2 feet, with 1 foot increments for the last 3 feet. Additional management data are shown in Table 2.

RESULTS AND DISCUSSION

Soil moisture data from the N-Fertility Management study are shown is Table 1 and Figure 1. Soil moisture was above normal compared to the 32-year average during the fall of 1997, and below normal for most of April thru July of 1998. Soil moisture levels remained normal throughout the growing season, with a dry spell from mid September thru mid October. Continuous corn yields (Table 3) were similar regardless of which form of nitrogen was applied (anhydrous ammonia or urea). Yields were greatest with 160 lb N/A in both the anhydrous ammonia and the urea nitrogen treatments, with no significant difference in yields between nitrogen timings. Sidedress application of nitrogen significantly increased yields at the 40 lb N/A rate, regardless of the nitrogen form (anhydrous ammonia or urea). Soybean yields (Table 4) showed no yield increase or decrease from residual nitrogen from 1997 nitrogen applications.

Table 1. Available Soil Moisture (0-5 ft.)

Sample Date	1997 Total Available Soil Moisture	32 Year Average (1966-1995)
	inches	
9/1/97	4.59	3.89
9/15/97	4.05	4.30
10/1/97	3.52	4.30
10/15/97	4.82	4.47
11/1/97	6.35	4.84

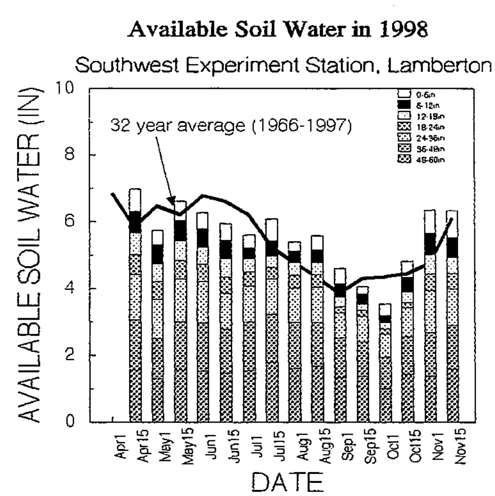

Figure 1. Available soil water sampled during the 1998 growing season at the Southwest Research and Outreach Center

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Table 2. N-Fertility Plot Management for 1998 - Continuous Corn and Soybean

Item	Type	Rate	Date
Primary Tillage	Disc	1 pass	10/24/97
	Moldboard Plow	1 pass	10/24/97
Secondary Tillage	Field Cultivate	2 pass	4/20/98 4/25/98
	Row Cultivation	1 pass	6/5/98
Seed - Corn	Pioneer 35M02	30,000/A	4/27/98
Seed - Soybean	Parker	160,000/A	4/28/98
Fertilizer - Corn	Starter	0-30-30 lb/A ($N-P_2O_5-K_2O$)	4/27/98
N Treatment- Corn	Fall	40, 80, 120, 160 lb/A	10/23/97
	Spring	40, 80, 120, 160 lb/A	4/2498
	Sidedress	40, 80, 120, 160 lb/A	6/3/98
N-Treatment- Soyb	None	None	None
Herbicides - Corn	Dual II Magnum	2.5 pts/A (ai)	4/25/98
	Accent	2/3 oz/A	5/20/98
	Buctril Atrazine	2 pt/A	5/20/98
Herbicides - Soyb	Dual II Magnum	2.5 pts/A (ai)	4/25/98
	Raptor	5 oz/A	5/26/98
Insecticides - Corn	Lorsban	8.7 lb/A	4/27/98

Table 3. Corn Yields in 1998 - Continuous Corn

	Anhydrous Ammonia				Urea			
N-Rate (lb/A)	Fall	Spring	Sidedress	$LSD_{0.05}$	Fall	Spring	Sidedress	$LSD_{0.05}$
	bu/A							
40	92.3	112.1	140.2	19.3	104.9	106.9	121.6	13.2
80	122.6	127.5	141.7	16.3	126.1	143.7	140.2	14.7
120	165.4	151.6	155.0	12.2	159.3	145.0	160.6	16.6
160	169.2	168.2	167.6	12.4	168.7	168.4	162.7	8.8
$LSD_{0.05}$	12.9	14.5	18.6		14.5	17.2	10.9	
Check	61.8							

Table 4. Soybean Yields in 1998 - corn-soybean

	Anhydrous Ammonia				Urea			
N-Rate (lb/A)	Fall	Spring	Sidedress	$LSD_{0.05}$	Fall	Spring	Sidedress	$LSD_{0.05}$
	bu/A							
40	43.6	44.1	43.7	2.1	44.7	43.9	43.4	1.8
80	41.1	42.9	41.6	2.4	43.4	43.7	43.6	1.8
120	42.2	44.6	44.4	3.1	45.9	43.3	43.9	3.9
160	42.8	43.6	45.0	3.4	44.5	43.8	43.2	3.1
$LSD_{0.05}$	3.2	3.6	2.62		2.0	3.7	1.9	
Check	44.4							

VARIABLE INPUT CROP MANAGEMENT SYSTEMS AT THE SOUTHWEST EXPERIMENT STATION: 1998 MANAGEMENT HISTORY AND YIELDS

L.D. Klossner, and P.M. Porter[1]

ABSTRACT

The development of methods to replace or supplement off-farm inputs and energy with on-farm resources is an important goal for agricultural sustainability. Cropping systems with minimum input, lower purchased input, higher purchased input, and organic input were established with two crop rotations and two prior levels of external inputs in 1989 on the Elwell Agroecology Farm and the Southwest Experiment Station at Lamberton. This presentation covers the inputs and yields for the 1998 growing season.

INTRODUCTION

In 1988 the University of Minnesota gained access to a research site called the 'Koch Farm'. This site was renamed the 'Elwell Agroecology Farm' (EAF) in 1996. The EAF was a minimum input farm for at least 35 years prior to 1988. The Variable Input Crop Management Study (VICM) was begun in 1989. The overall objective of this study is to determine how to replace off-farm inputs and energy with on-farm resources, and includes the evaluation of cropping systems with variable off-farm inputs. 1998 was the tenth year of crop production in the study.

METHODS AND MATERIALS

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

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

- MIN management systems receive no added nutrients or pesticides. Weed control is only through mechanical means (rotary hoe and row cultivation), and corn and soybeans are planted 1 to 2 weeks later than normal to allow for additional pre-planting tillage for weed control.
- LPI management systems are planted as soon as possible to maximize yield potential. Phosphorus & K fertilizers are applied in a 2x2 band for corn and soybeans, N is applied in a 2x2 band in corn, and N, P and/or K fertilizer is broadcast on the oats and alfalfa. Fertilizer rates are based on soil tests, previous crop and realistic yield goals. Weed control includes rotary hoe and row cultivation, as well as moderate herbicide application - banded for corn and soybean, broadcast in oat and alfalfa. Generally this treatment has less intensive fall tillage than the other management strategies.
- HPI management systems are planted as soon as possible to maximize yield potential. N, P and K are broadcast on all crops. Fertilizer rates are based on soil tests, previous crop and an optimistic yield goal (10% greater than realistic yield goal). Weed control is through row cultivation and herbicides.
- ORG management systems are planted with untreated seed 1 to 2 weeks later than normal (corn and soybeans) to allow additional pre-planting tillage for weed control. The CSOA corn and oat crops rotation receive solid beef manure in the prior fall. Corn in the CS corn rotation receives beef manure prior to planting in the spring. The rates are based on soil tests and previous manure application rates. Weed control is mechanical only, and includes rotary hoe and row cultivation.

Tables 1 and 2 show the details of plot management for 1998 for VICM I and VICM II, respectively.

RESULTS

Corn yields in the VICM I 4-year corn rotation were greatest in the LPI, HPI and ORG treatments. 2-year VICM I corn yields were significantly greater in the HPI treatment. VICM II corn rotation yields were significantly greatest in the LPI and HPI treatments in both the 4-year and 2-year rotations. VICM I and VICM II soybean yields were significantly greatest in the LPI and HPI treatments for both the 2 and 4-year rotations. VICM I oat yields were significantly higher in the LPI and HPI treatments. There was no significant difference in oat yields in VICM II. Alfalfa yields were significantly greater in the LPI and HPI treatments in VICM I. VICM II alfalfa yields were significantly greater in the LPI, HPI and ORG treatments.

Comparison of the corn and soybean yields for the two rotation lengths analyzed over all management treatments (Table 5) found a significant difference in corn yields in VICM I and VICM II. Corn yields were significantly higher in the 4-year rotation. There was a large difference in yields in both the MIN and ORG treatments. There was no significant difference between rotation length in VICM I soybean yields. VICM II soybean yields were significantly lower in the 2-year rotation, with a large difference in the ORG treatment.

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Table 1. 1998 management for each treatment - Variable Input Crop Management System I (VICM I).

Mgt Level	Primary Tillage	Secondary Tillage	Seed (rate:plants/ac)	Fertilizer	Herbicide (amount of material ac^{-1})	Rotary Hoe	Row Cult.
CS-Rotation: CORN							
MIN	Soil Saver 11/10/97	Field Cult. 5/5	P3730 (30,000) 5/5	None	None	5/7,5/13	5/26, 6/8, 6/22
LPI	No-till	Field Cult. 4/22	P3730 (30,000) 4/23	67-25-28 Band 4/23	Harness(2.25 pts) 4/23 - 10" band	4/28, 5/7 5/13	5/19, 6/8
HPI	Soil Saver 11/10/97	Field Cult. 4/22	P3730 (30,000) 4/23	109-45-42 broadcast 4/22	Doubleplay (6 pt) 4/22 Hornet (2.4 oz) 5/20	4/28	5/29
ORG	Soil Saver 11/10/97	Field Cult. 5/5	P3730 (30,000) 5/5	75-60-90 Beef Manure 4/29/98	none	5/7, 5/13	5/22, 5/26, 6/8 6/22
CS-Rotation: SOYBEAN							
MIN	Moldboard 10/27/97	Field Cult. 5/12	Parker (158,000) 5/13	none	none		5/28, 6/22, 6/28
LPI	Soil Saver 10/28/97	Field Cult. 5/1	Parker (158,000) 5/1	none	Poast Plus (1.5 pt)6/4 10" band	5/13	5/21, 6/10, 6/30
HPI	Moldboard 10/27/97	Field Cult. 5/1	Parker (158,000) 5/1	0-27-0 broadcast 5/1	Sonolan (2.5pts) 5/1 Raptor (4oz)SunIt (1.5 pt)6/19	5/13	6/30
ORG	Moldboard 10/27/97	Field Cult. 5/12	Parker (158,000) 5/13	none	none		5/28, 6/22, 6/30
CSOA-Rotation: CORN							
MIN	Moldboard 10/2797	Field Cult. 5/5	P3730 (30,000) 5/5	None	None	5/7, 5/13	5/26, 6/8, 6/22
LPI	Moldboard 10/2797	Field Cult. 4/22	P3730 (30,000) 4/23	9-24-17 Band 4/23	Harness (2.25 pts) 4/23,	4/28, 5/7, 5/13	5/19, 6/8
HPI	Moldboard 10/27/97	Field Cult. 4/22	P3730 (30,000) 4/23	29-44-42 broadcast 4/22	Doubleplay (6 pts) 4/22 Hornet (2.4 oz) 5/20	4/28	5/29
ORG	Moldboard 10/27/97	Field Cult. 5/5	P3730 (30,000) 5/5	180-135-255 beef man. 10/22/97	none	5/7, 5/13	5/22, 6/8, 6/22
CSOA-Rotation: SOYBEAN							
MIN	Moldboard 10/27/97	Field Cult. 5/12	Parker (158,000) 5/13	none	none	none	5/28, 6/22, 6/30
LPI	Soil Saver 10/28/97	Field Cult. 5/1	Parker (158,000) 5/1	none	Poast Plus (1.5 pts) 6/4, 10" band	5/13	5/21, 6/10, 6/30
HPI	Moldboard 10/27/97	Field Cult. 5/1	Parker (158,000) 5/1	0-27-0 broadcast 5/1	Sonolan (2 pts) 5/1 Raptor (4 oz) SunIt (1.5 pts) 6/9	5/13	6/30
ORG	Moldboard 10/27/97	Field Cult. 5/12	Parker (158,000) 5/13	none	none	none	5/28, 6/22, 6/30
CSOA-Rotation: OAT							
MIN	Soil Saver 11/10/97	Field Cult.4/14 Drag&Pack 4/16	Dane (90 lb/ac) 4/15	none	none	none	none
LPI	No-till	Field Cult. 4/14 Drag&Pack 4/16	Dane (90 lb/ac) 4/15	47-41-25 4/15	none	none	none
HPI	Soil Saver 11/10/97	Field Cult. 4/14 Drag&Pack 4/16	Dane (90 lb/ac) 4/15	47-41-25 4/15	none	none	none
ORG	Soil Saver 11/10/97	Field Cult. 4/14 Drag&Pack 4/16	Dane (90 lb/ac) 4/15	90-68-128 beef man. 10/24/97	none	none	none
CSOA-Rotation: ALFALFA							
MIN	none	none	P5262(16 lb/ac) 4/28/97	none	none	none	none
LPI	none	none	P5262(16 lb/ac) 4/28/97	18-70-50 7/16	none	none	none
HPI	none	none	P5262(16 lb/ac) 4/28/97	18-70-50 7/16	none	none	none
ORG	none	none	P5262(16 lb/ac)	none	none	none	none

Table 2. 1998 management for each treatment - Variable Input Crop Management System II (VICM II).

Mgt Level	Primary Tillage	Secondary Tillage	Seed (rate:plants/ac)	Fertilizer	Herbicide	Rotary Hoe	Row Cult.
CS-Rotation: CORN							
MIN	Soil Saver 11/10/97	Field Cult. 5/5	P3730 (30,000) 5/5	None	None	5/13	5/26, 6/9
LPI	No-till	Field Cult. 4/22	P3730 (30,000) 4/23	67-25-28 band 4/23	Harness (2.25 pts) 4/23 10" band	4/28, 5/13	5/19, 6/9
HPI	Soil Saver 11/10/97	Field Cult. 4/22	P3730 (30,000) 4/23	109-45-42 broadcast 4/22	Doubleplay (6pts) broadcast 4/22 Hornet (2.4 oz) 5/20	4/28	none
ORG	Soil Saver 11/10/97	Field Cult. 5/5	P3730 (30,000) 5/5	75-60-90 Beef manure 4/29/98	none	5/13	5/22, 5/26, 6/9
CS-Rotation: SOYBEAN							
MIN	Moldboard 10/24/97	Field Cult. 5/12	Parker (158,000) 5/13	none	none		5/29, 6/30
LPI	Soil Saver 10/28/97	Field Cult. 5/1	Parker (158,000) 5/1	none	Poast Plus (1.5 pts) 10" band 6/4	5/13	5/21, 6/30
HPI	Moldboard 10/24/97	Field Cult. 5/1	Parker (158,000) 5/1	none	Sonolan (2.5 pts) broadcast 5/1 Raptor (4 oz) Sunit (1.5 pts) 6/9	5/13	6/30
ORG	Moldboard 10/24/97	Field Cult. 5/12	Parker (158,000) 5/13	none	none		5/29, 6/30
CSOA-Rotation: CORN							
MIN	Moldboard 10/27/97	Field Cult. 5/5	P3730 (30,000) 5/5	None	None	5/13	5/21, 6/9
LPI	Moldboard 10/27/97	Field Cult. 4/22	P3730 (30,000) 4/23	9-24-17 Band 4/23	Harness (2.25pts) 4/23 all 10" band	4/28, 5/13	5/19, 6/9
HPI	Moldboard 10/27/97	Field Cult. 4/22	P3730 (30,000) 4/22	29-44-22 broadcast 4/22	Doubleplay (6 pts) broadcast 4/22 Hornet (2.4 oz) 5/20	4/28	none
ORG	Moldboard 10/27/97	Field Cult. 5/5	P3730 (30,000) 5/5	90-68-128 beef man. 10/22/97	none	5/13	5/26, 6/9
CSOA-Rotation: SOYBEAN							
MIN	Moldboard 10/24/97	Field Cult. 5/12	Parker (158,000) 5/13	none	none	none	5/29, 6/30
LPI	Soil Saver 10/28/97	Field Cult. 5/1	Parker (158,000) 5/1	none	Poast Plus (1.5 pts) 10" band 6/4	5/13	5/21, 6/30
HPI	Moldboard 10/24/97	Field Cult. 5/1	Parker (158,000) 5/1	0-27-0 broadcast 5/1	Sonolan (2.5 pts) broadcast 5/1 Raptor (4 oz), Sunit (1.5 pts) 6/9	5/13	6/30
ORG	Moldboard 10/24/97	Field Cult. 5/12	Parker (158,000) 5/13	none	none	none	5/29, 6/30
CSOA-Rotation: OAT							
MIN	Soil Saver 11/10/97	Field Cult. 4/14 Drag&Pack 4/16	Dane (90lb/ac) 4/15	none	none	none	none
LPI	No-till	Field Cult. 4/14 Drag&Pack 4/16	Dane (90lb/ac) 4/15	55-40-24 broadcast 4/15	none	none	none
HPI	Soil Saver 11/10/97	Field Cult. 4/14 Drag&Pack 4/16	Dane (90lb/ac) 4/15	55-40-24 broadcast 4/15	none	none	none
ORG	Soil Saver 11/10/97	Field Cult. 4/14 Drag&Pack 4/16	Dane (90lb/ac) 4/15	45-34-64 beef man. 11/10/97	none	none	none
CSOA-Rotation: ALFALFA							
MIN	none	none	P5265(16 lb/ac) 4/28/97	none	none	none	none
LPI	none	none	P5265(16 lb/ac) 4/28/97	none	none	none	none
HPI	none	none	P5265(16 lb/ac) 4/28/97	none	none	none	none
ORG	none	none	P5265(16 lb/ac)	none	none	none	none

Table 3. 1998 Yields - Variable Input Crop Management Systems (VICM I). LSD values are Fisher's Protected LSD (management effect significant at $p<0.05$), and refer to the least significant difference ($\alpha = 0.05$) between management systems within a given crop and rotation. (That is, values within the same row.)

		Management Level				
Rotation	Crop	MIN	LPI	HPI	ORG	$LSD_{0.05}$
		bu/A				
CSOA	Corn	80.0b	167a	183a	176a	18.2
CS	Corn	48.8c	148b	188a	82.6c	37.0
SOAC	Soybeans	37.8b	48.3a	47.0a	23.9c	7.0
SC	Soybeans	30.3b	42.3ab	44.0a	33.7b	9.2
OACS	Oats	32.4b	42.6a	42.4a	48.7b	14.9
ACSO	Alfalfa*	3.03c	5.63a	6.10a	4.97b	0.806

*Alfalfa yields are (T/A)

Table 4. 1998 Yields - Variable Input Crop Management Systems II (VICM II). LSD values are Fisher's Protected LSD (management effect significant at $p<0.05$), and refer to the least significant difference ($\alpha = 0.05$) between management systems within a given crop and rotation. (That is, values within the same row.)

		Management Level				
Rotation	Crop	MIN	LPI	HPI	ORG	$LSD_{0.05}$
		bu/A				
CSOA	Corn	148b	176ab	183a	163b	17.6
CS	Corn	43.5c	165a	183a	87.8b	37.5
SOAC	Soybeans	34.9b	44.0a	41.6a	32.3b	10.1
SC	Soybeans	26.0b	39.3a	42.7a	18.3b	10.8
OACS	Oats	58.4a	58.5a	59.2a	60.7a	19.4
ACSO	ALfalfa*	4.20b	5.36a	5.62a	5.30a	0.473

* Alfalfa yields are (T/A)

Table 5. 1998 corn and soybean yields calculated for each rotation length (2-year corn-soybean, and 4-year corn-soybean-oat/alfalfa-alfalfa) over all four management systems, allowing comparison of the effect of rotation length on crop yield (values in the same row).

		Rotation Length		
Experiment	Crop	2-year	4-year	$LSD_{0.05}$
		bu ac^{-1}		
VICM I				
	Corn	117b	151a	13.0
	Soybean	37.6a	39.2a	3.6
VICM II				
	Corn	120b	168a	11.5
	Soybean	31.6b	38.2a	4.3

COMPARISON OF ON-FARM TILLAGE OPERATIONS IN THE FALL OF 1997 AND 1998 IN SOUTHWEST MINNESOTA

S.R. Quiring and P.M.Porter[1]

Abstract

On-farm tillage operations were again monitored in the fall of 1998 to determine if there were tillage differences in different geographic locations in southwest Minnesota. Emphasis was put on corn and soybean field tillage operations. A total of 2263 corn and soybean field tillage operations were recorded in the counties of Brown, Cottonwood, Lincoln, Lyon, and Redwood. When the corn and soybean data were combined for all counties, 53% were corn fields and 47% were soybean fields compared to 1997 percentages of 51 and 49 respectively. Most all fall tillage operations were completed when these data were recorded in December. It is difficult to draw exact lines where tillage practices may be changing due to geographic location, but after a number of years of data this may become more apparent.

Materials and Methods

Methods remained the same in 1998 for making and recording fall tillage observations. Observations of the type of fall tillage on a field-by-field basis in the fall of 1998 were made by recording on a tape recorder while traveling in a vehicle on blacktop roads in southwest Minnesota. The routes chosen were in all directions from the Southwest Research and Outreach Center (SW-ROC). The data were transferred to spreadsheet form. Previous crop with type of tillage was recorded. Tillage practices on corn and soybean land were divided into the following categories: no-till standing, disk, moldboard plow and chisel. In 1998 ridge-till operations were recorded with the no-till operations. Chisel plow operations could include soilsavers and V-rippers.

Results and Discussion

A total of 2263 corn and soybean field tillage operations were recorded in the counties of Brown, Cottonwood, Lincoln, Lyon, and Redwood, in 1998 (Table 1). Of the 1200 fields of corn observed, 65% were tilled with reduced-tillage equipment such as chisel, soilsaver or V-ripper in 1998, compared to 60% in 1997; 31% were moldboard plowed in 1997 and 27 % in 1998; and no-till or ridge tilled remained about the same. Moldboard plowing was again done more frequently east of Highway 71 than in other areas observed. In 1998, of the 1063 soybean fields, 57% were chiseled, 27% were no till, 2% were disked, and 3% was moldboard plowed (Table 2). In 1997 chiseled and no-till fields were 70% and 27% respectively. No-till soybean stubble was more common south of Highway 14 and west of Highway 71. Total fields observed in 1998 was down from 1997. This could be due to larger field size and some CRP fields were converted to crop land in 1998.

Weather conditions in the fall of 1997 and 1998 were favorable and allowed farmers to accomplish fall tillage operations in most areas of southwest Minnesota. Crop prices, livestock trends, and adverse weather conditions are some of the factors that may change cropping systems and tillage operations. More years of data are needed to know if these tillage observations are consistent from year to year across the various locations.

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Table 1. Comparison of tillage operations of corn fields after fall tillage in 1997 and 1998.

Location	1997 Corn: Ridge %	1997 Corn: No Till standing %	1997 Corn: Disk %	1997 Corn: Mold-board %	1997 Corn: Chisel %	1997 Corn: Number of fields observed	1997 Corn: % in corn	1998 Corn: No Till standing %	1998 Corn: Disk %	1998 Corn: Mold-board %	1998 Corn: Chisel %	1998 Corn: Number of fields observed	1998 Corn: % in corn
South on Co. #6 (from Lamberton to Storden)	0	18	0	0	83	40	41	6	0	15	79	34	57
Hwy71 (from Windom north to Hwy 30)	0	25	0	3	72	32	51	18	0	5	76	38	56
Hwy71 (from Hwy 30 to Hwy 14)	0	18	0	12	69	49	51	12	0	12	77	26	46
Hwy71 (from Hwy 14 to Hwy 68)	0	6	0	17	78	54	50	0	0	16	84	37	62
Hwy71 (from Hwy 68 to Hwy 19)	0	9	0	22	70	23	44	0	0	19	81	27	66
Hwy19 (from Redwood Falls west to Red. Co. 6)	0	8	0	25	67	12	38	0	0	31	69	13	50
Red. Co. 6 (from Hwy 19 south to Wabasso)	0	6	0	31	64	36	50	18	0	27	55	22	40
Red. Co. 6 (from Wabasso south to Hwy 14)	0	3	0	26	71	38	45	0	0	40	60	30	55
Hwy14 (from Lamberton to Hwy 71)	0	8	0	12	81	26	63	9	0	13	78	23	51
Hwy14 (from Hwy 71 to Springfield)	0	0	0	58	42	19	44	0	0	25	75	16	46
Hwy14 (from Springfield to Cobden)	0	5	0	38	57	21	57	6	0	28	67	18	46
Hwy14 (from Cobden to Sleepy Eye)	0	0	0	39	61	23	55	0	0	30	70	23	66
Brown Co. 27 (from Sleepy Eye to New Ulm)	0	3	0	74	23	39	45	2	0	68	30	47	57
Cot. Co. 5 (from Storden south to Hwy 62)	0	17	3	17	63	35	55	20	0	13	67	30	52
Hwy 62 west to Cot Co.7 & north to Westbrook	0	20	0	23	57	35	45	12	4	15	69	26	46
Cot. Co. 6 (from Westbrook north to Revere)	0	10	0	26	64	39	47	4	0	8	88	48	51
Mur. Co.45 & 42 (from Hwy 14 to Hwy 30)	0	13	0	52	35	46	49	7	0	44	49	61	59
Mur. Co. 42 (from Hwy 30 south Fulda)	4	8	0	44	44	25	37	13	0	29	58	31	55
Hwy 59 (from Fulda south to Worthington)	0	15	0	20	66	41	47						
Hwy 14 (from Lamberton west to Red. Co. 8)	0	15	0	48	36	33	47	5	0	5	91	22	49
Red. Co. 8 (from Hwy 14 to Milroy)	0	4	0	4	93	27	47	6	0	19	75	32	59
Hwy 68 (from Red. Co. 8 to Wabasso)	4	4	0	26	66	47	48	4	0	8	88	26	53
Hwy 68 (from Wabasso to Hwy 71)	0	0	0	24	76	21	50	0	0	20	80	20	61
Hwy 68 (from Hwy 71 to Co 29)	0	0	0	46	54	41	49	3	0	45	53	38	49
Brown Co. 29 (from Hwy 68 to New Ulm)	0	2	0	68	30	60	43	0	0	69	31	74	62
Hwy 4 (from Sleepy Eye south to Hwy 30)	1	5	1	47	45	78	50	7	0	37	56	57	48
Hwy 30 (from Hwy 4 to Darfur)	0	0	0	50	50	30	48	0	0	39	61	23	47
Hwy 30 (from Darfur west to Hwy 71)	0	0	0	13	87	30	41	4	0	18	78	49	58
Hwy 30 (Hwy 71 to Storden)	7	11	4	11	67	27	54	13	0	23	65	31	48
Hwy 30 (Storden to Westbrook)	0	6	6	11	78	18	49	22	0	17	61	18	47
Hwy 7 (north from Westbrook to Walnut Grove)	3	3	3	50	42	36	48	7	0	10	83	42	76
Red. Co. 5 (Walnut Grove north to Hwy 68)	0	3	0	33	64	33	43	2	0	19	79	42	61
Red. Co. 10 (from Lucan to Hwy 14)	5	14	0	18	64	44	59	23	0	31	46	26	41
Hwy 14 (west from Co 8 to Hwy 59)	0	10	0	27	63	30	52	0	6	35	59	17	57
Hwy 14 (west from Hwy 59 to Hwy 23)	0	3	5	13	79	38	45	0	0	23	77	26	44
Hwy 14 (west from Hwy 23 to Lake Benton)	0	6	0	48	45	31	43	24	0	47	29	17	40
Hwy 75 (north from Lake Benton to Ivanhoe)	0	27	0	30	42	33	42	47	0	33	20	15	32
Hwy 19 (east From Ivanhoe to Marshall)	0	2	4	24	69	49	37	11	0	11	77	44	51
Lyon Co. 6 (from Marshall to Milroy)	0	3	0	32	65	31	47	10	0	16	74	31	58
Total number of fields	9	110	9	424	818	1370	--	87	2	327	784	1200	--
% for that crop	(1)	(8)	(1)	(31)	(60)			(7)	(<1)	(27)	(65)		

Table 2. Comparison of tillage operations of soybean fields after fall tillage in 1997 and 1998.

Location	1997 Soybeans: No Till standing %	Chisel %	Ridge %	Disk %	Mold-board %	Number of fields observed	% in soybeans	1998 Soybeans: No Till standing %	Chisel %	Disk %	Mold-board %	Number of fields observed	% in soybeans
South on Co. #6 (from Lamberton to Storden)	45	53	2	0	0	55	57	73	27	0	0	26	43
Hwy71 (from Windom north to Hwy 30)	21	79	0	0	0	29	46	67	33	0	0	30	44
Hwy71 (from Hwy 30 to Hwy 14)	18	82	0	0	0	38	39	53	47	0	0	30	54
Hwy71 (from Hwy 14 to Hwy 68)	18	82	0	0	0	51	48	30	61	9	0	23	38
Hwy71 (from Hwy 68 to Hwy 19)	12	88	0	0	0	26	50	29	71	0	0	14	34
Hwy19 (from Redwood Falls west to Red. Co. 6)	18	82	0	0	0	17	53	62	38	0	0	13	50
Red. Co. 6 (from Hwy 19 south to Wabasso)	31	69	0	0	0	32	44	33	67	0	0	33	60
Red. Co. 6 (from Wabasso south to Hwy 14)	8	93	0	0	0	40	48	20	80	0	0	25	45
Hwy14 (from Lamberton to Hwy 71)	7	86	0	0	7	14	34	9	82	9	0	22	49
Hwy14 (from Hwy 71 to Springfield)	17	83	0	0	0	18	42	16	79	0	5	19	54
Hwy14 (from Springfield to Cobden)	6	94	0	0	0	16	43	14	71	0	14	21	54
Hwy14 (from Cobden to Sleepy Eye)	12	88	0	0	0	17	40	8	92	0	0	12	34
Brown Co. 27 (from Sleepy Eye to New Ulm)	5	95	0	0	0	41	47	3	94	0	3	36	43
Cot. Co. 5 (from Storden south to Hwy 62)	41	56	0	4	0	27	42	43	54	4	0	28	48
Hwy 62 west to Cot Co.7 & north to Westbrook	38	62	0	0	0	26	33	27	70	3	0	30	54
Cot. Co. 6 (from Westbrook north to Revere)	47	51	0	0	2	43	52	83	17	0	0	47	49
Mur. Co.45 & 42 (from Hwy 14 to Hwy 30)	37	60	0	0	2	43	46	21	79	0	0	42	41
Mur. Co. 42 (from Hwy 30 south Fulda)	64	33	0	3	0	33	49	44	56	0	0	25	45
Hwy 59 (from Fulda south to Worthington)	38	62	0	0	0	45	51						
Hwy 14 (from Lamberton west to Red. Co. 8)	12	82	0	6	0	33	47	48	48	4	0	23	51
Red. Co. 8 (from Hwy 14 to Milroy)	47	53	0	0	0	30	52	59	36	5	0	22	41
Hwy 68 (from Red. Co. 8 to Wabasso)	40	56	2	2	0	45	46	48	48	4	0	23	47
Hwy 68 (from Wabasso to Hwy 71)	35	65	0	0	0	20	48	38	54	8	0	13	39
Hwy 68 (from Hwy 71 to Co 29)	34	56	0	10	0	41	49	30	65	3	3	40	51
Brown Co. 29 (from Hwy 68 to New Ulm)	11	77	0	1	11	75	54	16	76	0	9	45	38
Hwy 4 (from Sleepy Eye south to Hwy 30)	39	43	1	12	4	67	43	20	74	2	5	61	52
Hwy 30 (from Hwy 4 to Darfur)	34	63	0	0	3	32	51	35	54	8	4	26	53
Hwy 30 (from Darfur west to Hwy 71)	34	63	0	2	0	41	55	28	69	0	3	36	42
Hwy 30 (Hwy 71 to Storden)	10	86	0	5	0	21	42	58	39	3	0	33	52
Hwy 30 (Storden to Westbrook)	18	82	0	0	0	17	46	30	70	0	0	20	53
Hwy 7 (north from Westbrook to Walnut Grove)	19	81	0	0	0	37	49	15	85	0	0	13	24
Red. Co. 5 (Walnut Grove north to Hwy 68)	18	80	0	3	0	40	52	56	44	0	0	27	39
Red. Co. 10 (from Lucan to Hwy 14)	50	43	7	0	0	28	37	37	55	0	8	38	59
Hwy 14 (west from Co 8 to Hwy 59)	48	52	0	0	0	27	47	46	38	0	15	13	43
Hwy 14 (west from Hwy 59 to Hwy 23)	17	83	0	0	0	36	42	76	21	0	3	33	56
Hwy 14 (west from Hwy 23 to Lake Benton)	4	92	0	0	4	26	36	36	56	4	4	25	60
Hwy 75 (north from Lake Benton to Ivanhoe)	24	72	0	0	4	25	32	50	38	0	13	32	68
Hwy 19 (east From Ivanhoe to Marshall)	19	81	0	0	0	48	36	52	43	2	2	42	49
Lyon Co. 6 (from Marshall to Milroy)	23	77	0	0	0	35	53	23	77	0	0	22	42
Total number of fields	362	930	5	21	17	1335	--	408	611	17	27	1063	--
% for that crop each year	(27)	(70)	(0)	(2)	(1)			(38)	(57)	(2)	(3)		

HIGH-OIL CORN HYBRID TRIALS AT LAMBERTON AND WASECA - 1998.

P.M. Porter, D.R. Hicks, L.D. Klossner, and T.R. Hoverstad[1]

Abstract

Thirteen high-oil corn hybrids were grown at two locations (Lamberton and Waseca) in 1998. Averaged over 12 of the 13 hybrids, oil contents were the same at each location, averaging 6.7%. Normal commodity corn hybrids have oil contents of approximately 4%. Oil contents ranged from 6.1 to 7.3% at Waseca and from 6.1 to 7.5% at Lamberton. Yields were higher at Waseca than at Lamberton. Yields ranged from 165 to 211 bu/ac (average 185 bu/ac) at Waseca, and from 146 to 175 bu/ac (average 163 bu/ac) at Lamberton.

Experimental Procedure

The results of the high-oil corn hybrid trials at the Southwest Research and Outreach Center (Lamberton) and the Southern Research and Outreach Center (Waseca) in 1998 are reported. At each location, 13 high-oil hybrids were grown in four replicated plots with appropriate isolation to ensure that the correct pollinator pollinated each hybrid. This isolation included border areas of 12 rows of a male sterile hybrid surrounding each high-oil hybrid. Grain yield and a harvest moisture content were determined from each plot at harvest. Plot size was four 30"-wide rows by 22 feet. The trials were harvested with an Almaco small plot combine. Grain yield was adjusted to 15.5% moisture. Oil, protein, starch, and moisture contents were determined with an Infratec 1229 (near infrared transmittance) NIT whole grain analyzer, and are reported on a dry-weight basis. At Lamberton, plant stands in June, a green snap scoring at harvest, and test weights were also determined. Agronomic practices are listed in Table 1.

Results and Discussion

There were hybrid differences in yield, oil content, and moisture content and other parameters measured (Tables 2, 3, and 4). Similiar to last year's results, certain hybrids had high yields, high oil contents, and low harvest moisture contents relative to other hybrids tested, suggesting producers should prudently select the high-oil hybrid that they plan to grow. One particular hybrid (NC+ Re271H) tested low for oil content at Lamberton, and we question whether we had seed of the high-oil version for this hybrid at this location. Because of this apparent discrepancy, averaged results from 12 of the 13 hybrids are reported.

Oil contents for the 12 hybrids averaged 6.7% at both Waseca and Lamberton. Oil contents ranged from 6.1 to 7.3% at Waseca and from 6.1 to 7.5% at Lamberton. Averaged over both locations, the hybrids with the highest oil contents were hybrids Pfister SK1571-18, Brown 5241VP, Pioneer 37H97, Agri Pro 326HO, and NC+ 3688H.

Yields were higher at Waseca than at Lamberton. Yields ranged from 165 to 211 bu/ac (average 185 bu/ac) at Waseca, and from 146 to 175 bu/ac (average 163 bu/ac) at Lamberton. Averaged over both locations, 7 of the 12 hybrids had yields over 175 bu/ac, and their yields were not statistically different from one another. Hybrids that were high in oil content and yield at both locations included Pfister SK1571-18, Brown 5241VP, Pioneer 37H97, Agri Pro 326HO, and NC+ 3688H.

The moisture content at harvest ranged from 16.2 to 19.9% (average 18.3%) at Waseca, and from 16.6 to 23.3 (average 20.2%) at Lamberton. Corn at Lamberton, however, was combined almost three weeks earlier than the corn at Waseca corn. Averaged over both locations, the highest yielding hybrids tended to have the highest moisture contents at harvest.

Significant differences between hybrids existed for the protein and starch contents, and in general, those hybrids with higher starch or protein contents had relatively lower oil contents. At Lamberton, the test weights of the hybrids with the highest oil contents and yields were all above 57 lbs/bu.

Plant stands in mid-June averaged approximately 30,100 plants/ac at Lamberton. One hybrid, NC+ 3688H, had a significantly lower population (26,700 plants/ac). At Lamberton, high levels of green snap was recorded on Brown 6853VP and Pfister SK2025-18. This probably contributed to the lower yields of these hybrids at Lamberton relative to Waseca.

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Table 1. Agronomic practices for the high-oil corn trials at Lamberton and Waseca, 1998.

	Waseca	Lamberton
Planting date	April 29, 1998	April 28, 1998
Harvest date	Oct. 21, 1998	Oct. 1, 1998
Soil Test	6.5 pH, high P & K tests	6.1 pH, 22 ppm P, & 172 ppm K
Fertilizers	150-0-0 as A.A. (Applied in spring)	135-0-0 as A.A. (Applied fall, 1997)
Herbicides	Harness 2.25lb/A	Doubleplay 6 pt/A (4/23/98)
	Bladex 2.5lb/A	Accent Gold 2.9 oz/A (5/22/98)
	Atrazine 1.5lb/A (Applied May 5)	

Climate

	Waseca Rainfall	Waseca GDD (°F)	Lamberton Rainfall	Lamberton GDD (°F)
April	3.27 in.	--	1.75 in.	--
May	4.21	488	1.40	493
June	4.38	480	2.95	477
July	3.79	658	5.40	474
August	2.93	652	3.09	666
September	1.87	522	1.18	507
Total	20.45	2800	14.02	2782

For comparison, here are the yields for the Corn Performance Trials:

	Lamberton Average (range)	Waseca Average (range)	
	---- bu/ac ----		
Early (≤105 RM)	184 (140-214)	202 (161-249)	110 entries
Late (>105 RM)	185 (124-218)	229 (191-258)	24 entries

Table 2. Grain yield, kernel moisture, and grain quality traits of high-oil corn hybrids grown at Lamberton, 1998.

No.	Brand	Top Cross	Moisture[1]	Yield	Oil	Protein	Starch	Plant stand	Green snap	Test wt.
			%	bu/ac	%	%	%	plants/ac	No.	lbs/bu
1	Agri Pro	326HO	19.2	147	7.1	9.1	68.4	29400	2	57.8
2	Brown	4001VP	17.2	153	6.1	9.8	69.3	31900	1	59.1
3	Brown	4144VP	16.6	155	6.3	10.3	68.7	33900	1	60.1
4	Brown	5241VP	21.5	174	7.4	9.8	67.7	32000	2	58.9
5	Brown	6853VP	22.8	150	6.1	9.6	68.8	29800	10	55.3
6	Grast	8660TC3	22.4	174	6.9	8.9	68.5	29300	1	55.4
7	NK Brand	NX4206	17.2	161	6.1	9.8	69.8	33300	4	58.3
8	Pioneer	37H97	17.9	174	6.7	9.6	68.9	32300	2	57.6
9	Pfister	SK1571-18	21.5	175	7.3	9.6	67.8	29600	0	58.1
10	Pfister	SK2020-5	21.8	175	6.5	8.6	69.4	30000	0	56.7
11	Pfister	SK2025-18	23.3	148	6.5	9.6	68.3	30900	8	55.7
12	NC+	3688H	21.4	170	7.5	10.2	66.8	26700	0	57.8
13	NC+	Re271H[2]	17.4	185	4.7	9.5	71.9	30100	0	57.4
		Average	**20.2**	**163**	**6.7**	**9.6**	**68.5**	**30100**	**2**	**57.6**

[1] Protein, starch, and oil content are at 0.0% moisture, as measured on the Infratec 1229. Test weight were measured on the GAC. Yields (adjusted to 15.5% moisture) were obtained with the Almaco plot combine. Moisture content at harvest (Oct. 10).

[2] Because Re271H tested low for oil content and high for strach content, we question whether we had seed of the high-oil version for this location. Therefore, NC+ Re271H is not included in the 12 Top Cross averages.

Table 3. Grain yield, kernel moisture, and grain quality traits of high-oil corn hybrids grown at Waseca, 1998.

No.	Brand	Top Cross	Moisture[1]	Yield	Oil	Protein[1]	Starch[1]
			%	bu/ac	%	%	%
1	Agri Pro	326HO	17.6	182	7.0	8.4	69.0
2	Brown	4001VP	16.9	170	6.5	9.2	69.2
3	Brown	4144VP	16.5	166	6.8	9.2	68.7
4	Brown	5241VP	19.2	189	7.1	8.9	68.7
5	Brown	6853VP	19.2	211	6.2	8.7	69.5
6	Grast	8660TC3	18.8	186	6.1	8.1	70.2
7	NK Brand	NX4206	16.2	178	6.4	9.0	69.8
8	Pioneer	37H97	17.5	186	7.3	9.2	68.3
9	Pfister	SK1571-18	18.9	196	7.2	8.9	68.3
10	Pfister	SK2020-5	19.7	195	7.0	8.2	69.2
11	Pfister	SK2025-18	19.8	182	6.6	8.5	69.2
12	NC+	3688H	19.9	183	6.5	8.7	69.6
13	NC+	Re271H[2]	18.6	166	6.3	9.0	69.5
		Average	**18.3**	**185**	**6.7**	**8.8**	**69.1**

[1] Protein, starch, and oil content are at 0.0% moisture, as measured on the Infratec 1229. Yields (adjusted to 15.5% moisture) were obtained with the Almaco plot combine. Moisture contents were at harvest (Oct. 21).

[2] Because Re271H tested low for oil content and high for strach content, we question whether we had seed of the high-oil version for this location. Therefore, NC+ Re271H is not included in the 12 Top Cross averages.

Table 4. Grain yield, kernel moisture, and grain quality traits of high-oil corn hybrids grown at Lamberton and Waseca, 1998.

No.	Brand	Top Cross	Moisture[1]	Yield	Oil	Protein[1]	Starch[1]
			%	bu/ac	%	%	%
1	Agri Pro	326HO	18.4	165	7.0	8.8	68.7
2	Brown	4001VP	17.1	162	6.3	9.5	69.3
3	Brown	4144VP	16.6	160	6.6	9.7	68.7
4	Brown	5241VP	20.3	182	7.3	9.4	68.2
5	Brown	6853VP	21.0	180	6.1	9.2	69.1
6	Grast	8660TC3	20.6	180	6.5	8.5	69.4
7	NK Brand	NX4206	16.7	170	6.2	9.4	69.8
8	Pioneer	37H97	17.7	180	7.0	9.4	68.6
9	Pfister	SK1571-18	20.2	185	7.3	9.3	68.0
10	Pfister	SK2020-5	20.8	185	6.8	8.4	69.3
11	Pfister	SK2025-18	21.6	165	6.6	9.1	68.7
12	NC+	3688H	20.6	177	7.0	9.5	68.2
13	NC+	Re271H[2]	18.0	175	5.5	9.2	70.7
		Average	**19.3**	**174**	**6.7**	**9.2**	**68.8**
		LSD (0.05)	**0.7**	**11**	**0.4**	**0.3**	**0.6**

[1] Protein, starch, and oil content are at 0.0% moisture, as measured on the Infratec 1229. Yields (adjusted to 15.5% moisture) were obtained with the Almaco plot combine. Moisture contents are at harvest (Oct. 10 at Lamberton and Oct. 21 at Waseca).

[2] Because Re271H tested low for oil content and high for strach content, we question whether we had seed of the high-oil version for this location. Therefore, NC+ Re271H is not included in the 12 Top Cross averages.

SOYBEAN ROW SPACING AND PLANT POPULATION RESEARCH AT LAMBERTON AND WASECA - 1998.

P.M. Porter, D.R. Hicks, L.D. Klossner, and T.R. Hoverstad[1]

Abstract

At Lamberton and Waseca two soybean varieties were grown on both 10-inch and 30-inch row spacings at 8 seeding rates ranging from 75,000 to 250,000 seeds/acre, as well as at 200,000 seeds/acre which were thinned at the V1 growth stage to 4 seeding rates ranging from 75,000 to 150,000 seeds/acre. At both locations Asgrow 1923 out-yielded Asgrow 2247 regardless of row spacing and plant population. Averaged across both locations, both varieties and all plant populations, the 10-inch row spacing out-yielded the 30-inch row spacing by 6.3% (70.3 vs. 65.8 bu/acre, respectively). Averaged across both locations, varieties and row spacings, yields were the same for seeded populations ranging from 125,000 to 225,000 seeds/acre. There was a marked difference between the seeding rate and the final plant stand, with the reduction being greatest at the highest seeding rates. These results support the agronomic recommendation that soybean yield are not affected with seeding rates ranging from 125,000 to 225,000 seeds/acre in both wide and narrow row spacings.

Experimental Procedure

Two soybean varieties (Asgrow 1923 and Asgrow 2247) were planted at two row widths (10-inches and 30-inches) at plant populations ranging from 75,000 to 250,000 plants per acre at the Southwest Research and Outreach Center (Lamberton) and the Southern Research and Outreach Center (Waseca) in 1998. Agronomic practices are listed in Table 1. The experimental design at each location was a randomized complete block with a split plot layout. The main plot variable was row spacing and the split plot variables were soybean variety and plant populations in a factorial arrangement.

At Lamberton there were 4 replicates of each treatment, whereas at Waseca there were only 3 replicates. Plot size was 10 feet by 12 feet at Lamberton and 10 feet by 14 feet at Waseca. Plots were planted with a cone type plot planter, where the appropriate number of seeds are packaged separately for each plot for accurate seeding rates. The seeding rates were 75,000, 100,000, 125,000, 150,000, 175,000, 200,000, 225,000 and 250,000 seeds per acre, as well as 200,000 seeds per acres which were thinned to 75,000, 100,000, 125,000 and 150,000 plants per acre at the V1 growth stage.

Grain yield and harvest moisture content were determined from each plot at harvest. The trials were harvested with an Almaco small plot combine. Grain yield was adjusted to 13.0% moisture. Oil, protein, starch, and moisture contents were determined with an Infratec 1229 (near infrared transmittance) NIT whole grain analyzer, and are reported on a dry-weight basis.

At Lamberton, plant stands were determined 3 times during the growing season in each plot by counting the plants in 3 foot of row by 2 row and 4 rows in the 30-inch and 10-inch row widths, respectively. Flags were placed in the plots to mark the exact row length at the southern most row to ensure the same areas were measured each time.

Results and Discussion

Excellent yields were obtained at both locations in part because of very good growing conditions (see Table 1 in the article entitled "High-oil corn hybrid trials at Lamberton and Waseca - 1998" for monthly rainfall and growing degree unit accumulations). At both locations Asgrow 1923 out-yielded Asgrow 2247 regardless of row spacing and plant population (Table 2). Averaged across both locations, varieties and all plant populations, the 10-inch row spacings out-yielded the 30-inch row spacings (70.3 vs. 65.8 bu/acre, respectively). The yield advantage to narrow row spacing was more apparent at Lamberton than at Waseca (67.3 vs. 60.1 bu/acre at Lamberton and 73.3 vs. 71.6 bu/acre at Waseca for 10-inch and 30-inch row spacings, respectively).

Location had a greater influence on yield than plant population, even though the soybeans were seeded at populations ranging from 75,000 to 250,000 seeds/acre (Table 2). Averaged over both locations, there was no difference in yield between seeding rates of 125,000 to 225,000 seeds/acre. At 75,000 seeds/acre the yield decline was only approximately 6% compared to the more optimal seeding rates. One should remember that at the seeding rate of 75,000 seeds/acre the plant distribution across the plots in this study was good, but if a field averaged 75,000 plants/acre and the stand was patchy with large bare areas, one should expect a greater percentage yield loss. It should be noted that there was a slight yield decline at the highest seeding rate of 250,000 seeds/acre. Row width, whether at 10-inch or 30-inch row spacings, did not have an influence on the yield response to seeding rates. These results support the agronomic recommendation that soybean yield are not affected with seeding rates ranging from 125,000 to 225,000 seeds/acre in both wide and narrow row spacings.

Treatments that were planted to 200,000 seeds/acre and thinned to between 75,000 and 150,000 plants/acre had yields quite similar to the corresponding un-thinned seeding rate. Again, it should be noted that the thinning occurred evenly across the plot, resulting in good plant distribution.

At Lamberton, plant stand counts indicated a sizeable difference between the seeding rate and final plant stands, especially at the higher seeding rates (Table 3). Row spacing had little influence on lodging, although the 10-inch row spacing had slightly taller plants than the 30-inch row spacing. Row spacing had no influence on oil content, protein content, or test weight.

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Table 1. Agronomic data from the soybean plant population by row spacing by variety study at Lamberton and Waseca, 1998.

	Lamberton	Waseca
Planting date	May 20, 1998	May 14
Harvest date	Oct. 17	Oct. 12
Seeding rate (seeds/acre)	varied by trt	varied by trt
Row spacing (inches)	10 & 30 inches	10 and 30 inches
Herbicides	Treflan 1.5 pts/acre	Treflan 1.5 pts/acre
	Pursuit 1.44 oz/acre	Pursuit 1.44 oz/acre

Table 2. Soybean yields from the row spacing by plant population by variety study at Lamberton and Waseca, 1998.

	Lamberton	Waseca	Both locations
	bu/acre		
Variety averages:			
Asgrow 1923	65.2	73.1	69.1
Asgrow 2247	62.2	71.8	67.0
Row spacing averages:			
10-inch row widths	67.3	73.3	70.3
30-inch row widths	60.1	71.6	65.8
Plant population averages:			
seeds/acre			
75000	61.3	70.0	65.6
100000	62.3	71.3	67.3
125000	66.6	73.3	70.0
150000	64.7	73.9	69.3
175000	62.7	73.2	68.0
200000	64.6	73.2	68.9
225000	66.1	76.0	71.0
250000	62.4	70.5	66.4
Thinned to 75000	60.6	70.1	65.4
Thinned to 100000	63.7	72.1	67.9
Thinned to 125000	64.6	72.6	68.6
Thinned to 150000	63.7	73.3	68.5

Soybean yields averaged across both varieties:

Seeding rate	Lamberton Row spacing		Waseca Row spacing	
	10-inch	30-inch	10-inch	30-inch
seeds / acre	bu/acre			
75000	65.0	57.6	66.5	73.6
100000	66.0	60.6	71.7	70.9
125000	71.0	62.2	75.6	71.1
150000	66.7	62.8	74.9	73.0
175000	67.4	58.0	75.9	70.6
200000	68.6	60.6	75.6	70.9
225000	69.5	62.8	76.1	75.8
250000	65.9	58.8	69.9	71.1
Thinned to 75000	69.1	52.1	70.5	69.8
Thinned to 100000	65.8	61.5	73.3	70.9
Thinned to 125000	65.9	63.2	74.3	70.9
Thinned to 150000	66.7	60.8	75.4	71.2

Table 3. Results from the soybean row spacing by plant population by variety study at Lamberton, 1998.

Trt #	Row width	Asgrow variety	Desired pop'n	Plant Counts 6/11/98	Plant Counts 6/18/98	Plant Counts 9/18/98	Yield	Lodge rating	Plant ht.	Protein	Oil	Test wt.
	in.		plants/acre				bu/ac		in.	%	%	lbs/bu
1	10	1923	75000	63000	72000	63000	68.7	2.0	34.5	43.5	23.8	56.5
2	10	1923	100000	105000	108000	100000	67.6	2.0	36.0	43.2	23.9	57.1
3	10	1923	125000	117000	120000	109000	73.8	2.0	37.3	43.5	23.8	56.7
4	10	1923	150000	121000	120000	120000	70.0	2.0	36.8	43.7	23.6	56.9
5	10	1923	175000	157000	169000	154000	67.3	2.0	38.0	44.0	23.3	56.5
6	10	1923	200000	186000	184000	168000	71.2	2.0	38.0	43.9	23.4	57.0
7	10	1923	225000	209000	196000	188000	71.1	2.8	39.8	44.5	23.1	56.9
8	10	1923	250000	250000	252000	201000	67.8	2.8	39.8	44.5	23.0	56.6
9	10	2247	75000	68000	69000	59000	61.3	2.5	38.0	43.9	24.5	56.3
10	10	2247	100000	95000	97000	95000	64.4	2.5	38.5	44.2	24.3	55.7
11	10	2247	125000	113000	123000	114000	68.2	2.0	38.5	44.3	24.3	55.9
12	10	2247	150000	129000	126000	122000	63.3	2.8	40.8	44.6	23.9	56.1
13	10	2247	175000	146000	140000	142000	67.5	2.3	41.0	44.7	24.1	56.2
14	10	2247	200000	174000	183000	170000	66.0	2.8	41.8	44.8	23.9	56.1
15	10	2247	225000	178000	176000	163000	67.8	2.5	41.5	44.7	24.0	56.0
16	10	2247	250000	256000	250000	199000	64.0	2.8	41.3	44.9	23.8	55.8
17	10	1923	75000			76000	71.2	2.0	35.5	42.9	23.9	56.9
18	10	1923	100000			105000	66.6	2.0	37.3	43.5	23.7	56.9
19	10	1923	125000			118000	70.5	2.3	37.8	43.4	23.6	57.0
20	10	1923	150000			162000	69.3	2.0	37.8	44.0	23.4	56.9
21	10	2247	75000			71000	66.9	2.3	37.5	44.0	24.3	56.3
22	10	2247	100000			102000	65.0	2.3	39.5	44.6	23.9	56.0
23	10	2247	125000			107000	61.3	2.0	39.0	44.8	23.9	56.1
24	10	2247	150000			151000	64.0	2.3	39.8	44.4	24.1	56.0
25	30	1923	75000	73000	71000	70000	60.4	2.3	35.5	43.0	23.9	56.4
26	30	1923	100000	120000	95000	92000	61.9	2.0	36.5	43.3	23.8	56.7
27	30	1923	125000	115000	113000	103000	62.9	2.0	37.8	43.3	23.8	56.7
28	30	1923	150000	126000	130000	128000	64.2	2.0	37.3	43.9	23.4	56.8
29	30	1923	175000	149000	150000	127000	61.6	2.5	36.3	43.6	23.6	56.5
30	30	1923	200000	186000	187000	160000	61.3	2.5	38.3	44.1	23.3	56.2
31	30	1923	225000	189000	190000	147000	63.2	2.5	36.5	44.1	23.3	56.4
32	30	1923	250000	197000	199000	158000	57.7	2.5	35.5	43.8	23.5	56.2
33	30	2247	75000	56000	57000	51000	54.7	2.8	37.3	43.7	24.6	55.3
34	30	2247	100000	94000	94000	89000	59.2	2.0	38.5	44.2	24.4	55.7
35	30	2247	125000	106000	112000	103000	61.4	2.5	38.5	44.5	24.1	55.9
36	30	2247	150000	113000	117000	104000	61.4	2.0	37.8	44.4	24.1	55.9
37	30	2247	175000	132000	134000	115000	54.4	2.3	39.5	44.7	24.0	56.0
38	30	2247	200000	188000	191000	154000	59.9	2.5	38.8	44.8	23.9	56.1
39	30	2247	225000	194000	179000	173000	62.4	2.8	40.3	44.8	23.8	55.8
40	30	2247	250000	204000	191000	168000	59.9	2.8	40.3	45.0	23.8	56.1
41	30	1923	75000			46000	51.6	2.0	35.3	42.8	24.0	56.9
42	30	1923	100000			103000	62.8	2.0	36.3	43.0	23.9	56.6
43	30	1923	125000			115000	62.6	2.0	36.0	43.5	23.8	56.6
44	30	1923	150000			148000	59.5	2.0	36.5	43.5	23.6	56.6
45	30	2247	75000			59000	52.6	2.0	36.5	44.3	24.4	56.2
46	30	2247	100000			95000	60.2	2.3	38.5	44.1	24.3	55.9
47	30	2247	125000			115000	63.8	2.5	38.5	44.5	24.2	55.4
48	30	2247	150000			126000	62.0	2.8	38.8	44.5	24.1	55.9

Averages over row spacings	Plant Counts 6/11/98	Plant Counts 6/18/98	Plant Counts 9/18/98	Yield	Lodge rating	Plant ht.	Protein	Oil	Test wt.
Variety	plants/acre			bu/ac		in.	%	%	lbs/bu
10-inch rows									
Asgrow 1923	151000	152000	138000	69.7	2.2	37.5	43.8	23.5	56.8
Asgrow 2247	145000	147000	133000	65.3	2.5	40.2	44.5	24.1	56.0
30-inch rows									
Asgrow 1923	144000	142000	123000	61.6	2.3	36.7	43.6	23.6	56.5
Asgrow 2247	136000	134000	120000	59.2	2.4	38.8	44.5	24.1	55.8

PLANTING DATE EFFECTS ON CORN AND SOYBEAN DEVELOPMENT AND YIELD AT LAMBERTON - 1998

P.M. Porter and S.R. Quiring[1]

Abstract

Planting date studies were conducted at the Southwest Research and Outreach Center near Lamberton in 1998 to determine the influence of planting date on crop yield. Two soybean varieties (DeKalb CX232 and Parker) were planted on seven dates at 7 day intervals and two corn hybrids (P3730 and NK4640) were planted on five dates at 7 day intervals beginning April 14. In general, soybean yields were greatest when planted between April 28 and May 12. The soybean variety CX232 yielded substantially more than Parker. The two corn hybrids yielded the same, however, NK4640 was drier than P3730 at harvest. Planting date influenced yield to a small extent, with the corn planted in April yielding only 5% more than the corn planted in mid-May. The earliest planted corn had lower oil and protein content than the later planted corn, whereas the earliest planted corn had higher starch content than the later planted corn.

Experimental Procedure

SOYBEAN: Two soybean varieties were planted on seven dates at 7 day intervals (April 14, 21, & 28 and May 5, 12, 19, & 26) in a randomized complete block design with four replicates of each treatment. Varieties were DeKalb CX232 (2.3 MG) and Parker (1.5 MG). Soil test results were 22 ppm P_2O_5, 170 ppm K_2O, and 6.5 pH. Row spacing was 30 inches, and the seeding rate was approximately 160,000 plants/acre. Herbicides included Dual II at 2½ pints/acre, and Raptor at 5 ounce/acre.

CORN: Two corn hybrids were planted on five dates at 7 day intervals (April 14, 21, & 28 and May 5 & 12) in a randomized complete block design with four replicates of each treatment. Hybrids were Pioneer Brand P3730 (100-day relative maturity), and Northrup King Brand NK4640 (105-day relative maturity). Anhydrous ammonia (125 lb N ac^{-1}) was applied in Fall 1997. Soil test was 28 ppm P_2O_5, 118 ppm K_2O, and 6.0 pH. Row spacing was 30 inches, and the seeding rates was approximately 30,0000 pants/acre. Herbicides included Dual II at 2½ pints/acre, Accent at 2/3 ounce/acre, and Buctril at 1 pint/acre.

Soybean and corn plant heights and growth stages were monitored bi-weekly through early July.

Results and Discussion

SOYBEAN YIELDS: Soybean yields were influenced by planting date and variety (Table 1). In addition, there was a plating date by variety interaction, however, in general the yields were highest when planted between April 28 and May 12. Yields of CX232 dropped off at the later planting dates, whereas yields of Parker were lowest for the earlier planting dates but remained relatively high for the later planting dates. The variety CX232 yielded substantially more than Parker, except for the latest planting date.

CORN YIELDS: The two corn hybrids responded similarly to planting date: the earlier planting dates yielded more than the later planting dates (Table 2). The yield difference between the earliest and latest planting dates was only 5.4%. As expected, the earliest planted corn was the driest at harvest, and the latest planted corn was the wettest at harvest. NK4640 was drier than P3730 at harvest.

Date of planting influenced the oil, protein, and starch content. The earliest planted corn had lower oil and protein content than the later planted corn, whereas the earliest planted corn had higher starch content than the later planted corn. Protein and starch were not influenced by hybrid selection, however NK4640 had lower oil content than P3730.

PLANT HEIGHTS AND GROWTH STAGES: The early planted soybeans were were taller than the latest planted soybeans, however, by 9 July the plant height differences were relatively small for the first 4 planting dates (Table 3). The early warm spring pushed the maturity on the soybeans, resulting in the early planted soybean going from V5 to R1 as early as 22 June. There was a dramatic difference in plant height and growth stage between Parker soybeans planted in 1997 and 1998. By 9 July the plant height for soybeans planted on comparable dates was approximately 2½ times taller in 1998 compared with 1997 (Table 4).

Corn planted on April 14, 21, and 28 was at pretty much the same stage of growth and plant height by early June, regardless of planting date (Table 5). The later planted corn, however, was delayed in maturity by one or two leaf stages and was also shorter in height. The influence of the growing season is evident in the shorter plant heights and delayed crop maturity in 1997 compared with 1998 (Table 6).

Conclusions

In 1998, weather conditions permitted the planting of soybeans exactly 7 days apart for 7 straight plantings. The soybean varieties we selected to study responded differently to planting date, however, one variety (CX232) consistently out-yielded the other variety (Parker) except for the latest planting date. The two corn hybrids yielded the same, however, NK4640 had less grain moisture at harvest than P3730. Later planted corn had higher oil and protein contents but lower starch contents than the earlier planted corn. These data support the recommendation to plant corn prior to soybeans in this environment.

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Table 1. Soybean yields in a trial with two varieties and seven planting dates at Lamberton, 1998.

	Planting date	Variety CX232	Variety Parker	Average
		bu/ acre		
1	04/14/98	52.2	40.9	46.5 b
2	04/21/98	52.2	40.0	46.1 b
3	04/28/98	52.8	44.2	48.5 a
4	05/05/98	53.0	44.6	48.8 a
5	05/12/98	50.8	46.6	48.7 a
6	05/19/98	47.8	42.5	45.1 b
7	05/26/98	45.2	44.7	44.9 b
	Average	50.6	43.4	47.0

ANOVA

CV (%) = 3.7

Effect	df	Pr>f	
Replication	3	0.05	
Variety	1	<0.001	Var. LSD(0.05) = 0.95
Date of planting	6	<0.001	DoP LSD(0.05) = 1.80
Var. X DoP	6	<0.001	

Table 2. Corn moisture at harvest, yields, and kernel oil, protein, and starch content in a trial with two hybrids and five planting dates at Lamberton, 1998.

Hybrid	Date of planting	Moisture	Yield	Oil	Protein	Starch
		%	bu/A	%	%	%
NK4640	April 14	16.5	178	4.21	8.51	73.2
	April 21	16.5	172	4.28	8.82	72.8
	April 28	17.5	168	4.36	9.01	72.6
	May 5	18.5	172	4.49	9.27	72.2
	May 12	20.3	169	4.61	9.17	72.0
P3730	April 14	18.6	179	4.40	8.71	73.2
	April 21	19.2	184	4.57	8.86	72.8
	April 28	18.9	175	4.54	9.12	72.5
	May 5	20.7	167	4.62	9.19	72.1
	May 12	22.1	167	4.79	9.36	71.6
Average of two hybrids	April 14	17.5c	178a	4.31 c	8.61c	73.2a
	April 21	17.8c	178a	4.43 bc	8.84b	72.8b
	April 28	18.2c	172ab	4.45 bc	9.07a	72.5c
	May 5	19.6b	169ab	4.56ab	9.23a	72.1d
	May 12	21.2a	168 b	4.70a	9.26a	71.8e
	CV (%)	4.1	5.3	3.0	2.3	0.4
	Mean	18.9	173	4.50	9.00	72.5
	Effects	Pr>F				
	Replication	.93	.0001	.40	.15	.22
	Hybrid	.0001	.39	.0001	.18	.20
	Date of planting	.0001	.09	.0001	.0001	.0001
	Hybrid X DoP	.55	.34	.62	.60	.50

Table 3. Stage of growth and plant height of 2 soybean varieties planted on 7 dates from April 14 through May 26 at Lamberton.

Variety & planting date	Date of observation															
Stage of Growth	5/8	5/18	5/21	5/27	5/29	6/2	6/5	6/9	6/11	6/15	6/19	6/22	6/26	6/30	7/2	7/9
CX232																
4/14/98	VC	V1	V1	V1	V2	V2	V2	V3	V3	V4	V5	R1	R1	R2	R2	R2
4/21/98	VE	V1	V1	V1	V2	V2	V3	V3	V3	V5	R1	R1	R1	R2	R2	R2
4/28/98	-	VC	V1	V1	V1	V2	V2	V2	V3	V3	V4	V5	R1	R1	R2	R2
5/5/98	-	VE	VC	VC	V1	V1	V1	V2	V2	V3	V3	V4	V5	R1	R1	R2
5/12/98	-	-	VE	VE	VC	VC	V1	V1	V2	V2	V3	V4	V5	R1	R1	R1
5/19/98	-	-	-	-	VE	VC	VC	VC	VC	V2	V2	V3	V4	V4	V5	V5
5/26/98	-	-	-	-	-	VE	VE	VC	VC	V1	V2	V2	V3	V3	V4	V5
Parker																
4/14/98	VC	VC	V1	V2	V2	V3	V3	V3	V4	V5	R1	R2	R2	R2	R2	R2
4/21/98	VC	VC	V1	V1	V2	V2	V2	V3	V3	V4	R1	R1	R2	R2	R2	R2
4/28/98	-	VC	VC	V1	V2	V2	V2	V2	V3	V4	R1	R1	R1	R2	R2	R2
5/5/98	-	VE	VC	V1	V1	V1	V2	V2	V2	V4	V5	V5	R1	R1	R2	R2
5/12/98	-	-	VE	VC	VC	VC	V1	V2	V2	V3	V3	V4	V5	R1	R1	R2
5/19/98	-	-	-	VE	VE	VC	VC	VC	VC	V1	V2	V2	V4	V5	V5	R1
5/26/98	-	-	-	-	-	VE	VE	VC	VC	VC	V1	V2	V3	V4	V4	V5
Plant height (in inches)	5/8	5/18	5/21	5/27	5/29	6/2	6/5	6/9	6/11	6/15	6/19	6/22	6/26	6/30	7/2	7/9
CX232																
4/14/98	0.9	3.4	4.1	5.8	5.6	7.1	7.6	8.3	8.9	10.1	13.0	14.3	17.5	20.5	23.6	27.1
4/21/98	0.5	2.9	3.9	5.3	5.6	7.4	7.8	8.6	9.0	10.4	12.6	15.3	16.8	21.0	24.3	26.8
4/28/98	0.0	2.3	3.1	4.6	4.8	6.4	7.1	7.8	8.5	9.5	10.8	14.1	15.3	21.0	24.0	26.5
5/5/98	0.0	1.5	2.6	3.9	4.4	5.4	5.9	6.8	7.3	9.3	9.9	12.4	15.6	18.8	23.1	26.3
5/12/98	0.0	0.0	0.9	3.0	3.4	3.9	4.4	5.6	6.0	7.5	10.0	11.6	14.5	19.8	22.3	25.5
5/19/987	0.0	0.0	0.0	0.3	1.5	1.9	2.9	3.6	4.0	5.5	7.8	8.6	10.5	15.4	16.6	21.0
5/26/98	0.0	0.0	0.0	0.0	0.0	0.6	1.1	2.4	3.0	4.3	5.3	7.1	8.8	13.6	15.5	18.0
Parker																
4/14/98	1.0	3.0	3.9	5.6	6.0	7.0	7.5	9.3	10.3	11.4	13.9	16.5	18.4	24.8	27.3	31.3
4/21/98	0.5	2.8	4.1	5.8	5.9	6.1	7.4	8.1	9.1	11.0	12.6	15.6	17.6	24.1	26.3	31.5
4/28/98	0.0	2.7	3.3	5.1	5.5	6.4	7.0	7.9	8.3	9.4	12.8	15.1	16.9	23.3	26.9	29.3
5/5/98	0.0	1.6	2.8	4.1	5.1	5.9	6.3	6.9	7.8	9.6	12.1	13.6	16.8	22.3	25.1	29.4
5/12/98	0.0	0.0	0.6	2.5	3.8	3.8	4.5	5.4	6.0	7.5	9.9	12.6	15.1	19.9	24.6	27.4
5/19/98	0.0	0.0	0.0	0.4	1.4	1.9	2.6	3.4	4.0	5.3	7.6	9.0	11.5	16.8	19.9	24.8
5/26/98	0.0	0.0	0.0	0.0	0.0	1.3	1.0	2.4	2.9	3.6	5.4	6.9	8.3	13.5	16.4	20.9

Table 4. Plant height and stage of growth comparisons for Parker soybean in date of planting studies at Lamberton in 1997 and 1998.

Date planted	Plant height in inches					Stage of growth				
	5/23/97	5/26/97	6/6/97	6/23/97	7/11/97	5/23/97	5/26/97	6/6/97	6/23/97	7/11/97
4/23/97	0.4	1.0	2.6	4.9	12.5	VE	VE	V2	V3	R1
5/1/97	0.4	1.0	2.6	5.3	14.5	VE	VE	V2	V3	R1
5/9/97	0.0	0.1	1.0	4.5	11.0	-	-	VE	V2	V7
5/20/97	0.0	0.0	1.3	4.4	12.3	-	-	VE	V2	V7
5/29/97	0.0	0.0	0.5	4.0	10.8	-	-	VE	V2	V7
6/9/97	0.0	0.0	0.0	0.0	4.8	-	-	-	VE	V4
6/17/97	0.0	0.0	0.0	0.0	4.5	-	-	-	VE	V4
	5/21/98	5/27/98	6/5/98	6/22/98	7/9/98	5/21/98	5/27/98	6/5/98	6/22/98	7/9/98
4/14/98	3.9	5.6	7.5	16.5	31.3	V1	V2	V3	R2	R2
4/21/98	4.1	5.8	7.4	15.6	31.5	V1	V1	V2	R1	R2
4/28/98	3.3	5.1	7.0	15.1	29.3	VC	V1	V2	R1	R2
5/5/98	2.8	4.1	6.3	13.6	29.4	VC	V1	V2	V5	R2
5/12/98	0.6	2.5	4.5	12.6	27.4	VE	VC	V1	V4	R2
5/19/98	0.0	0.4	2.6	9.0	24.8	-	VE	VC	V2	R1
5/26/98	0.0	0.0	1.0	6.9	20.9	-	-	VE	V2	V5

Table 5. Stage of growth and plant height of two corn hybrids planted on seven dates from April 14 through May 26 at Lamberton.

Variety & planting date	Date of observation															
Stage of Growth																
	5/8	5/18	5/21	5/26	5/29	6/2	6/5	6/9	6/11	6/15	6/19	6/22	6/26	6/30	7/2	7/9
NK4640																
4/14/98	V1	V3	V3	V4	V5	V5	V5	V5	V6	V7	V7	V7	V9	V11	V11	V15
4/21/98	V1	V2	V2	V4	V5	V5	V5	V6	V6	V7	V7	V8	V9	V10	V12	V15
4/28/98	VE	V2	V2	V3	V4	V5	V5	V5	V6	V7	V7	V8	V9	V11	V12	V15
5/5/98	-	V1	V1	V2	V3	V4	V4	V4	V4	V5	V6	V7	V7	V8	V9	V12
5/12/98	-	-	VE	V2	V2	V3	V4	V4	V4	V5	V5	V6	V7	V8	V9	V12
P3730																
4/14/98	V1	V3	V3	V4	V4	V5	V5	V5	V6	V7	V7	V8	V9	V11	V12	V15
4/21/98	V1	V2	V3	V3	V4	V5	V5	V6	V6	V6	V7	V7	V9	V10	V12	V15
4/28/98	VE	V2	V2	V3	V3	V5	V5	V5	V6	V6	V7	V8	V8	V10	V11	V14
5/5/98	-	V1	V1	V2	V3	V4	V4	V4	V4	V5	V6	V7	V7	V8	V10	V12
5/12/98	-	-	VE	V2	V3	V3	V3	V3	V4	V5	V5	V6	V7	V8	V9	V12
Plant height (in inches)																
	5/8	5/18	5/21	5/26	5/29	6/2	6/5	6/9	6/11	6/15	6/19	6/22	6/26	6/30	7/2	7/9
NK4640																
4/14/98	2.1	4.1	5.3	5.9	8.3	11.4	11.9	12.4	13.3	15.4	17.5	25.0	32.8	41.0	51.4	76.9
4/21/98	2.0	4.0	5.0	5.6	7.3	8.5	11.3	11.8	12.3	14.4	17.4	26.0	33.0	41.0	50.5	75.9
4/28/98	0.6	3.5	4.1	4.5	6.8	9.9	8.1	11.1	11.9	13.9	15.8	25.3	32.5	42.3	52.0	75.8
5/5/98	0.0	2.1	3.4	3.8	5.8	6.6	7.8	8.0	8.6	10.6	13.5	21.5	25.0	33.1	42.5	65.9
5/12/98	0.0	0.0	2.1	2.9	3.9	6.0	6.4	7.4	7.9	9.3	11.5	19.5	23.8	32.3	39.3	64.6
P3730																
4/14/98	2.5	5.1	5.6	6.3	8.3	11.3	12.0	13.3	14.4	16.3	18.5	28.5	36.3	43.3	55.6	78.8
4/21/98	2.0	4.1	6.1	6.0	9.0	11.0	11.6	12.5	13.9	14.9	17.9	27.4	35.8	41.6	54.5	81.0
4/28/98	0.4	4.6	5.0	5.5	7.4	10.8	11.3	11.6	12.6	14.1	16.6	27.8	32.0	39.0	50.0	76.5
5/5/98	0.0	2.6	3.6	4.6	6.8	9.0	9.3	10.1	11.3	13.3	15.0	23.3	28.5	36.3	43.8	71.0
5/12/98	0.0	0.0	2.1	3.4	5.8	6.5	7.0	7.3	8.4	9.6	13.5	21.4	25.6	32.4	41.3	68.5

Table 6. Plant height and stage of growth comparisons for corn hybrids in date of planting studies at Lamberton in 1997 and 1998.

Date planted	Plant height in inches						Stage of growth					
Hybrid	5/20/97	5/26/97	6/6/97	6/13/97	6/23/97	7/10/97	5/20/97	5/26/97	6/6/97	6/13/97	6/23/97	7/10/97
P3531												
4/23/97	2.3	2.4	5.0	8.5	18.0	51.8	VE	VE	V1	V3	V4	V14
5/1/97	0.4	2.1	4.3	7.8	16.3	49.3	VE	VE	V1	V2	V4	V13
5/9/97	0.0	1.8	3.9	6.8	16.3	43.5	-	VE	VE	V2	V4	V13
5/20/97	0.0	0.0	2.9	5.0	12.8	36.0	-	-	VE	V1	V3	V11
5/30/97	0.0	0.0	1.0	3.5	10.0	30.0	-	-	VE	VE	V2	V11
P3769												
4/23/97	1.9	2.1	4.5	8.3	18.5	51.8	VE	VE	V1	V3	V4	V14
5/1/97	0.6	1.9	4.1	7.0	15.5	43.0	VE	VE	V1	V2	V4	V12
5/9/97	0.0	1.8	3.5	6.5	15.3	43.0	-	VE	VE	V2	V4	V12
5/20/97	0.0	0.0	3.5	4.5	12.0	37.5	-	-	VE	V1	V3	V12
5/30/97	0.0	0.0	1.0	3.5	8.3	27.0	-	-	VE	VE	V2	V10
	5/21/98	5/26/98	6/5/98	6/11/98	6/22/98	7/9/98	5/21/98	5/26/98	6/5/98	6/11/98	6/22/98	7/9/98
NK4640												
4/14/98	5.3	5.9	11.9	13.3	25.0	76.9	V3	V4	V5	V6	V7	V15
4/21/98	5.0	5.6	11.3	12.3	26.0	75.9	V2	V4	V5	V6	V8	V15
4/28/98	4.1	4.5	8.1	11.9	25.3	75.8	V2	V3	V5	V6	V8	V15
5/5/98	3.4	3.8	7.8	8.6	21.5	65.9	V1	V2	V4	V4	V7	V12
5/12/98	2.1	2.9	6.4	7.9	19.5	64.6	VE	V2	V4	V4	V6	V12
P3730												
4/14/98	5.6	6.3	12.0	14.4	28.5	78.8	V3	V4	V5	V6	V8	V15
4/21/98	6.1	6.0	11.6	13.9	27.4	81.0	V3	V3	V5	V6	V7	V15
4/28/98	5.0	5.5	11.3	12.6	27.8	76.5	V2	V3	V5	V6	V8	V14
5/5/98	3.6	4.6	9.3	11.3	23.3	71.0	V1	V2	V4	V4	V7	V12
5/12/98	2.1	3.4	7.0	8.4	21.4	68.5	VE	V2	V3	V4	V6	V12

TILLAGE MANANGEMENT IN CORN-SOYBEAN ROTATIONS AT THE SOUTHWEST RESEARCH AND OUTREACH CENTER

J.S. Strock, N.S. Eash, and L.D. Klossner[1]

ABSTRACT

Tillage management strategies that improve environmental quality and that are financially beneficial to growers is one of the missions of agricultural research. Tillage management strategies that reduce soil erosion potential, improve and/or maintain soil quality, and maximize yield potential are important to scientists and farmers. Five tillage systems were established in a corn – soybean rotation in 1986. The original tillage systems were: paraplow, ridge tillage, conventional tillage, reduced tillage, and spring tillage. In 1989, the paraplow treatment was discontinued and converted to no-tillage management. In 1994, five row management sub-treatments were added to the study. The row management sub-treatments were discontinued in 1996. No statistical differences were found among the five tillage system soybean yields in 1998. Corn yields were not significantly different for the ridge, reduced, and spring tillage systems. Long-term corn and soybean yield data (1986 – 1998) has shown that, for a majority of the time, the conventional tillage system has been the greatest yielding tillage system.

INTRODUCTION

This study was initiated in 1986, on a Normania clay loam, to evaluate crop growth, development, yield, soil hydraulic and structural properties, and other soil quality properties. Five tillage systems were evaluated in a corn-soybean rotation.

EXPERIMENTAL DESIGN AND TREATMENTS

The experimental design of the study was a randomized complete block design with four replications. Plot size was 50 feet by 155 feet. The five tillage systems were:

Plots planted to Corn
1) No-Tillage (no fall tillage)
2) Ridge-Tillage (no fall tillage)
3) Conventional (chisel plow - fall 1997)
4) Reduced (no fall tillage)
5) Flex Tillage (no fall tillage, spring tillage - 1998)

Plots planted to Soybean
1) No-Tillage (no fall tillage)
2) Ridge-Tillage (no fall tillage)
3) Conventional (moldboard plow - fall 1997)
4) Reduced (soil saver fall 1997)
5) Flex Tillage (no fall tillage, spring tillage - 1998)

RESULTS AND DISCUSSION

Conventional tillage corn and soybean yields were the highest of the five tillage systems in 1998 (Table 1 and Table 2). There were no significant treatment differences among the five tillage system soybean yields. Corn yields were not significantly different for the ridge, reduced, and spring tillage systems. No-tillage corn had the lowest yield at 169.2 bu/A.

Long-term corn yield data (1986 – 1998) has shown that the conventional tillage system has produced the highest yield, 134.2 bu/A, of the five tillage systems in 10 out of 13 years. The long-term average yield of corn grown with conventional tillage has averaged 6 bu/A or more over the other four tillage systems. Long-term soybean yield data (1986 – 1998) has also shown that the conventional tillage system has been the highest yielding, 43.0 bu/A, of the five tillage systems in 8 out of 13 years. The long-term average soybean yield with conventional tillage has averaged 2.1 bu/A or more over the other four tillage systems.

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Table 1. Corn yields from 1986 through 1998 from a corn-soybean management system at Lamberton.

Tillage	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	Avg.
							bu/A							
No-till	142.0	132.4	73.7	122.2	114.5	133.4	134.2	71.9	146.7	117.4	117.1	92.0	169.2	120.5
Ridge	145.4	125.4	82.2	132.6	118.4	128.9	145.3	72.0	162.2	120.4	119.0	118.0	174.3	126.5
Conv.	141.5	136.4	76.7	139.0	137.2	132.2	153.6	76.6	166.3	134.4	134.5	128.8	187.1	134.2
Reduced	139.8	124.8	70.1	128.1	120.5	133.6	130.7	75.1	162.7	126.2	123.3	114.6	180.2	125.4
Spr. till	132.4	119.8	65.4	131.8	122.8	132.6	136.6	73.4	164.5	127.0	129.3	112.8	179.5	125.2
$LSD_{0.05}$	11.7*	6.7*	6.7*	6.9*	6.0*	6.2	10.2*	4.3*	6.9*	8.7*	13.2*	14.8*	6.4*	

* Significant treatment difference

Table 2. Soybean yields from 1986 through 1998 from a corn-soybean management system at Lamberton.

Tillage	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	Avg.
							bu/A							
No-till	47.4	39.3	26.9	40.9	44.7	40.3	35.9	19.8	41.7	40.5	42.1	25.3	38.6	37.2
Ridge	47.2	38.7	26.7	49.2	48.7	41.3	35.3	31.5	42.6	38.9	42.5	38.9	36.4	39.8
Conv.	47.9	38.8	32.7	48.8	51.8	48.0	37.3	38.9	47.1	42.4	43.2	42.1	39.4	43.0
Reduced	46.7	39.5	26.3	45.8	51.6	46.2	37.7	34.5	43.1	40.3	42.2	41.4	37.0	40.9
Spr. till	48.9	37.0	26.2	47.1	45.4	44.4	36.5	33.1	41.6	43.3	40.8	37.9	36.9	39.9
$LSD_{0.05}$	1.5*	1.4*	1.5*	2.6*	2.6*	3.5*	2.0*	2.9*	1.9*	1.5*	3.5	5.4*	4.1	

* Significant treatment difference

INFLUENCE OF TILLAGE AND SOIL TEMPERATURE ON NITRATE-N

G. Nelson and G. Rehm[1]

ABSTRACT

The fall conversion of ammonium -N to nitrate-N from urea applications made at soil temperatures at a 6-inch depth of 60°F, 50°F, and 40°F was evaluated under no-tillage, fall chisel plow, and fall moldboard plow tillage systems. Urea was broadcast the fall of 1997, nitrate-N soil testing was conducted the fall of 1997 and spring of 1998, and grain yield was recorded the fall of 1998. October 1997 soil temperatures were warmer at an 8-inch depth than at a 6-inch depth. Shallower incorporation of urea, at the 50°F 6-inch soil temperature, resulted in less total nitrification than with deeper incorporation.

INTRODUCTION

Fall nitrogen fertilizer applications for the following years crop are an accepted management practice in western Minnesota when limited to incorporation of ammonium fertilizers such as urea or anhydrous ammonia once soil temperatures are below 50°F (6-inch depth). Ammonium fertilizers applied to soils below 50°F will have limited fall conversion of ammonium-N to nitrate-N, and thus limit leaching losses. Relationships between soil temperature and nitrification have been investigated frequently and from this work the benchmark guide of 50°F soil temperatures at a 6-inch depth has been used for determining when safe fall N application may commence. Typically 6-inch soil temperatures are recorded in undisturbed soil profiles. However, temperatures recorded in undisturbed soil profiles at a 6-inch depth fail to take temperature changes throughout the soil profile during declining fall temperatures and depth of fertilizer incorporation into account. Some concerns with using a standard 6-inch soil temperature for N recommendations are: 1.) What is actual placement depth of the fertilizer in the soil profile, 2.) What is the relationship between soil temperatures at a 6-inch depth verses shallower or deeper depths during declining fall temperatures, and 3.) What is the impact of tillage on soil temperature. This study will examine conversion of urea fertilizer (ammonium-N) to nitrate-N based on depth of nitrogen incorporation into the soil profile by 3 tillage methods at soil temperatures of 60°F, 50°F, and 40°F at a 6-inch depth.

MATERIALS AND METHODS

The experimental design was a randomized complete block split plot. Main plots were application date and sub-plots were tillage system. Plot size was 10 feet wide (4-30 inch rows) and 45 feet long. There were 10 treatments, 3 application dates based on soil temperature in combination with 3 tillage treatments and an untilled/unfertilized check. The study was seeded to Pioneer 38W36 corn. Nitrogen was fall applied as urea at 130lb N/ac on all treatments. The urea was applied on 3 dates (soil temperatures, 60°F, 50°F, and 40°F), soil temperature was based on an undisturbed 6-inch soil temperature measurement made adjacent to the plot area. Minimum and maximum soil temperatures were recorded at 4, 6,and 8-inch depths using Campbell soil thermistors. Moldboard plow (MP), chisel plow (CP), and no tillage (NT) were performed on designated plots immediately following urea application. MP depth was 10-12 inches and CP depth was 6-8 inches. Urea application and tillage were performed on October 7th at (60°F), October 15th at (50°F), and October 24th at (40°F). All plots were soil sampled on November 5, 1997, after soil temperature at an 8-inch depth remained below 40°F. Plots were soil sampled in 0-3, 3-6, 6-9, and 9-15 inch depth increments, 4 subsamples per depth increment were combined. MP and CP treatments were field cultivated on May 1, 1998 for seedbed preparation. There was no spring tillage on NT plots. The study was seeded to corn and then soil sampled, in the same manner as the previous fall, on May 1st. The study was harvested on October 2, 1998.

RESULTS

<u>Conversion to Nitrate (Nov.5, 1997 soil samples)</u>

Daily soil temperatures at three depths are shown in Table 1. In general, temperatures were warmer as depth increased. As air temperatures decline in the fall the soil immediately below the surface cools first while deeper soils in the profile remain warmer. Figure 1 shows total nitrates found in the 0-15 inch profile from soil samples taken on November 5, 1997. When urea was applied at 130 lbs/N/ac at 60°F, 64%, 54%, and 46% (calculated by subtracting nitrates found in the CK treatment) of applied urea was converted to nitrate-N under NT, CP, and MP tillage, respectively. This magnitude of nitrification was expected because soil temperatures were between 57°F and 63°F throughout the soil profile. Total precipitation of 2.06 inches, spread over several days, followed the 60°F application (prior to 50°F application), which incorporated the NT urea into the soil and provided ideal conditions for nitrification to proceed. Prior to this rain the soil profile was dry. When urea was applied at 50°F 5%, 13%, and 25% of urea-N was converted to nitrate-N in the NT, CP, and MP, respectively. At 40°F 1%, 2%, and 5% of urea-N was converted to nitrate-N in the NT, CP, and MP, respectively. Nitrification increased significantly as tillage depth increased from NT, to CP, to MP at the 50°F application. At the 40°F application there was no

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significant difference in nitrification between the 3 tillage systems. Thus, the extent of urea conversion to nitrate-N varies with both tillage and soil temperature. Regardless of tillage little nitrification occurs when soil temperatures are below 50°F.

Figure 2 shows total and incremental nitrate conversion that took place throughout the 0-15 inch soil profile with the CK values subtracted from the treatments. Soil temperatures were 3° - 4°F warmer at the 8-inch depth than at the 6-inch depth and 3° - 4°F warmer at the 6-inch depth than at the 4-inch depth at all application dates. At the 50°F application date soil temperatures at the 8-inch MP depth remained above 50°F for 5 days after application. When urea was applied at 50°F the majority of nitrification in the CP treatment took place in the 0-3 inch profile, while in the MP treatment the majority of nitrification took place in the 3-9 inch profile. Almost twice as much N was nitrified in the MP treatment as in the CP treatment. No significant rainfall was recorded between the 50°F application and November 5th soil testing. At 60°F applications where we expect rapid conversion of N the majority of nitrification took place in the same profiles as at 50°F. This indicates that a CP operating 6-8 inches deep was placing the most of the urea 0-3 inches deep and a MP operating 8-10 inches deep was placing the most of the urea 3-9 inches deep.

Conversion to Nitrate and N Losses (May 1, 1998 Soil Samples)

The total precipitation between the November 5th and May 1st soil sampling dates was 5.69 inches, a drier than normal winter. Soil temperatures went above 50°F on April 23rd and remained above thereafter, providing for earlier than normal spring planting. Nitrification proceeded rapidly. Figure 3 shows total and incremental nitrates found in the 0-15 inch soil profile on May 1st. Nitrate-N levels declined in the 0-15 inch profile from the previous fall in all tillage treatments when urea was applied at 60°F, an indication that nitrates were moved below the 15-inch profile. Nitrate-N levels increased in all 50°F and 40°F treatments. Of the 50°F and 40°F treatments the highest spring nitrate-N levels were found in the MP treatment at 50°F and this treatment also had the highest nitrate content in the 9-15 inch profile. The majority of the nitrates were located in the bottom of the profile with 60°F applications and in the top of the soil profile with 40°F applications. CP treatments at 50°F or 40°F resulted in almost identical nitrate-N positioning in the profile. N movement and position below the 15-inch profile was not measured.

Grain Yield

There were no significant differences in grain yield in 1998 due to application date (Pr>F .1619) or tillage practice (Pr>F .1714). An early planting date with warm temperatures and dry weather, followed by regularily spaced rainfall and a long growing season resulted in ideal growing conditions. Grain yields are shown in Table 2.

Table 2. Grain yield, bu/ac, on 3 tillages at 60°F, 50°F, 40°F, 6-inch soil temperatures.

	Urea Application 60°F	Urea Application 50°F	Urea Application 40°F	Mean
No Tillage (NT)	189.7	172.2	172.9	178.3
Chisel Plow (CP)	183.4	185.7	186.6	185.2
Moldboard Plow (MP)	188.0	183.7	193.7	188.4
Mean	187.0	180.5	184.4	

CONCLUSIONS

Best Management Practices necessitate that we control fall conversion of ammonium-N to nitrate-N as much as possible. Treatments in this study had large fall nitrate conversions and nitrates in some of those treatments leached beyond the 0-15 inch soil profile by early May. Although grain yields were not influenced by nitrate losses during this study year there is potential for significant N losses in wetter, more unfavorable springs.

Applying urea at 130 lbs/N/ac at 60°F soil temperatures resulted in fall nitrate accumulations of 83 lbs, 70 lbs, and 60 lbs, over the check treatment, in the NT, CP, and MP treatments in a 0-15 inch soil profile. These are fall nitrate conversion rates of 64% to 46% while BMP would like to keep this conversion rate to less than 10%. Fall urea applications at 40°F had less than 5% of applied urea converted to nitrate-N.

Fall urea applications at the benchmark 50°F 6-inch soil temperature recommendation resulted in 5% (NT), 13% (CP), and 25% (MP) of urea ammonium-N converted to nitrate-N by soil freeze-up on November 5th. The conversion to nitrate-N was a function of placement, driven by slight soil temperature changes in the profile. Soil temperatures were 3° - 4°F warmer at 8 inches than at 6 inches and were 3° - 4°F warmer at 6 inches than at 4 inches. In the NT treatment where urea was not incorporated only 5% of the urea was converted to its nitrate form. However, urea placed on surface soils is highly susceptible to spring N losses. In the CP treatment with an operating tillage depth of 6-8 inches, 53% of total nitrates formed were found in the 0-3 inch profile, 15% in the 3-6 inch profile, but only 13% of total N applied was converted to its nitrate form. The shallow incorporation associated with the CP left the urea in the colder surface soils. In the MP treatment with an operating tillage depth of 8-10 inches, 64% of total nitrates formed were found in the 3-9 inch profile, and 25% of total N applied was converted to its nitrate form. This indicates that placement in deeper, warmer soils, increases nitrification above accepted BMP levels based on a 6-inch soil temperature. Shallower CP incorporations, where the soil is coolest during dropping fall temperatures comply fairly closely with the 50°F soil temperature benchmark recommendation. Shallower incorporation during early fall urea application and saving deeper incorporation for later fall urea applications could reduce total fall nitrification.

Table 1. Average soil temperatures at 4, 6, and 8 inch depths, (Degrees Fahrenheit).

Oct.	Air	4 Inch	6 inch	8 inch	Precip.	Oct.	Air	4 Inch	6 inch	8 inch	Precip.
1	57	56	59	62		17	48	44	47	51	
2	61	54	56	62		18	56	47	49	52	
3	68	60	62	64		19	56	50	52	55	
4	62	58	61	64	0.01	20	38	42	47	52	
5	62	57	60	63	trace	21	41	41	44	48	
6	63	60	63	66	0.13	22	29	36	40	44	
7	61	57	**60 (60F)**	63	trace	23	33	34	38	42	
8	70	60	62	64		24	42	38	**41 (40F)**	43	trace
9	62	57	61	65	0.6	25	35	36	39	43	
10	49	48	53	57		26	30	35	38	41	
11	57	50	53	57	0.25	27	21	30	35	39	
12	73	62	62	64	0.14	28	34	32	35	38	
13	50	50	55	60	1.05	29	42	38	39	41	
14	37	39	45	51	0.02	30	42	36	39	42	
15	44	42	**45 (50F)**	48		31	45	39	41	44	trace
16	47	45	48	52							

Figure 1. Total Nitrate-N, November 5, 1997.

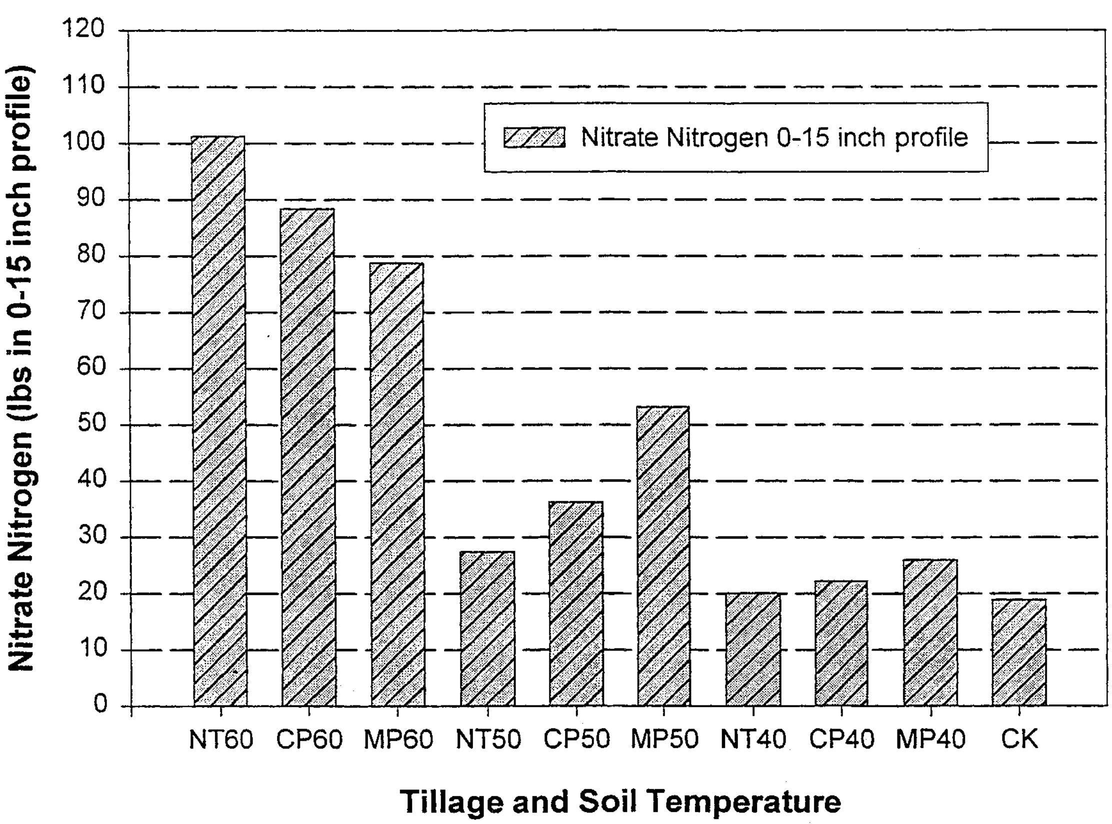

Figure 2. Incremental Nitrate-N, November 5, 1997.

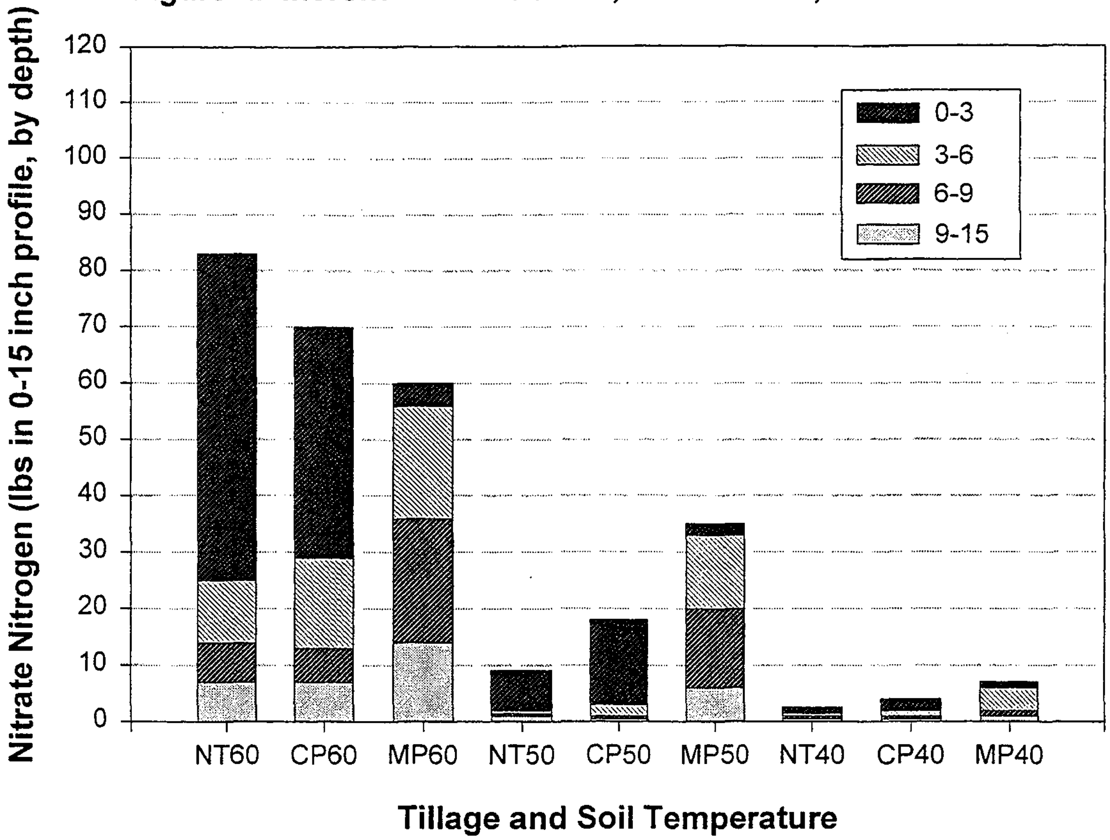

Figure 3. Incremental Nitrate-N, May 1, 1998.