Red Norland and Russet Norkotah Response to Nitrogen Source, Timing, and Rate

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Summary: A field experiment was conducted for the second year at the Sand Plain Research Farm in Becker, Minn. to evaluate the effects of nitrogen source, timing, and rate on yield and quality of Red Norland and Russet Norkotah potato. For each variety, nine N treatments were evaluated, which included a zero N control. Four of the nine treatments were conventional N sources with the following N rates (lb/A): 160 and 220 split applied urea, 220 preplant applied urea and 220 emergence applied urea for Red Norland and 180 and 240, 240 preplant applied urea and 240 emergence applied urea for Russet Norkotah. Four of the seven treatments were ESN: 160 and 220 lb N/A preplant and 160 and 220 lb N/A banded at planting for Red Norland and 180 and 240 lb N/A preplant and 180 and 240 lb N/A banded at planting for Russet Norkotah. A starter N rate of 40 lb N/A as diammonium phosphate was included in the total N rate applied. Release of N from ESN was similar to that recorded in 2008 and about 20-30 days faster than that recorded in years prior to 2008, suggesting that the coating was either different or perhaps subjected to more abrasion. Soil chemical properties had a major influence on potato response to ESN in application in 2009. Soil pH was 4.8 and soil P was 29 ppm prior to planting. Growth and yield of both varieties was poor when ESN was applied in a band at planting suggesting that roots were slow to reach the band. The preplant applied urea treatment resulted in higher yields for both varieties than urea applied at emergence. Yields with preplant ESN were similar to those with preplant urea and this timing resulted in the best performance for both varieties. Leaching was not a major factor in 2009 so early applied N as urea was not lost during the season.

Background: Previous studies with ESN have focused on late maturing processing cultivars. Preliminary ESN demonstrations have shown some promise with early and mid season maturing cultivars such as 'Red Norland' and 'Russet Norkotah' if the application is made at planting or earlier. As with late maturing cultivars, the advantage of using ESN is that multiple N fertilizer applications can be reduced or eliminated. In addition, the potential for N losses with early season rainfall may be minimized. The overall objective of this study is to evaluate the effects of ESN applications on yield and quality of Red Norland and Russet Norkotah potato. This was the second year of the study.

Materials and Methods

This study was conducted at the Sand Plain Research Farm in Becker, Minnesota on a Hubbard loamy sand soil. The previous crop was rye. Selected soil chemical properties before planting in the plot area planted to Red Norland were as follows (0-6"): water pH, 4.8; buffer pH, 6.0; organic matter, 2.2%; Bray P1, 29 ppm; ammonium acetate extractable K, Ca, and Mg, 78, 363, and 42 ppm, respectively; Ca-phosphate extractable SO_4-S, 4.5 ppm; and DTPA extractable Zn, Cu, Fe, and Mn, 1.4, 0.5, 122.0, and 36.4 ppm, respectively. Extractable nitrate-N and ammonium-N in the top 2 ft prior to planting were 10.0 and 15.6 lb/A, respectively.

Selected soil chemical properties before planting in the Russet Norkotah plot area were as follows (0-6"): water pH, 5.0; organic matter, 1.7%; Bray P1, 23 ppm; ammonium acetate extractable K, Ca, and Mg, 59, 301, and 36 ppm, respectively; Ca-phosphate extractable SO_4-S, 4.0 ppm; and DTPA extractable Zn, Cu, Fe, and Mn, 0.7, 0.3, 67.5, and 15.2 ppm, respectively.

Extractable nitrate-N and ammonium-N in the top 2 ft prior to planting were 10.3 and 12.6 lb/A, respectively.

The two cultivars were planted as separate experiments and each treatment was replicated four times for each cultivar in a randomized complete block design. Four, 20-ft rows were planted for each plot with the middle two rows used for sampling and harvest. Whole "B" seed was used for both cultivars. Red Norland was hand planted in furrows on April, 17, 2009 and Russet Norkotah was planted on April 21. Row spacing was 12 inches within each row and 36 inches between rows. Admire Pro was applied in-furrow for beetle control. Weeds, diseases, and other insects were controlled using standard practices during the growing season. Rainfall was supplemented with sprinkler irrigation using the checkbook method of irrigation scheduling.

Each cultivar was subjected to nine N treatments with different N sources, rates, and application timing as described in Tables 1 and 2. Comparisons among N sources and application timing were the same for the two cultivars, but total N rates were 0, 160, or 220 lb N/A for Red Norland and 0, 180, or 240 lb N/A for Russet Norkotah.

Table 1. Nitrogen fertilizer treatments for Red Norland.

Treatment	**Preplant**	**Planting**	**Emergence**	**Posthilling**	**Total**
	--------------------------N sources* and rates (lb N/A) ----------------------				
1	0	0	0	0	0
2	0	40 D	90 U	30 UAN	160
3	0	40 D	120 U	60 UAN	220
4	120 E	40 D	0	0	160
5	180 E	40 D	0	0	220
6	0	40 D + 120 E	0	0	160
7	0	40 D + 180 E	0	0	220
8	0	40 D	180 U	0	220
9	180 U	40 D	0	0	220

*E = ESN, D = diammonium phosphate (DAP), U = urea, UAN = a combination of granular urea and ammonium nitrate.

Table 2. Nitrogen fertilizer treatments for Russet Norkotah.

Treatment	**Preplant**	**Planting**	**Emergence**	**Post-hilling**	**Total**
	--------------------------N sources* and rates (lb N/A) ----------------------				
1	0	0	0	0	0
2	0	40 D	90 U	50 UAN	180
3	0	40 D	120 U	80 UAN	240
4	140 E	40 D	0	0	180
5	200 E	40 D	0	0	240
6	0	40 D + 140 E	0	0	180
7	0	40 D + 200 E	0	0	240
8	0	40 D	200 U	0	240
9	200 U	40 D	0	0	240

*E = ESN, D = diammonium phosphate (DAP), U = urea, UAN = a combination of granular urea and ammonium nitrate.

Preplant ESN fertilizer was applied for both Red Norland and Russet Norkotah on April 16 and disked in. Nitrogen applications at planting were banded 3 inches to each side and 2 inches below the seed piece using a belt type applicator. For all treatments, banded fertilizer at planting included 100 lb P_2O_5/A as diammonium phosphate or triple superphosphate (for the 0 N control), 200 lb K_2O/A as potassium chloride and potassium magnesium sulfate, 30 lb Mg/A and 55 lb S/A as potassium magnesium sulfate, 2 lb Zn/A as zinc oxide, and 0.5 lb B/A as boric acid. Emergence N applications were supplied as urea and mechanically incorporated. Post-hilling N was applied by hand as 50% granular urea and 50% ammonium nitrate, which was watered-in with overhead irrigation to simulate fertigation with a 28% UAN solution. For both cultivars, emergence fertilizer was applied on May 18 and post-hilling N was applied on June 11.

Plant stands were measured on June 3 for Red Norland and June 9 for Russet Norkotah, and the number of stems per plant was counted on June 9 for both cultivars. Petiole samples were collected from the 4th leaf from the terminal on three dates: June 16, June 30, and July 15 for Red Norland and June 16, June 30, and July 14 for Russet Norkotah. Petioles were analyzed for nitrate-N on a dry weight basis. Vines were harvested from two, 10-ft sections of row on July 30 for Red Norland (104 days after planting) and Aug. 13 for Russet Norkotah (114 days after planting), followed by mechanically beating the vines over the entire plot area. Plots were machine harvested on Aug. 24 for Red Norland and Aug. 27 for Russet Norkotah and total tuber yield and graded yield were measured. Sub-samples of vines and tubers were collected to determine moisture percentage and N concentrations, which were then used to calculate N uptake and distribution within the plant. Nitrogen uptake results were not available at the time of this report. Tuber sub-samples were also used to determine tuber specific gravity and the incidence of hollow heart and brown center.

A WatchDog weather station from Spectrum Technologies was used to monitor rainfall, air temperature, and soil temperature at the fertilizer band depth. Measured amounts of ESN fertilizer were placed in plastic mesh bags and buried at the depth of fertilizer placement when both the preplant and emergence applications were made. Bags were removed on April 28, May 11, May 22, June 3, June 16, July 1, July 22, Aug 12, Sept 9, and Oct 20 to track N release over time.

RESULTS

Weather

Rainfall and irrigation for the 2009 growing season for the Norland plot are provided in Figure 1. The Norkotah graphs would be similar except that they were planted 5 days later than Norland. From April 17 to September 9, approximately 13.4 inches of rainfall was supplemented with 11.0 inches of irrigation for Norland and 13.1 inches for Norkotah. There were no leaching events early in the season. Leaching events (greater than 1 inch of water) occurred at 60, 113, and 123 days after planting. Air temperature measurements and soil temperature and moisture measurements at the fertilizer band depth (10 inches below the top of the hill) are provided in Figure 2. Soil moisture was only monitored in the banded at planting 240 lb N/A ESN treatment. Of interest is that the water potential from 10 to 60 days after planting indicated almost saturated conditions with very little water uptake, suggesting that roots were very shallow for most of the season. Reasons for the shallow root system are discussed below.

Nitrogen Release from ESN

Figures 3 and 4 show release of N from ESN applied preplant and at emergence for the Norland and Norkotah plots respectively. The shape of the curves was similar for both plots. Release of N from ESN tended to be similar to that reported in 2008, but faster than that recorded in previous years. In 2007, approximately 80% of N was released by 70 days after planting for preplant and planting applied fertilizer and by 80 days after planting for ESN applied at emergence. In 2008, 80% had been released by 40 days after planting for the preplant application and by about 50 days for the emergence application. In 2009, 80% had been released by 45 days after planting for the preplant application and by about 55 days for the emergence application. Given the apparent need for early season N for these potato varieties, the shorter release time may have been advantageous. Differences in release rate are likely due to difference in abrasion of the coating as well as temperature difference. Temperatures in 2009 were cooler than those in 2008.

Stand Count and Stems per Plant

The stand of both Norland and Norkotah crops ranged from 95 to 100% (Table 3 and 4). For Norland, stand was not affected by treatment but for Norkotah, urea applied at emergence resulted in slightly lower stand. Reasons for this reduction are not clear. For Norland, stem number per plant ranged for 4.1 to 4.7 while for Norkotah, stem number per plant ranged from 3.6 to 4.4. The slightly higher stems per plant for Norland were likely due to the use of "B" seed as compared with cut "A" seed for Norkotah. Nitrogen treatments did not significantly affect stem number.

Tuber Yield and Size Distribution

The effects of N application rate, source, and timing on tuber yield and size distribution for both varieties are shown in Tables 5 and 6. For Norland (Table 5), total yields increased with increasing N rate with the highest yield at 220 lb N/A in the preplant urea and preplant ESN treatments. One of the more dramatic effects that occurred in 2009 was the negative effects of planting applied ESN on Norland yield. Plants in these treatments appeared stunted most of the season with signs of nitrogen and phosphorus stress. The low pH and P in this site apparently limited growth of the roots to the fertilizer band (where all the N fertilizer was located) and resulted in poor yields. Vine dry matter at harvest was also lower for these ESN treatments. Unlike previous years ESN did not increase the yield of smaller tubers. The preplant urea treatment (treatment #9) resulted in higher yields than urea applied at emergence and numerically higher yields than urea split applied. Yields with preplant ESN (treatment #5) were similar to those with preplant urea and this timing resulted in the best performance for Norland in 2009. Leaching was not a major factor in 2009, so early applied N was not lost during the season.

Yield of Norkotah increased with N compared with the control, but effects at higher N rates depended on N source (Table 6). For split applied urea and preplant applied ESN, yield with 180 lb N/A was similar to yield with 240 lb N/A. Highest yields were with 240 lb N/A preplant applied urea, which were similar to yields with preplant applied ESN at the same N rate. Tuber size in general increased with increasing N rate regardless of source. The one exception was planting applied ESN, which resulted in the lowest yields due to limited root growth as a result of low pH and nitrogen/phosphorus deficiency. As stated above, leaching was not a major factor in 2009, so early applied N was not lost during the season.

Tuber Quality

Tables 7 and 8 show the effects of N application source, timing, and rate on tuber quality. For Norland (Table 7), hollow heart was not detected. Scab incidence and red skin color was not affected by N treatments. For Norkotah (Table 8), specific gravity tended to be highest in the control and lowest with ESN applied at planting. It is likely that roots in the planting ESN treatments had reached the fertilizer band by the end of the growing season and delayed maturity (see petiole nitrate discussion below). Hollow heart was generally low with no differences due to N treatment. Scab incidence was variable and not consistently affected by N source or rate.

Petiole Nitrate-N Concentrations

Nitrogen rate, source, and timing comparisons

Petiole NO_3-N concentrations on three dates as affected by N source, timing, and rate are presented in Table 9 for Norland and Table 10 for Norkotah. As expected, petiole NO_3-N increased with increasing N rate for both varieties and decreased as the season progressed, with the exception of the planting applied ESN treatments. Samples collected on the first sampling date indicated deficient levels of petiole nitrate with planting applied ESN. These results are consistent with the suggestion that root growth was poor for most of the season with banded applied nutrients in this low pH and P soil. Once roots did grow into the banded area, petiole nitrate increased. These effects were apparent in both varieties, but were more distinct for Norland than for Norkotah. Preplant urea and ESN resulted in the higher petiole NO_3-N levels than split applied urea early in the season and lower levels later in the season. Petiole P was also determined in selected treatments on the June 30 sampling date. For Norland, planting applied ESN resulted in lower petiole P (0.31% P) than with preplant applied ESN (0.48% P) or with split applied urea (0.44% P). For Norkotah, planting applied ESN resulted in lower petiole P (0.31% P) than with preplant applied ESN (0.32% P) or with split applied urea (0.38% P). These results suggest that N was more limiting than P as all petiole P concentrations were in a range considered to be sufficient.

CONCLUSIONS

During this year of low leaching events in May and June, the best yields were obtained with preplant applied urea or ESN at 220 lb N/A for Norland and 240 lb N/A for Norkotah. In many years, early applied N would be subject to leaching with heavy spring rainfall; however, because leaching was not a major factor in 2009, early applied N was not lost during the season.

Banded applied ESN did not perform well this year due to the low pH and low P in this soil, which resulted in poor root growth within the hill. It took almost the whole season for the roots to reach the fertilizer band. Release of N from ESN was 20-30 days faster than that recorded in previous years, suggesting that the coating was either different or perhaps more abraded.

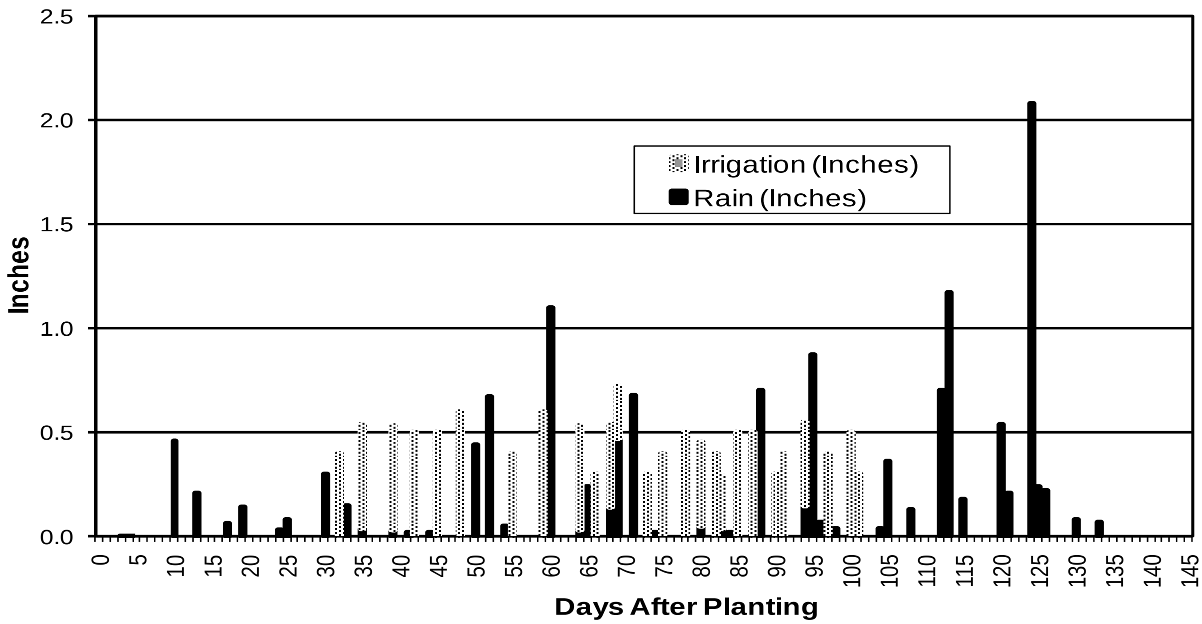

Figure 1. Rainfall and irrigation over the 2009 growing season for the Norland Plots.

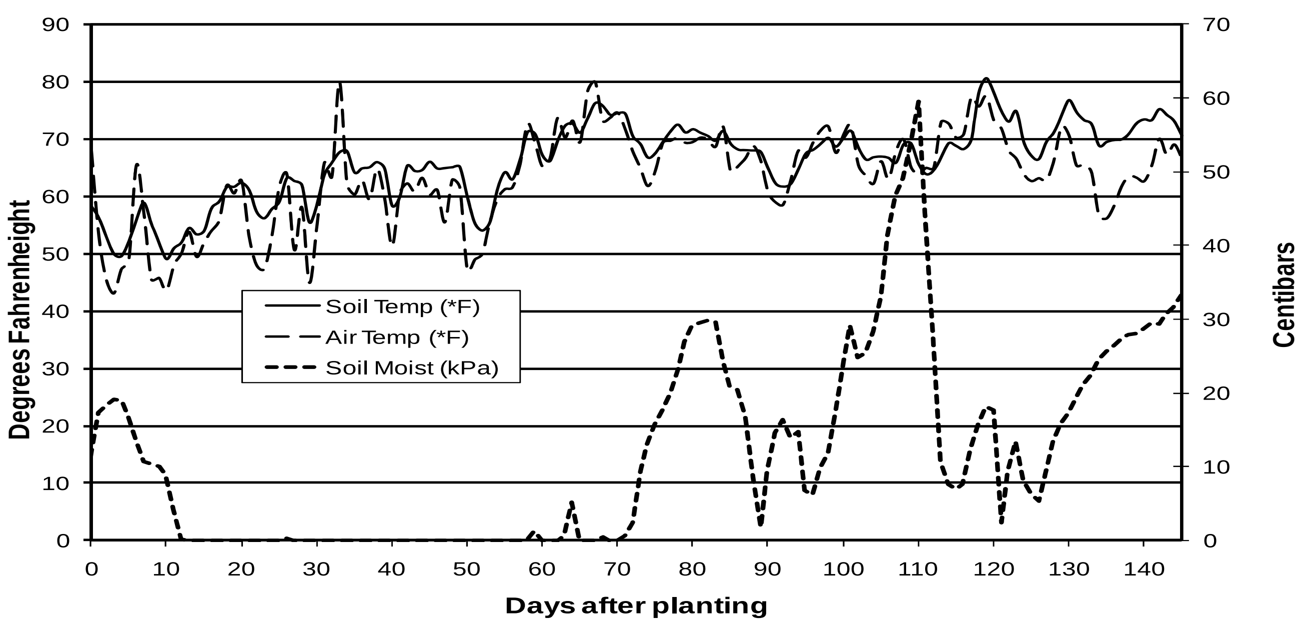

Figure 2. Average daily air and soil temperature and moisture at the 10 inch depth below the top of the hill over the growing season.

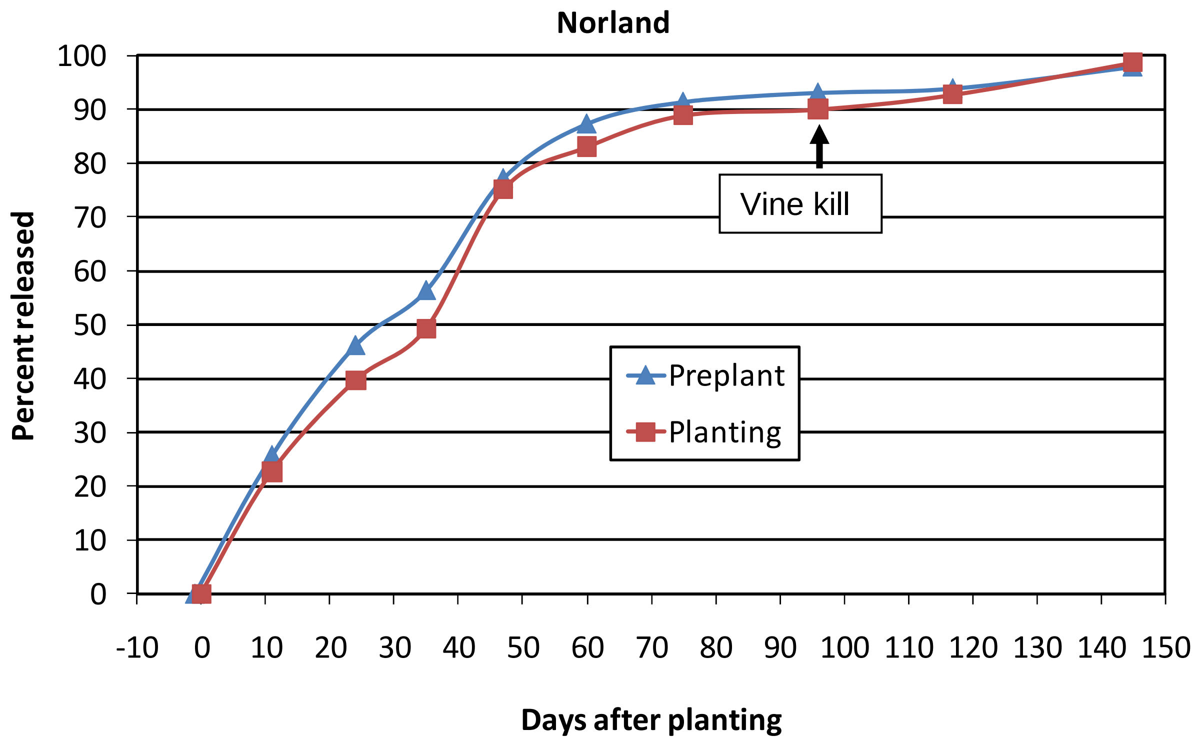

Figure 3. N released from ESN applied preplant and at planting for Norland potato in 2009.

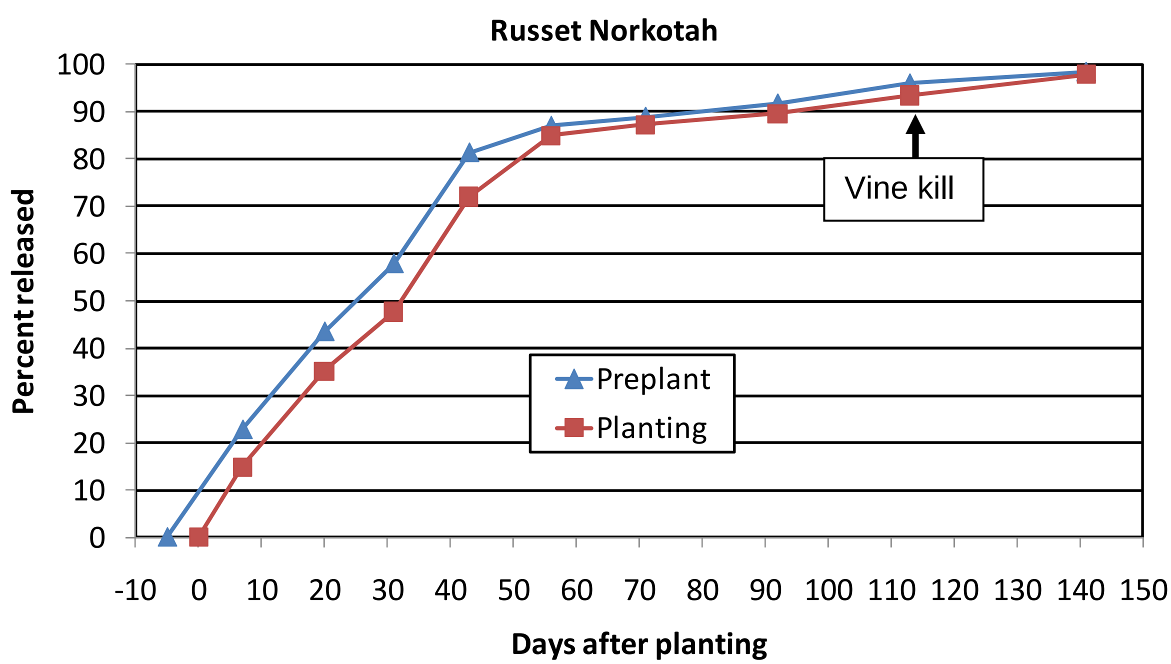

Figure 4. N released from ESN applied preplant and at planting for Norkotah potato in 2009.

Table 3. Effect of N source, timing, and rate on Norland stand and number of stems per plant.

Treatment #	Source	Rate (lb N/A)	Stand (%)	Number of Stems per plant
1	Control	0	100.0	4.4
2	Urea	160	100.0	4.5
3	Urea	220	100.0	4.1
4	ESN	160 pre	100.0	4.6
5	ESN	220 pre	99.3	4.5
6	ESN	160 plt	100.0	4.4
7	ESN	220 plt	100.0	4.5
8	Urea	220 em	99.3	4.5
9	Urea	220 pre	97.8	4.7
		Significance[2]	NS	NS
		LSD (0.1)	--	--

[2]NS = Non significant; ++, *, ** = Significant at 10%, 5%, and 1%, respectively

Table 4. Effect of N source, timing, and rate on Norkotah stand and number of stems per plant.

Treatment #	N Source	Rate (lb N/A)	Stand (%)	Number of Stems per plant
1	Control	0	98.5	4.0
2	Urea	180	100.0	3.9
3	Urea	240	99.3	4.0
4	ESN	180 pre	100.0	4.4
5	ESN	240 pre	100.0	3.6
6	ESN	180 plt	100.0	3.8
7	ESN	240 plt	100.0	4.0
8	Urea	240 em	95.5	3.7
9	Urea	240 pre	100.0	4.2
		Significance[1]	**	NS
		LSD (0.1)	1.5	--

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

Table 5. Effect of N source, timing, and rate on Norland tuber yield and size distribution and vine weights at harvest.

Treatment #	Source	Rate lb N/A	< 1.75"	1.75-2.25"	2.25-2.50"	2.50-3.00"	> 3.00"	Total	% > 2.25"	Vine DM Tons/A
			Tuber Yield (cwt/A)							
1	Control	0	16.6	114.7	95.2	22.5	2.0	251.0	47.3	0.42
2	Urea	160	11.4	71.2	142.1	135.0	47.5	407.3	78.7	0.82
3	Urea	220	12.1	81.5	147.3	143.2	32.5	416.5	77.2	0.91
4	ESN	160 pre	11.6	77.0	144.1	144.4	22.1	404.6	76.8	0.83
5	ESN	220 pre	11.0	73.1	128.3	169.8	64.1	446.3	81.0	0.99
6	ESN	160 plt	12.2	87.7	133.9	112.0	13.2	358.9	72.1	0.72
7	ESN	220 plt	12.2	89.5	128.6	57.2	6.5	294.0	64.9	0.67
8	Urea	220 em	14.3	77.3	133.7	144.4	22.4	392.1	76.3	0.85
9	Urea	220 pre	10.3	62.0	144.8	142.0	71.1	443.2	80.2	0.87
	Significance[2]		NS	**	*	**	*	**	**	**
		LSD (0.1)	--	15.9	27.3	35.9	37.2	37.9	6.7	0.11

[2]NS = Non significant; ++, *, ** = Significant at 10%, 5%, and 1%, respectively

Table 6. Effect of N source, timing and rate on Norkotah tuber yield and size distribution and vine weights at harvest.

Treatment #	N Source	Rate lb N/A	0-3oz	3-6oz	6-10 oz	10-14oz	>14oz	Total	#1 > 3oz	# 2 >3oz	Total marketable	> 6oz %	> 10 oz %	Vine DM Tons /A
			Tuber Yield (cwt/A)											
1	Control	0	79.8	137.7	58.4	1.0	0.0	276.9	193.8	3.3	197.1	21.2	0.3	0.28
2	Urea	180	72.5	157.1	194.4	68.5	27.1	519.4	434.3	12.6	446.9	55.8	18.5	0.87
3	Urea	240	81.1	139.8	151.8	96.9	52.2	521.7	421.6	19.0	440.6	57.5	28.4	0.91
4	ESN	180 pre	77.1	168.9	179.9	79.2	26.1	531.2	444.0	10.0	454.1	53.7	19.8	0.81
5	ESN	240 pre	58.5	127.1	160.3	105.8	69.6	521.3	444.7	18.2	462.8	64.4	33.7	0.79
6	ESN	180 plt	61.7	115.4	151.7	68.2	23.6	420.6	338.9	20.0	358.9	57.9	21.9	0.72
7	ESN	240 plt	53.6	119.2	145.2	68.3	26.7	413.1	342.6	16.8	359.4	57.9	22.8	0.80
8	Urea	240 em	55.8	111.7	159.8	115.0	67.7	510.0	430.8	23.4	454.2	67.1	35.7	0.75
9	Urea	240 pre	71.8	153.6	186.6	89.7	43.9	545.6	460.5	13.3	473.8	58.6	24.4	0.80
	Significance[2]		**	**	**	**	**	**	**	*	**	**	**	**
		LSD (0.1)	13.1	19.7	23.7	16.6	19.6	26.1	32.8	10.5	31.7	5.1	4.4	0.20

[2]NS = Non significant; ++, *, ** = Significant at 10%, 5%, and 1%, respectively

Table 7. Effect of N source, timing, and rate on Norland tuber quality.

Treatment #	Source	Rate lb N/A	Visred[2]	Scab %	HH %
1	Control	0	2.9	5.1	0.0
2	Urea	160	3.0	9.0	0.0
3	Urea	220	3.0	7.0	0.0
4	ESN	160 pre	3.0	4.9	0.0
5	ESN	220 pre	3.0	4.0	0.0
6	ESN	160 plt	2.9	4.0	0.0
7	ESN	220 plt	3.0	7.0	0.0
8	Urea	220 em	3.0	1.0	0.0
9	Urea	220 pre	3.0	9.1	0.0
		Significance[1]	NS	NS	NS
		LSD (0.1)	--	--	--

[1]NS = Non significant; ++, *, ** = Significant at 10%, 5%, and 1%, respectively
[2]Visual red color rating: 1(pale red/pink) to 5 (dark red).

Table 8. Effect of N source, timing, and rate on Norkotah tuber quality.

Treatment #	N Source	Rate lb N/A	Specific gravity	HH %	Scab %
1	Control	0	1.0747	0.0	2.0
2	Urea	180	1.0718	1.0	11.4
3	Urea	240	1.0692	3.0	7.1
4	ESN	180 pre	1.0704	0.0	7.0
5	ESN	240 pre	1.0735	0.0	7.2
6	ESN	180 plt	1.0676	0.0	11.0
7	ESN	240 plt	1.0673	0.0	17.0
8	Urea	240 em	1.0720	0.0	1.0
9	Urea	240 pre	1.0720	1.0	12.0
		Significance[2]	*	NS	++
		LSD (0.1)	0.0041	--	10.5

[2]NS = Non significant; ++, *, ** = Significant at 10%, 5%, and 1%, respectively

Table 9. Effect of N source, timing, and rate on Norland petiole nitrate-N.

Treatment #	Source	Rate (lb N/A)	Petiole Nitrate - N 16-Jun	30-Jun	15-Jul
			------------------ppm	----------------	
1	Control	0	3064	342	319
2	Urea	160	12531	15159	9789
3	Urea	220	13708	19870	12816
4	ESN	160 pre	12881	14160	7237
5	ESN	220 pre	16935	19724	14911
6	ESN	160 plt	8940	11727	13246
7	ESN	220 plt	9774	10841	14934
8	Urea	220 em	14794	18276	15594
9	Urea	220 pre	16321	17990	12347
		Significance[2]	**	**	**
		LSD (0.1)	1143	2507	2593

Table 10. Effect of N source, timing, and rate on Norkotah petiole nitrate-N.

Treatment #	N Source	Rate (lb N/A)	Petiole Nitrate - N 16-Jun	30-Jun	14-Jul
			------------------ppm	------------------	
1	Control	0	3926	704	573
2	Urea	180	17720	18305	11583
3	Urea	240	18145	21127	16682
4	ESN	180 pre	18801	17264	9320
5	ESN	240 pre	20204	19153	13554
6	ESN	180 plt	12767	19474	17079
7	ESN	240 plt	14314	20746	17981
8	Urea	240 em	18051	21466	16892
9	Urea	240 pre	20576	20469	12749
		Significance[2]	**	**	**
		LSD (0.1)	1661	2285	2672

[2]NS = Non significant; ++, *, ** = Significant at 10%, 5%, and 1%, respectively