Evaluation of Kingenta and ESN Controlled Release Fertilizers For Irrigated Russet Burbank Potato Production

Carl Rosen, Peter Bierman, and Matt McNearney
Dept. of Soil, Water, and Climate, University of Minnesota
crosen@umn.edu

Summary: This was the third year for field experiments conducted at the Sand Plain Research Farm in Becker, MN comparing controlled release fertilizers made by Kingenta (a Chinese company) with ESN and conventional N sources. Treatments compared differences between N sources at 160 lb N/A and 240 lb N/A and differences between preplant and planting applications of the controlled release fertilizers. Nitrogen release rate from the Kingenta product K3 was slower and less complete than from ESN, but more rapid and complete than from the Kingenta product KB. Tuber yields were lower at 160 lb N/A than 240 lb N/A for urea, K3, and ESN, due to greater amounts of small tubers and lower amounts of large tubers. There were no significant yield differences between preplant vs. planting/postplant applications of urea, K3, KB, and ESN, but application timing did affect tuber size for K3 and ESN. Preplant application of these CRF's resulted in significantly greater amounts of small tubers and lower amounts of large tubers. The treatment with 240 lb N/A mostly applied as urea preplant had the highest yield, but averaged over all treatments yields were similar for urea, K3, and ESN when applied at equivalent N rates. Marketable yields and tuber size tended to be lower for K3 than ESN, although the differences were not significant. KB generally had lower yields than the other fertilizer sources, although most of these differences were also not significant. Nitrogen source and timing did not affect tuber quality, except that the KB treatments had the highest specific gravities. This has not occurred previously and the reason for it is unclear. Vine dry matter was generally lower for K3 and KB than for urea and ESN, probably due to delayed N release. Petiole nitrate-N was significantly lower with 160 lb N/A than with 240 lb N/A for all N sources, which is consistent with the fertilizer rate effects on yield. Nitrate-N tended to be lower for K3 and KB than ESN, except on the first sampling date when petiole concentrations were highest for KB. Other than KB on the first sampling date, these trends were consistent with differences in N release from the three CRF's. The two KB treatments had the highest amounts of residual inorganic soil N one month after harvest, which was consistent with the late-season N release from KB. For the 240 lb N/A treatments with most of the N applied at planting, urea had significantly lower residual soil N than K3, KB, or ESN.

Background: Studies with ESN, a controlled release N fertilizer, have been conducted for a number of years. The main findings have shown that the fertilizer can be used as a substitute for many split applications of 28-0-0. The best results indicate an early sidedress application provides the best yield and quality. However, growers would be more likely to adopt the fertilizer if it could be used preplant. In this study, we compared three controlled release fertilizers (CRF's) to each other and with conventional fertilization practices. One of the CRF's is manufactured by Agrium and called ESN. The other two, K3 and KB, are manufactured by Kingenta (a fertilizer company in China). The objectives of this study were to 1) evaluate the effects of ESN, K3, and KB applications on yield and quality of 'Russet Burbank' potato, 2) compare various N rates, sources, and timing on Russet Burbank yield and quality, and 3) determine if nitrate leaching can be reduced with use of CRF's. This study is in its third year.

Materials and Methods

The study was conducted at the Sand Plain Research Farm in Becker, Minnesota on a Hubbard loamy sand using the cultivar Russet Burbank. The previous crop was rye. Selected soil chemical properties before planting were as follows (0-6"): water pH, 4.9; buffer pH, 5.8; organic matter, 2.4%; Bray P1, 25 ppm; ammonium acetate extractable K, Ca, and Mg, 66, 335, and 40 ppm, respectively; hot water extractable B, 0.3 ppm; Ca-phosphate extractable SO_4-S, 5.0 ppm; and DTPA extractable Zn, Cu, Fe, and Mn, 1.4, 0.5, 114.2, and 37.6 ppm, respectively. Extractable nitrate-N and ammonium-N in the top 2 ft prior to planting were 10.8 and 13.1 lb/A, respectively.

Four, 20 ft rows were planted for each plot with the middle two rows used for sampling and harvest. Whole "B" seed was hand planted in furrows on April 28, 2009. Spacing was 36 inches between rows and 12 inches within each row. Each treatment was replicated four times in a randomized complete block design. Admire Pro was applied in-furrow for beetle control, along with the fungicides Quadris and Ultra Flourish. Weeds, diseases, and other insects were controlled using standard practices. Rainfall was supplemented with sprinkler irrigation using the checkbook method of irrigation scheduling.

Three types of CRF's were tested in this study, along with uncoated urea (46-0-0). Shandong Kingenta Ecological Engineering Co., Ltd manufactures a polymer coated urea (K3, 43-0-0) and a polymer coated, blended fertilizer (KB, 20-8-10). Agrium, Inc. produces Environmentally Smart Nitrogen (ESN, 44-0-0), which is also a polymer coated urea. Twelve treatments were tested and are listed below.

Nitrogen treatments tested in the controlled release fertilizer study.

Treatment	Preplant	Planting	Emergence	Post-hilling**	Total
	------------------------ N sources* and rates (lb N/A) ------------------------				
1	0	0	0	0	0
2	0	40 D	60 U	UAN: 30 + 3x10	160
3	0	40 D	100 U	UAN: 50 + 3x16.7	240
4	200 U	40 D	0	0	240
5	120 K3	40 D	0	0	160
6	200 K3	40 D	0	0	240
7	0	40 D + 200 K3	0	0	240
8	240 KB	0	0	0	240
9	0	240 KB	0	0	240
10	120 E	40 D	0	0	160
11	200 E	40 D	0	0	240
12	0	40 D + 200 E	0	0	240

*K3 = Kingenta 43-0-0, KB = Kingenta 20-8-10, E = ESN 44-0-0, D = diammonium phosphate (DAP), U = urea, UAN = a combination of granular urea and ammonium nitrate.
**Post-hilling N was applied 4 times at 10-11 day intervals.

On April 13, 150 lb K_2O/A as potassium chloride was broadcast on all plots and later incorporated by plowing. Preplant CRF's were applied the day before planting on April 28 and incorporated with a field cultivator. At the same time, 150 lb K_2O/A as potassium chloride was applied and incorporated on all plots. Controlled release fertilizer at planting was banded 3 inches to each side and 2 inches below the seed piece using a belt type applicator. The same starter fertilizer was band-applied to all plots, except for the 0 N control and the three KB treatments. It consisted of 40 lb N/A and 100 lb P_2O_5/A as diammonium phosphate (DAP), 200 lb K_2O/A as potassium chloride and potassium magnesium sulfate, 30 lb Mg/A and 60 lb S/A as potassium magnesium sulfate, 2 lb Zn/A as zinc oxide, and 0.5 lb B/A as boric acid. For the control plots and the KB treatments, a modified starter without the N and P from DAP was used. It consisted of the same amounts and sources of K_2O, Mg, S, B, and Zn, but equivalent P_2O_5 rates were supplied to the control by triple superphosphate (TSP) and to the KB treatments by the P contained in the KB fertilizer. Treatments 7 and 8, therefore, received their P preplant when the KB was applied.

Plant emergence N applications were sidedressed as urea on May 22 and mechanically incorporated. Post-hilling N was applied by hand as 50% granular urea and 50% granular ammonium nitrate and watered-in with overhead irrigation to simulate fertigation with 28% N. The four post-hilling applications took place on June 15, June 25, July 6, and July 16.

Stand and stem counts were done on June 9. Petiole samples were collected from the 4th leaf from the terminal on June 24, July 7, and July 21. Petioles were analyzed for nitrate-N on a dry weight basis. Vines were harvested from two, 10-ft sections of row on September 17, followed by mechanically beating the vines over the entire plot area. On September 21, plots were machine-harvested and total tuber yield, graded yield, tuber specific gravity, and the incidence of hollow heart and brown center were measured. Subsamples of vines and tubers were collected to determine moisture percentage and N concentrations, which were then used to calculate N uptake and distribution. Uptake results were not available at the time of this report.

Measured amounts of K3 and ESN fertilizer were placed in plastic mesh bags and buried at the depth of fertilizer placement when both the preplant and planting applications were made. Bags were removed on May 11, May 22, June 3, June 16, July 1, July 16, July 29, Aug 12, Sept 17, and Oct 20 to track N release over time. Soil samples from the 0-2 ft depth were collected on Oct 20 to measure residual inorganic N levels. Each sample consisted of six soil cores that were composited, air dried, extracted with 2 N KCl, and analyzed for nitrate-N and ammonium-N. A WatchDog weather station from Spectrum Technologies was used to monitor rainfall, air temperature, soil temperature, and soil moisture. Soil temperature and soil moisture were measured at two depths: 1) about 4 inches below the top of the hill and 2 inches in from the side of the hill and 2) about 12 inches below the top of the hill at the fertilizer band depth. Rainfall and irrigation amounts are shown in Fig. 1 and air temperature, soil temperature, and soil moisture in Fig. 2.

Suction cup lysimeters were installed at the 4-ft soil depth on May 5 to measure the amount of inorganic N leaching below the crop root zone. Three plots per treatment in treatments 3, 6, 8, and 11 were monitored. These treatments all received total N applications of 240 lb N/A. They included a conventional treatment and the K3, KB, and ESN treatments where the controlled release fertilizer was applied preplant. Water samples were collected on a weekly basis, or more often when a leaching rainfall event occurred, and analyzed for nitrate-N and ammonium-N.

Sampling continued after harvest until the ground was frozen. Leaching results were not available at the time of this report.

Results

Nitrogen release: Release curves for the K3, KB, and ESN controlled release fertilizers are presented in Fig. 3. Preplant and planting applications had similar release curves for all three CRF's, which is not surprising since they were applied only one day apart. The largest differences between planting and preplant applications on any of the sampling dates were less than 10%. Nitrogen release from ESN was more rapid and more complete than from K3 and N release from K3 was more rapid and complete than from KB. The release curves had similar shapes, but N release from ESN more closely matched the N uptake pattern of Russet Burbank potatoes. Russet Burbank takes up the majority of its N between 40 and 80 days after planting. ESN had released about 80 to 85% of its N by 50 days after planting, while K3 had released only 50% and KB less than 25% of their N by day 50.

There were large differences between the three CRF's in the proportion of their total N that was eventually released. ESN released about 98%, K3 about 78%, and KB about 65%. Nitrogen release by K3 was much greater than the 60% N release from the Kingenta product K2 that was studied in 2007 and 2008, although environmental conditions may have played a role in these differences. ESN and K3 had released nearly all the N they were going to release by 100 days after planting, whereas KB had released less than 75% of the N it eventually released. Late N release increases the potential for N leaching between the end of one growing season and the beginning of the next.

Tuber yield: Treatment #4 with 240 lb N/A mostly applied as urea preplant had the highest total tuber yield and it was significantly greater than 160 lb N/A mostly applied as urea after planting, both of the KB treatments, and 240 lb N/A with ESN applied at planting (Table 1). The treatment with 160 lb N/A mostly applied as urea after planting also had significantly lower total yields than 240 lb N/A with K3 applied preplant and 160 lb N/A with ESN applied preplant. There were no significant differences between 160 and 240 lb N/A for the urea, K3, and ESN treatments that had similar application timing. There were also no significant differences between the comparable preplant vs. planting/postplant applications of urea, K3, KB, and ESN at 240 lb N/A. The KB treatments generally had lower total yields than the other N fertilized treatments, probably because of delayed N release (Fig. 3). The delayed N release from K3 compared with ESN (Fig. 3) did not affect total yield, because there were no significant differences between the K3 and ESN treatments applied at comparable rates and timing.

Treatment #4 with 240 lb N/A mostly applied as urea preplant also had the highest marketable tuber yield. It was significantly greater than 160 lb N/A mostly applied as urea after planting and the K3 treatment that received 160 lb N/A. Marketable yields were consistently lower at 160 lb N/A than 240 lb N/A for the urea, K3, and ESN treatments that had similar application timing. Only the difference for urea was significant, but the three treatments receiving 160 lb N/A had lower marketable yields than all of the other N fertilized treatments. Low marketable yields at 160 lb N/A were due to greater amounts of small tubers (0-4 oz) and a lower proportion of large tubers (>6 oz and >10 oz) than all of the other treatments receiving N.

There were no significant differences between the comparable preplant vs. planting/postplant applications of urea, K3, KB, and ESN at 240 lb N/A. The KB treatments generally had lower marketable yields than the other 240 lb N/A treatments. The 240 lb N/A treatment with K3 applied preplant was similar to the two KB treatments, due to significantly greater amounts of small tubers and a significantly lower proportion of large tubers compared with K3 applied at planting. Similar tuber size differences occurred between preplant and planting applications of ESN. The 240 lb N/A treatment with ESN applied preplant had a significantly greater amount of small tubers and a significantly lower proportion of large tubers than 240 lb N/A with ESN applied at planting. These differences in tuber size distribution for preplant vs. planting applications of K3 and ESN did not result in significant differences in marketable yield, because the preplant applications had numerically greater total yields. Marketable yields and tuber size tended to be greater with ESN than K3, although there were no significant differences between them when applied at comparable rates and timing.

Plant stand, stems per plant, tuber quality, and vine dry matter: Plant stands were above 98% for all treatments (Table 2). There were also no significant differences among treatments in the number of stems per plant or the incidence of hollow heart. The two KB treatments had the highest specific gravities and KB at planting was significantly higher than any of the treatments except KB at planting. Specific gravities were similar for all of the non-KB treatments. KB application did not affect specific gravity in previous years and the reason for higher levels in 2009 is not clear.

Treatment #3 with 240 lb N/A mostly applied as urea after planting had the highest vine dry matter production. It was significantly higher than the all of the other treatments except 240 lb N/A mostly applied as urea before planting and the two 240 lb N/A treatments with ESN applied preplant or at planting. Vine dry matter was generally lower for K3 and KB than for ESN, probably due to delayed N release (Fig. 3). Vine dry matter production was consistently lower at 160 lb N/A than 240 lb N/A for the urea, K3, and ESN treatments that had similar application timing. The differences for urea and ESN were statistically significant and the three treatments receiving 160 lb N/A had lower vine dry matter than any of the other N fertilized treatments. There were no significant differences between the comparable preplant vs. planting/postplant applications of urea, K3, KB, and ESN at 240 lb N/A.

Petiole nitrate-N concentrations: On all three sampling dates, petiole nitrate-N was significantly lower with 160 lb N/A than with 240 lb N/A for the urea, K3, and ESN treatments that had similar application timing (Table 3). For the comparable preplant vs. planting applications of K3 and ESN at 240 lb N/A, nitrate-N was significantly higher for preplant on the first sampling date and significantly higher for application at planting on the second and third dates. There was no difference in nitrate-N between preplant and planting applications of KB. For urea applied preplant vs. postplanting there was no difference in nitrate-N on the first sampling date, but the postplanting applications maintained significantly higher petiole concentrations on the second and third dates. Nitrate-N tended to be slightly lower for comparable K3 vs. ESN treatments. On the first sampling date, concentrations were significantly higher for comparable KB vs. K3 and ESN treatments, but lower for KB on the second and third dates. Except for KB on the first sampling date, these trends were generally consistent with differences in N release from the three CRF's (Fig. 3). For comparable treatments, nitrate-N was significantly higher with urea than K3 and ESN on the first sampling date, but not on the second and third dates. These results are consistent with the rapid availability of urea-N compared with CRF's.

Residual soil N: The two KB treatments had the highest amounts of residual inorganic soil one month after harvest (Table 4). This was consistent with late-season N release from KB (Fig. 3). Nitrogen release from K3 was slower than from ESN, but residual soil N tended to be lower for K3. There were no significant differences in residual N between 160 and 240 lb N/A for the urea, K3, and ESN treatments that had similar application timing. For the comparable preplant vs. planting/postplant applications of urea, K3, and ESN at 240 lb N/A, residual N was consistently lower with preplant applications, although only the difference for K3 was statistically significant. For the 240 lb N/A treatments with most of the N applied at planting, urea had significantly lower residual soil N than K3 or ESN.

Conclusions

Nitrogen release rate from the Kingenta product K3 was slower and less complete than from ESN, but more rapid and complete than from the Kingenta product KB. Differences in N release were reflected in the results obtained, although many of the differences were not statistically significant. Marketable yields and tuber size tended to be lower for K3 than ESN, and KB generally had lower yields than the other fertilizer sources. The treatment with 240 lb N/A mostly applied as urea preplant had the highest yield, but averaged over all treatments yields were similar for urea, K3, and ESN. Preplant application of K3 and ESN resulted in significantly greater amounts of small tubers and lower amounts of large tubers than applications at planting, although yield differences were not significant. Tuber yields were lower at 160 lb N/A than 240 lb N/A for urea, K3, and ESN, due to greater amounts of small tubers and lower amounts of large tubers. Vine dry matter was generally lower for K3 and KB than for urea and ESN, probably due to delayed N release. Petiole nitrate-N was generally lower for K3 and KB than ESN and the two KB treatments had the highest amounts of residual inorganic soil N one month after harvest. These results were also consistent with differences in N release rates.

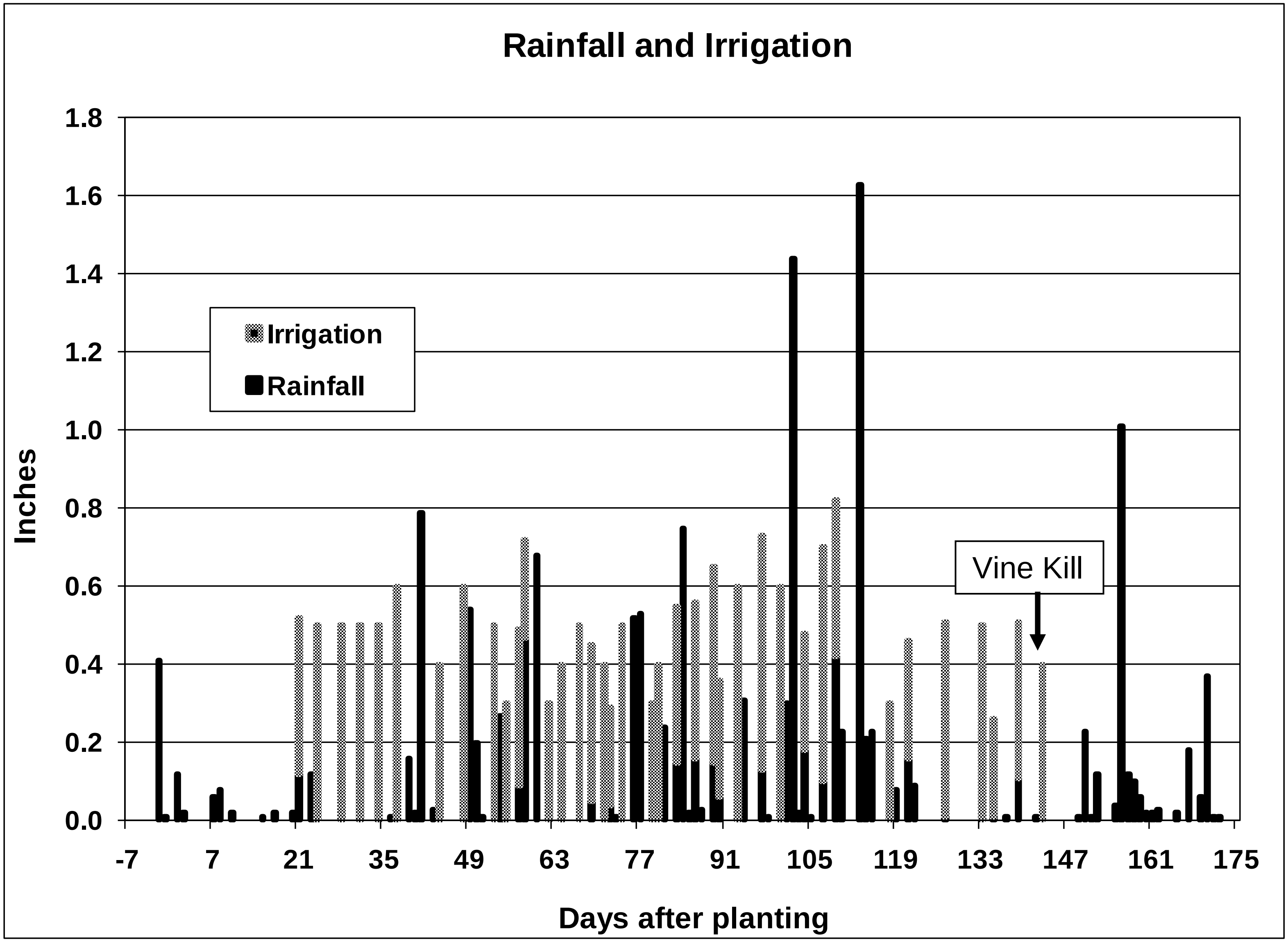

Figure 1. Rainfall and irrigation amounts during the 2009 growing season.

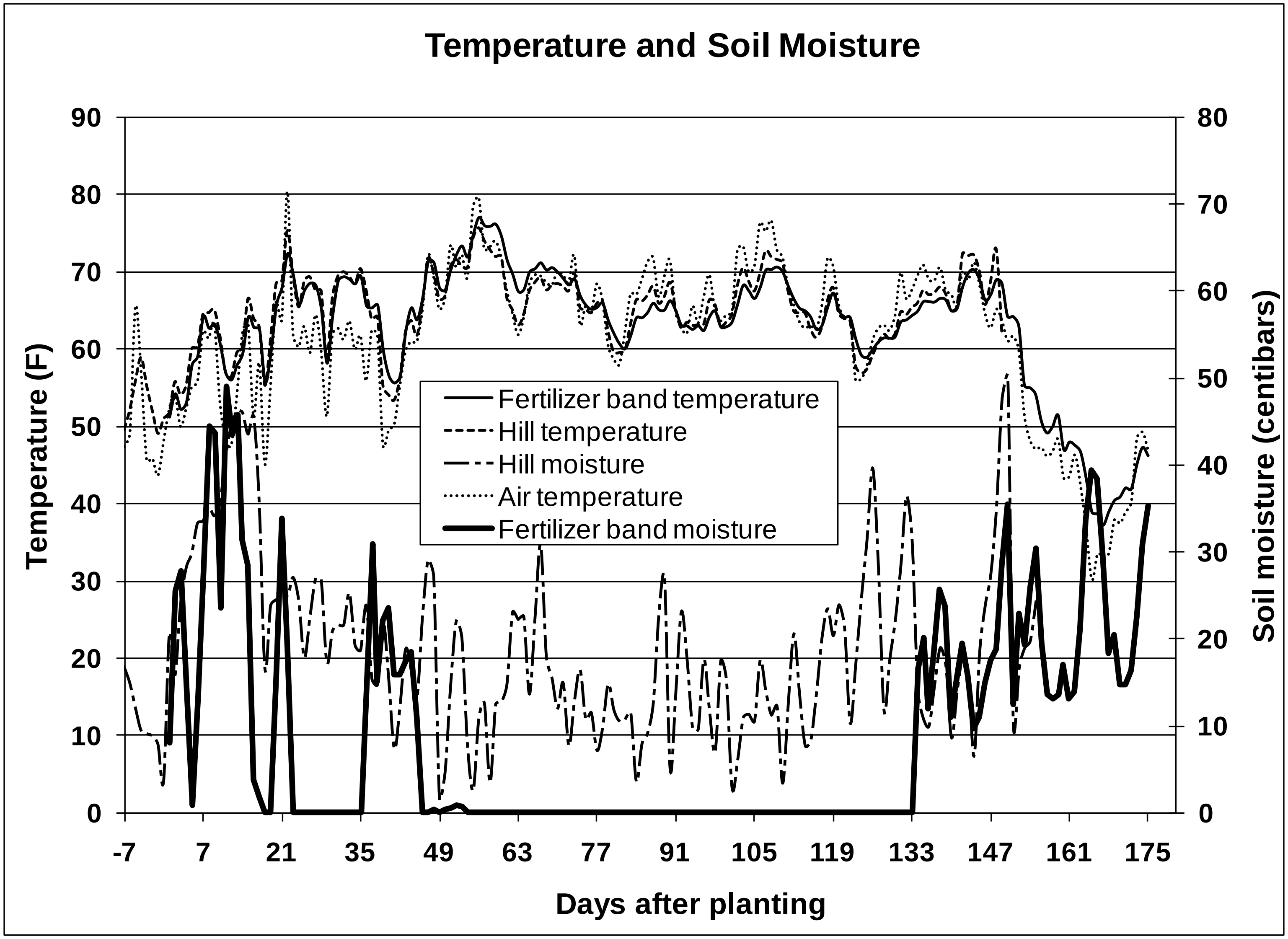

Figure 2. Soil temperature, air temperature, and soil moisture during the 2009 growing season.

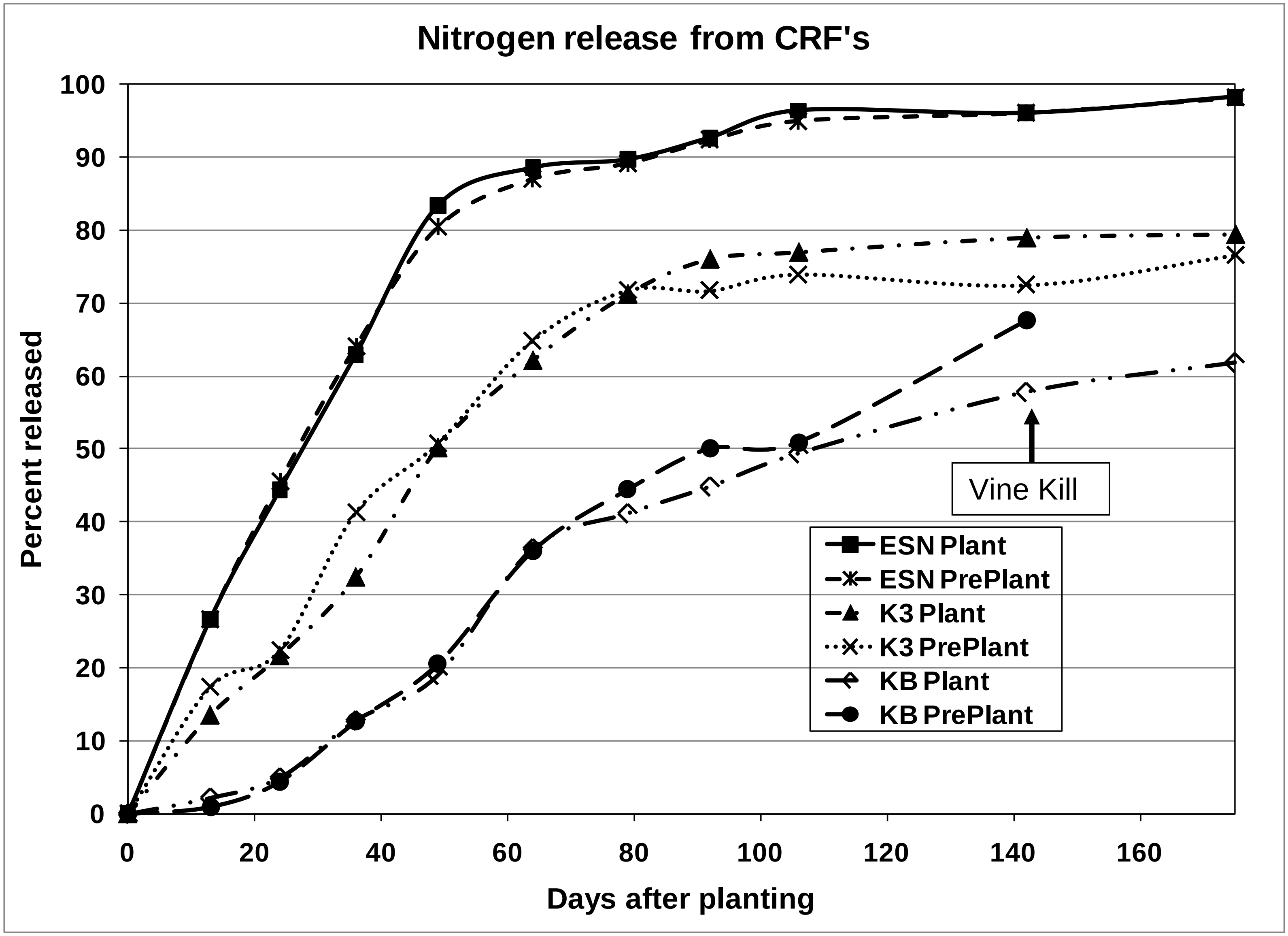

Figure 3. Nitrogen release from controlled release fertilizers during the 2009 growing season.

Table 1. Effects of N source, rate, and timing on Russet Burbank tuber yield and size distribution.

			Tuber Yield										
Treatment #	Nitrogen Source	N Rate/Timing lb N/A	0-4 oz	4-6 oz	6-10 oz	10-14 oz	>14 oz	Total	#1 > 4 oz	# 2 > 4 oz	Total marketable	> 6oz	> 10 oz
			---- cwt/A ----									%	%
1	Control	0	117.2	168.4	120.1	42.5	0.0	448.2	99.2	231.8	331.0	36.1	9.3
2	Urea	160	113.7	161.9	236.8	94.6	40.9	647.8	386.2	147.9	534.1	57.4	20.7
3	Urea	240	85.8	129.8	200.1	145.2	137.1	697.9	445.0	167.2	612.2	69.0	40.4
4	Urea	240 pre	83.6	123.0	219.1	168.0	132.9	726.5	522.2	120.8	643.0	71.5	41.3
5	Kingenta 43-0-0 (K3)	160 pre	129.8	185.2	221.7	106.6	43.8	687.0	382.2	175.1	557.3	53.2	21.4
6	Kingenta 43-0-0 (K3)	240 pre	105.8	149.4	232.3	136.4	87.8	711.8	435.8	170.1	605.9	64.3	31.6
7	Kingenta 43-0-0 (K3)	240 plt	50.7	78.8	187.9	188.2	162.1	667.5	499.3	117.6	616.9	80.6	52.5
8	Kingenta 20-8-10 (KB)	240 pre	58.0	104.6	235.7	165.2	99.9	663.2	466.2	139.1	605.3	75.5	40.0
9	Kingenta 20-8-10 (KB)	240 plt	58.2	108.0	234.3	167.3	97.9	665.7	466.6	140.9	607.5	75.1	40.0
10	ESN 44-0-0	160 pre	112.4	184.3	253.2	99.3	57.8	706.9	448.4	146.2	594.6	57.8	21.8
11	ESN 44-0-0	240 pre	79.9	116.7	227.5	141.0	136.4	701.3	499.2	122.2	621.5	72.1	39.8
12	ESN 44-0-0	240 plt	42.5	57.7	160.5	180.4	229.2	670.2	545.3	82.4	627.6	85.0	61.1
		Significance[1]	**	**	**	**	**	**	**	**	**	**	**
		LSD (0.1)	20.1	21.6	41.2	25.5	37.3	54.8	57.8	50.5	59.5	5.4	6.1

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

Table 2. Effects of N source, rate, and timing on plant stand, number of stems per plant, tuber quality, and vine dry matter.

Treatment #	Nitrogen Source	N Rate/Timing lb N/A	% Stand	# Stems per plant	Specific gravity	HH %	Vine DM Tons/Acre
1	Control	0	100.0	2.6	1.0860	0.0	0.37
2	Urea	160	98.5	3.1	1.0891	9.0	0.98
3	Urea	240	100.0	3.0	1.0878	9.0	1.46
4	Urea	240 pre	99.3	2.8	1.0880	11.0	1.35
5	Kingenta 43-0-0 (K3)	160 pre	100.0	2.9	1.0892	9.0	0.97
6	Kingenta 43-0-0 (K3)	240 pre	100.0	2.9	1.0864	6.0	1.09
7	Kingenta 43-0-0 (K3)	240 plt	100.0	3.3	1.0847	6.0	1.22
8	Kingenta 20-8-10 (KB)	240 pre	100.0	2.7	1.0903	12.0	1.11
9	Kingenta 20-8-10 (KB)	240 plt	100.0	2.8	1.0942	13.0	0.99
10	ESN 44-0-0	160 pre	98.5	2.8	1.0888	10.3	0.87
11	ESN 44-0-0	240 pre	100.0	3.2	1.0878	8.0	1.28
12	ESN 44-0-0	240 plt	100.0	2.9	1.0890	4.0	1.39
		Significance[1]	NS	NS	++	NS	**
		LSD (0.1)	--	--	0.0054	--	0.21

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

Table 3. Effects of N source, rate, and timing on nitrate-N concentrations in petioles on three sampling dates.

Treatment #	Nitrogen Source	N Rate/Timing lb N/A	Petiole Nitrate - N 24-Jun	7-Jul	21-Jul
			----------------- ppm ---------------		
1	Control	0	2815	367	149
2	Urea	160	14973	6362	3780
3	Urea	240	19652	14724	12415
4	Urea	240 pre	20588	11893	6426
5	Kingenta 43-0-0 (K3)	160 pre	14290	5817	1770
6	Kingenta 43-0-0 (K3)	240 pre	17695	11485	7115
7	Kingenta 43-0-0 (K3)	240 plt	15468	14488	11484
8	Kingenta 20-8-10 (KB)	240 pre	22770	10804	6292
9	Kingenta 20-8-10 (KB)	240 plt	21598	11315	5063
10	ESN 44-0-0	160 pre	16024	7107	3113
11	ESN 44-0-0	240 pre	19238	11964	7216
12	ESN 44-0-0	240 plt	16306	16724	12588
		Significance[1]	**	**	**
		LSD (0.1)	2139	2067	1736

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

Table 4. Effects of N source, rate, and timing on residual inorganic soil N after harvest.

Treatment #	Nitrogen Source	N Rate/Timing lb N/A	Residual Soil N Total	NH_4-N	NO_3-N
			---------------lbs. / A --------------		
1	Control	0	41.2	25.4	15.9
2	Urea	160	42.8	25.8	17.0
3	Urea	240	44.6	23.1	21.5
4	Urea	240 pre	37.4	21.1	16.3
5	Kingenta 43-0-0 (K3)	160 pre	37.3	23.8	13.5
6	Kingenta 43-0-0 (K3)	240 pre	38.5	21.9	16.6
7	Kingenta 43-0-0 (K3)	240 plt	54.6	32.3	22.3
8	Kingenta 20-8-10 (KB)	240 pre	61.3	28.2	33.1
9	Kingenta 20-8-10 (KB)	240 plt	62.1	32.0	30.1
10	ESN 44-0-0	160 pre	48.0	28.6	19.4
11	ESN 44-0-0	240 pre	48.1	27.8	20.3
12	ESN 44-0-0	240 plt	57.9	33.0	24.8
		Significance[1]	**	++	**
		LSD (0.1)	11.4	9.4	7.8

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