ACAAF Project
Final Report - 2010

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Application of polymer-coated urea (ESN) in potato production in southern Alberta (Project #2007F065R; ACAAF Project AB0279)

1. Performance Story

Recent work in other potato production areas with polymer-coated-urea products demonstrated improved nitrogen-use efficiency and decreased nitrate leaching. This project involved growing Russet Burbank potatoes at two southern Alberta research stations to evaluate the use of a polymer coated urea product locally. The purpose of the trial was to determine whether environmentally smart nitrogen (ESN, Agrium) could be used in potato production to reduce the total amount of nitrogen (N) or the number of N applications without sacrificing yield or processing quality. Various quantities of urea and ESN were applied pre-plant and compared with urea applied at planting followed by top-dressing at emergence.

Results indicate that ESN can be used in place of or in concert with urea as an N source for Russet Burbank production in southern Alberta. Six site years of data were generated during the trial. Marketable yields from treatments involving ESN were greater or not significantly different from the split urea (STD) treatment each year of the trial, even when 25% less N was applied. Average tuber size and tuber count in a 10 kg sample were affected more by environmental conditions each year than by N treatments. Applying N as ESN at emergence tended to reduce average tuber size relative to other comparable treatments applied pre-plant or as split applications. In general, the more N applied, the lower the specific gravity and the fewer tubers over 10 oz. ESN has less of an effect on tuber specific gravity than the same quantity of urea.

When economic return was taken into account, marketable yield had a greater impact on crop value than fertilizer price, average tuber size or specific gravity bonuses. That is, the treatments resulting in the greatest marketable yield, also resulted in the greatest economic returns. Most treatments with a better economic return than the STD used a reduced rate of N. Based on the results of this trial, it is feasible to reduce overall N applications by 25%. It is also feasible to use ESN to eliminate the need for in-season N applications. Reducing the quantity of N applied and splitting N applications between pre-plant urea and ESN at emergence gave good marketable yields and good economic returns 4 out of 6 site years.

In my opinion, the project was successful. This information allows us to make recommendations to growers about the effective use of ESN in the nitrogen management of Russet Burbank potatoes. The reduction in applied N and the potential for fewer in-season applications should compensate for the price premium on ESN.

2. Acknowledgements

Funding for the project was provided by Ag & Food Council, Agrium, Alberta Agriculture and Rural Development, and Potato Growers of Alberta.

Special thanks to Ross May and McCain Foods Canada for grading and assessing crop quality each year of the trial, Sandberg Laboratories for petiole nitrate analyses and Dr. Ted Harms for statistical analyses. Technical support from Simone Dalpé, Allan Middleton, Pat Pfiffner, and Len Hingley (ARD), Jim Sukeroff and Ron Gregus (AAFC) was essential for the success of the project.

3. Introduction

Potatoes managed for maximum productivity exert a heavy demand on soil fertility (Hopkins et al. 2008, Westermann 2005, Waterer and Heard 2001). Nitrogen (N) management affects vine and tuber biomass production as well as tuber size, grade, specific gravity and internal and external quality (Hopkins et al. 2008, Stark and Westermann 2003). Insufficient available N leads to insufficient canopy establishment, decreased yield, increased disease susceptibility and early crop senescence. Excessive N before tuber formation can delay tuber bulking and reduce yield, while excessive late-season N usually reduces specific gravity and delays skin set (Stark and Westermann 2003).

Potato producers use a number of tools to manage nitrogen such as soil sampling, fertilizer formulations, timing and placement of fertilizer, and in-season crop monitoring through tissue testing (Hopkins et al. 2009, Zebarth and Rosen 2007). The potential for leaching of nitrogen is closely related to the efficiency of the N management program (Shock et al. 2007, Stark and Westermann 2003). Strategies that match crop N needs with applications during the first 60 days of emergence, improve N-use efficiency (Hopkins et al 2009, Munoz et al. 2005,Westermann 2005, Vos 1999). In recent years, split or periodic N application procedures have become common in many potato-producing regions (Wilson et al. 2009, Hopkins et al. 2008, Love et al. 2005). Splitting the N application is an effective strategy to increase fertilizer use efficiency while limiting nitrate leaching (Zebarth and Rosen 2007, Waterer and Heard 2001) and nitrous oxide emissions (Hyatt et al. 2010, Shoji et al. 2001).

Another tool that is available for N management is polymer-coated urea fertilizers. Urea is an economical source of nitrogen that is converted by soil microbes to ammonium nitrogen. Ammonium forms of nitrogen become available to plants as microbes convert it to nitrate forms. Coated urea products are part of a larger group of controlled-release fertilizers (CRF's), but the release rate is mostly influenced by soil temperature and is less affected by soil moisture than other CRFs. Earlier versions of controlled release fertilizers did not closely match N release with plant demand and resulted in less than satisfactory results. This coupled with higher costs of CRFs has limited their use to high value greenhouse and nursery crops (Munoz et al. 2005, Simonne and Hutchinson 2005).

ESN, environmentally smart nitrogen (44-0-0), is a made in Alberta polymer-coated urea fertilizer. ESN provides a steady N supply for the growing plants while reducing losses due to leaching and denitrification. Both Munoz et al. (2005) and Zvomuya and Rosen (2001) reported that a synchronous association between availability and demand of N could be achieved with just one fertilizer application of a polymer-coated urea at potato planting. Such products can reduce fertilizer application costs because a single application can replace multiple fertilizer applications (Wilson et al. 2009, Zebarth and Rosen 2007). Spring applied ESN could potentially be used to replace broadcast fertilizer at the time of hilling and replace the need for in-season fertigation applications. Recent work in other potato production areas with polymer-coated urea products, have demonstrated improved N-use efficiency and decreased nitrate leaching (Hopkins et al. 2009, Hutchinson 2005, Shoji et al. 2001, Zvomuya and Rosen 2001). Coated urea products range in their peak release dates, and the maximum N release for ESN is approximately 45 days after application. Results from Alberta petiole-N research indicate that N uptake by the potato crop increases dramatically as the plant switches from flowering and tuber initiation to tuber bulking around 75 to 80 days after planting (Woods et al., 2008). Local evaluation is needed to identify products or blends that match the uptake patterns for potato plants.

Project Description:
The trial was conducted on Russet Burbank potatoes at two southern Alberta research stations to ensure that background N was moderate and that N applications could be controlled. One set of replicated plots was established at the Crop Diversification Centre South (CDCS), Brooks and the other was established at the AAFC Substation, Vauxhall, AB. The trial was planned for a total of 3 years to determine the impact of the treatments under a variety of environmental conditions. A total of 6 site years of data was generated and provided sufficient information to develop recommendations for incorporating ESN as part of an N management strategy for Russet Burbank potato producers.

The purpose of the current research was to determine whether ESN could be used in potato production to improve nitrogen use efficiency while maintaining yield and processing quality. The use of polymer coated urea in potato production could potentially reduce the total amount of nitrogen required to grow a high quality processing potato crop.

4. Objectives

- To determine the effect of combinations of urea and polymer-coated urea on yield, specific gravity and quality of Russet Burbank potatoes; and
- To determine whether polymer-coated urea could replace the need for in-season N applications (top-dressing, side-dressing or fertigation), and
- To determine whether polymer-coated urea reduced the risk of nitrate leaching in irrigated potato production; and

- To determine whether polymer-coated urea could be used as a tool for better nitrogen management in Alberta potato production.

5. Methods

This study was conducted for three years (2007 – 2009) at two research facilities in southern Alberta; the Crop Diversification Centre South (CDCS) in Brooks, AB and the Vauxhall substation of the Lethbridge Research Station in Vauxhall, AB. The soils at the CDCS station are Orthic Brown Chernozem with soil textures ranging from loam to silt loam. The soils at the Vauxhall site are also Brown Chernozemic with a sandy loam texture. Composite soil samples were taken at three depths (0 to 15 cm, 15 – 30 cm and 30 – 60 cm) in the spring before planting to test for available nitrate N. Results for each site are presented in Table 10.

Table 10: Selected chemical properties of soils at the **Brooks, AB** and **Vauxhall, AB** sites each year. Composite samples were collected before establishing treatments (April / May) from three depths (0 to 15 cm, 15 – 30 cm and 30 – 60 cm).

	Brooks, AB			**Vauxhall, AB**		
0 – 15 cm	**2007**	**2008**	**2009**	**2007**	**2008**	**2009**
pH	7.7	8.2	7.6	7.7	6.9	7.5
Electrical conductivity mS/cm	0.66	0.41	0.52	0.99	0.66	1.18
Organic Matter %	1.2	1.5	<1.2	2.4	1.9	3.0
Nitrate Nitrogen (NO3-N) lb/ac	40	22	20	24	51	53
Phosphorus (P) lb/ac	102	196	78	73	110	55
Potassium (K) lb/ac	690	760	520	860	1000	980
Sulfate-sulfur (SO4-S) lb/ac	<10	<10	<10	70	24	39
15 – 30 cm						
pH	7.9	8.2	7.6	7.9	7.5	734
Electrical conductivity mS/cm	0.74	0.45	0.50	0.91	0.76	1.75
Nitrate Nitrogen (NO3-N) lb/ac	20	20	27	25	27	38
Sulfate-sulfur (SO4-S) lb/ac	76	<10	<10	69	25	>200
30 – 60 cm						
pH	8.1	8.3	8.2	8.1	8.0	7.3
Electrical conductivity mS/cm	1.01	1.11	0.50	1.36	0.72	6.21
Nitrate Nitrogen (NO3-N) lb/ac	30	40	28	26	32	36
Sulfate-sulfur (SO4-S) lb/ac	>400	348	20	>400	120	>400

Ten N treatments were replicated 5 times in a randomized complete block design. Two sources of N, a 45-day release polymer coated urea (ESN, 44-0-0) manufactured by Agrium Inc. and granular urea (45-0-0) were compared across several rates and application strategies to determine if ESN could be used to reduce nitrogen application costs in-season. Nitrogen treatments were applied using banding equipment in 2007. The nitrogen treatments were banded using a direct seeder at both locations May 9, 2008 and May 15, 2009. Treatments included:

1. No additional nitrogen – check
2. Urea applied pre-plant to bring available N to 225 kg/ha – urea 100% pp
3. Urea applied pre-plant to bring available N to 170 kg/ha – urea 75% pp
4. Urea applied pre-plant to bring available N to 115 kg/ha – urea 50% pp
5. ESN applied pre-plant to bring available N to 225 kg/ha – ESN 100% pp
6. ESN applied pre-plant to bring available N to 170 kg/ha – ESN 75% pp
7. ESN applied pre-plant to bring available N to 115 kg/ha – ESN 50% pp
8. No additional N at planting; **plus** ESN applied and cultivated in at emergence (Idaho) – ESN 75% td
9. Urea applied pre-plant to bring available N to 115 kg/ha plus ESN applied to bring available N to 170 kg/ha and cultivated in at emergence - Urea/ESN split
10. Urea applied pre-plant to bring available N to 170 kg/ha plus urea applied to bring available N to 225 kg/ha and cultivated in at emergence - Urea split – STD 100%

Potatoes were planted approximately 13 – 15 cm deep using a two-row wheel planter in **Brooks** on May 10, 2007, May 14, 2008, and May 19, 2009 and in **Vauxhall** on May 11, 2007, May 13, 2008 and May 22, 2009. Russet Burbank seed (E3) of the same seed lot was used for both locations each year. Seed was cut (70 – 85g seed pieces), suberized, treated with Maxim^{TM} seed piece treatment (500g/100kg seed) in 2007, and Maxim MZ PSP seed piece treatment (500g/100kg seed) in 2008 and 2009. Potatoes were planted 30 cm apart in 6 m rows spaced 0.90 m apart. Each treatment was 4 rows wide. Only one of the centre rows was harvested for yield estimates and tuber evaluations. Each treatment was replicated 5 times to reduce some of the variability inherent in small plot research (see plot plan in Appendix).

Wireless temperature loggers (Model 150 Watchdog, Spectrum Technologies, Plainfield, IL) were attached to the first seed piece in one row of each rep at both locations. Soil temperature data was recorded every two hours for the entire growing season. The data loggers were recovered just prior to harvest and daily maximum, minimum and mean temperature data from each device were retrieved.

Lysimeters (61 cm Soil Water Sampler, Soilmoisture Equipment Corp., Santa Barbara, CA) were installed in four replicates of six treatments (Trt #1, 2, 5, 8, 9, and 10) at the CDCS site each year to compare the potential for nitrate leaching between treatments. Lysimeters were positioned between adjacent potato plants within a potato row in each treatment. A vacuum was established is each tube using a Vacuum Test Hand Pump and Extraction Kit (Soilmoisture Equipment Corp.). Ground water samples were collected from each lysimeter starting June 14 (2007), July 4 (2008) and July 22 (2009) and approximately every two weeks throughout the growing season. Samples were analyzed for nitrate concentration at Lakeside Research Labs, Brooks, AB.

In **Brooks**, the plots were managed following the guidelines for the Western Canadian Potato Breeding Program. Eptam (2.0 L/ac) and Sencor (150 g/ac) were applied (April 30, 2007; May 7, 2008 and April 29, 2009) to control weeds prior to planting. Additional ESN and urea were applied (top-dressed) to treatments 8, 9, and 10 prior to power hilling June 5, 2007 (Tables 1), May 29, 2008 (Table 2) and June 15, 2009 (Table 4). The plots were irrigated with solid set sprinklers to maintain adequate soil moisture.

Foliar fungicides were applied at the **Brooks** location during the growing season to prevent early blight and late blight from developing (Tables 1 – 3). In **Brooks**, Decis 5 EC (60 ml/ac) was applied July 13, 2007, Thionex (0.60 L/ac) was applied July 7, 2008 and Thionex (0.60 L/ac) was applied July 7, 2009 to control Colorado Potato Beetles.

Table 1: Foliar fungicides applied to the 2007 ESN potato trial to prevent early blight and late blight development in **Brooks**, **AB**.

Date of Application	***Fungicide***	***Rate***
July 13	Dithane DG Rainshield	0.70 kg/ac
July 26	Bravo 500	0.80 L/ac
Aug 24	Ridomil Gold/Bravo	883 mls/ac

Table 2: Foliar fungicides applied to the 2008 ESN potato trial to prevent early blight and late blight development in **Brooks, AB.**

Date of Application	***Fungicide***	***Rate***
July 7	Quadris	324 mL/ac
July 25	Dithance DG Rainshield	0.70 kg/ac
Aug 20	Ridomil Gold with Bravo	883 mL/ac

Table 3: Foliar fungicides applied to the 2009 ESN potato trial to prevent early blight and late blight development in **Brooks, AB.**

Date of Application	***Fungicide***	***Rate***
July 8	Quadris	324 mL/ac
July 30	Ridomil Gold with Bravo	883 mL/ac
Aug 24	Bravo 500	0.65 L/ac

In **Vauxhall**, the plots were managed by sub-station staff. Eptam (3.0 L/ac) was applied (May 7, 2007, April 28, 2008 and May 21, 2009) to control weeds prior to planting. Additional ESN and urea were applied (top-dressed) to treatments 8, 9, and 10 prior to hilling June 8, 2007, June 3, 2008 and June 16, 2009. The plots were irrigated with a combination of solid set sprinklers in 2007 and 2008 and with wheel move and solid set sprinklers in 2009. Soil moisture monitoring equipment was installed in 2008 and 2009 to track soil moisture and recommend irrigation events to maintain soil moisture near 70%.

Foliar fungicides were applied at the **Vauxhall** location during each growing season to prevent early blight and late blight from developing (Tables 4 – 6).

Table 4: Foliar fungicides applied to the **2007** ESN potato trial in **Vauxhall**, AB to prevent early blight and late blight development.

Date of Application	***Fungicide***	***Rate***
June 19, 2007	Bravo 500	0.8 L/ac
July 3	Ridomil Gold/Bravo	883 mL/ac
July 11	Bravo 500	0.8 L/ac
July 20	Tattoo	1.1 L/ac
Aug 1	Bravo 500	0.80 L/ac
Aug 13	Bravo 500	0.8 L/ac
Aug 22	Bravo 500	0.8 L/ac

Table 5: Foliar fungicides applied to the **2008** ESN potato trial in **Vauxhall, AB** to prevent early blight and late blight development.

Date of Application	***Fungicide***	***Rate***
June 23	Bravo	0.8 L/ac
July 3	Bravo	0.8 L/ac
July 18	Bravo	0.8 L/ac
Aug 5	Ridomil Gold with Bravo	883 mL/ac
Aug 18	Bravo	0.8 L/ac

Table 6: Foliar fungicides applied to the **2009** ESN potato trial in **Vauxhall, AB** to prevent early blight and late blight development.

Date of Application	***Fungicide***	***Rate***
July 16	Bravo	0.8 L/ac
July 30	Bravo Ridomil Gold	883 mL/ac
Aug 12	Bravo	0.8 L/ac
Aug 20	Bravo	0.8 L/ac

Foliar insecticides were applied at the **Vauxhall** location during each growing season to control aphids and Colorado Potato Beetles (Tables 7 – 9).

Table 7: Foliar insecticides applied to the **2007** ESN potato trial in **Vauxhall, AB** to control aphids and Colorado Potato Beetles.

Date of Application	***Fungicide***	***Rate***
June 19, 2007	Monitor	0.8 L/ac
June 26	Admire	80 mL/ac
July 11	Monitor	0.8 L/ac
July 20	Monitor	0.8 L/ac
Aug 1	Admire	80 mL/ac
Aug 13	Monitor	0.8 L/ac
Aug 22	Monitor	0.8 L/ac

Table 8: Foliar insecticides applied to the **2008** ESN potato trial in **Vauxhall, AB** to control aphids and Colorado Potato Beetles.

Date of Application	*Insecticide*	*Rate*
June 23	Admire	80 mL/ac
July 3	Monitor	0.8 L/ac
July 18	Success	40 mL/ac
Aug 5	Admire	80 mL/ac
Aug 18	Monitor	0.8 L/ac

Table 9: Foliar insecticides applied to the **2009** ESN potato trial in **Vauxhall, AB** to control aphids and Colorado Potato Beetles.

Date of Application	*Insecticide*	*Rate*
July 16	Monitor	0.8 L/ac
July 30	Admire	80 mL/ac
Aug 12	Admire	80 mL/ac
Aug 20	Monitor	0.8 L/ac

Petiole samples were taken at three dates during each season (**Brooks**: July 4, July 25 and August 8, 2007; June 26, July 18 and August 8, 2008; July 7, July 21 and August 11, 2009 and **Vauxhall**: July 5, July 26, and August 10, 2007; June 27, July 22, and August 6, 2008 and July 9, July 23, and August 13, 2009) to ascertain the N status of the crop and determine any effects of treatments on N levels in petioles.

Reglone (1.4 L/ac) was applied Sept 5, 2007, Sept 12, 2008 and Sept 11, 2009 in **Brooks** to desiccate potato vines. All treatments were harvested mechanically with a one-row Grimme harvester September 21, 2007, Sept 18, 2008, and Sept 23, 2009 at the Brooks location. Reglone (1.0 L/ac) was applied Sept 11, 2007, Sept 11, 2008 and Sept 9, 2009 in **Vauxhall** to desiccate potato vines. Treatments were dug mechanically and hand collected September 18, 2007 at the Vauxhall location. Treatments were harvested with a one-row Grimme harvester Sept 18, 2008. Treatments were dug with a one-row chain digger and hand collected September 24, 2009. At both locations a greater number of small tubers were harvested than with commercial harvesting equipment. This tended to inflate the percentage of small tubers, but did not affect marketable yield figures.

Yield, grade, specific gravity and defects for both sites were determined by McCain Foods Canada after harvest. Yield estimates are presented in tons/acre. An economic analysis of the crop was conducted by McCain using a base price per ton based on delivery from storage prior to Nov 15. It does not include bonus for color or payment for smalls. For the analysis, urea was estimated to cost $400/ton in 2007, $800/ton in 2008 and $600/ton in 2009 and a 15% premium was added for ESN pricing. Each field application was estimated to cost $5 per acre in 2007 and 2008 and $7 per acre in 2009.

Statistical analysis of the petiole nitrate data included analysis of variance (ANOVA) and separation of means by Tukey's multiple means comparison test using Sigma Stat statistical software (SPSS, Chicago, IL). Nitrate concentrations from lysimeter samples were analyzed using a Kruskal-Wallis one-way analysis of variance on ranked data ($p \leq 0.05$).

The yield data presented here were statistically analyzed in SAS using generalized linear model (GLM) and means separation was done using the Duncan's Multiple Range Test ($p \leq 0.05$).

6. Results

Weather Data

Mean temperature and rainfall for the 2007, 2008 and 2009 growing season (May through September) are shown for both sites in Table 10. There were some differences in the weather conditions between growing seasons each year of the trial (Table 10). Mean temperatures in July in 2007 were warmer than normal at both locations. Accumulated precipitation was lower in 2007 than 2008 or 2009 at both sites, but irrigation was used to maintain adequate soil moisture.

Table 10: Mean monthly temperature, rainfall and physiological days (P-days*) for 2007 – 2009 at the **Brooks, AB** and **Vauxhall, AB** sites.

	Brooks, AB			**Vauxhall, AB**		
Temperature (mean, ˚C)	**2007**	**2008**	**2009**	**2007**	**2008**	**2009**
May	12.0	11.9	11.1	12.2	11.7	11.5
June	16.4	14.9	15.1	16.4	15.1	14.9
July	22.8	18.1	17.8	22.7	18.0	17.8
August	17.1	17.8	16.8	17.3	17.8	17.0
September	10.9	11.3	15.3	11.3	11.6	15.8
Rainfall (mm)						
May	59.4	65.9	14.1	57.3	66.5	30.0
June	43.1	68.3	57.7	35.0	85.2	44.8
July	5.2	61.6	135.6	11.0	56.7	47.5
August	41.7	15.8	41.8	28.4	36.3	85.1
September	31.7	32.1	2.0	14.8	48.3	3.7
Total	181.1	243.7	251.2	146.5	293.0	211.1
P-Days*						
May	137.2	136.0	122.3	143.3	135.9	123.3
June	207.4	181.9	173.2	210.2	185.3	172.4
July	211.9	235.0	235.2	216.3	238.4	241.4
August	213.8	207.1	218.3	212.0	209.9	220.3
September	123.2	137.9	171.5	125.5	140.4	173.4
Total	893.5	897.9	920.2	907.3	909.9	930.8

* P-days: an indexing system, widely used in potatoes for determining stage of development and initiation of disease. With the P-Day approach, the minimum temperature for potato growth and development is 7°C, while the most rapid growth and development takes place at 21°C. The growth rate decreases with the increase in temperature and finally stops at 30°C.

Physiological-days (P-days, Sands et al. 1979) were calculated from the weather data as a method of comparing the growing seasons for potato production (Table 10). An initial comparison of total P-days in each growing season did not indicate much difference between the seasons. However, an evaluation of P-days accumulated within each month of the growing season emphasized differences during specific parts of the season (Table 10). Differences experienced during key stages of growth and development of the tubers are expected to have a greater impact on yield and size profiles than differences very early or very late in the season. Comparing the month of July, there were 21 days over 30˚C in 2007, 3 days in 2008, and 4 days in 2009 (data not shown). The difference in temperatures is reflected in the P-days accumulated in June and July of each year. In 2007, approximately 25 to 30 more P-days were accumulated in June of 2007 than 2008 or 2009 and 20 fewer P-days were accumulated in July than in 2008 and 2009. September was also much cooler in 2007 and may have affected tuber bulking.

Maximum, minimum and mean soil temperatures were collected within the hills each year (data not shown). In 2007, soil temperatures at the **Brooks** location ranged from approximately 5°C at planting to almost 35˚C before row close. Throughout most of the growing season, soil temperatures fluctuated between 10˚C and 25˚C with cooler soil temperatures evident at harvest. Soil temperatures in **Vauxhall** were slightly warmer than in Brooks. Soil temperatures in Vauxhall ranged from 7˚C to over 30˚C until row close. As in Brooks, soil temperatures fluctuated less after row closure and cooled off toward harvest.

In 2008, soil temperatures at the **Brooks** location ranged from approximately 10˚C at planting to over 30˚C before row close. Throughout most of the growing season, soil temperatures fluctuated between 10˚C and 20˚C with cooler soil temperatures evident in September. Soil temperatures in **Vauxhall** fluctuated in a narrower range than in Brooks. Soil temperatures in Vauxhall ranged from 10˚C to 25˚C until row close and between 12˚C and 22˚C through most of July and August. Somewhat cooler soil temperatures were evident in September.

In 2009, soil temperatures at the **Brooks** location ranged from less than 5˚C at planting to over 30˚C before row close. Once plants were up and row-close had occurred, soil temperatures fluctuated between 10˚C and 26˚C. August was cooler than July and September was warmer than normal. Soil temperatures in **Vauxhall** plots fluctuated in a narrower range than in Brooks. Soil temperatures in Vauxhall ranged from 5˚C to 28˚C until row close and between 12˚C and 22˚C through most of July and August. Differences between locations may have been due, in part, to the use of different hilling equipment as well as to differences in the growing season.

Nitrate Leaching

There were no rainfall events in 2007 or 2008 that would have lead to nitrate leaching during the time frame that lysimeters were monitored in the plots. In 2009, there was one potential leaching event in mid-July (Table 10). Lysimeters were installed in early June in 2007 and June 5, 2008 just prior to emergence of the potato plants and June 26, 2009 just after emergence of the potato plants. Lysimeters were removed in September prior to harvest each year. In 2007, rainfall while monitoring for nitrate leaching totaled 70.8 mm, well below the 30-year average, especially for July. In 2008, rainfall during this period totaled 163.8 mm and in 2009 rainfall during this period totaled 180.3 mm. Irrigation was necessary and was scheduled to produce optimal yield of potatoes based on estimated soil moisture. Irrigation sufficient to incur leaching would have been counter-productive to the primary objectives of the trial.

In 2007, the median background levels of nitrate in ground water collected from a 60 cm depth ranged from 11 ppm to 360 ppm depending on the location of the replicate in the field and the time of sampling (Fig 7). In 2008, the median background levels of nitrate in leachate ranged from 32 ppm to 170 ppm depending on the location of the replicate in the field (Fig 8). In 2009, the median background levels of nitrate in leachate ranged from 30 ppm to 80 ppm depending on the location of the replicate in the field (Fig 9).

2007: Treatment 1 (check), 2 (100% urea pre-plant), 5 (100% ESN pre-plant) and 8 (75% ESN at emergence) showed fluctuations between sampling dates of up to 20 ppm but the net change was small (Fig. 7). Treatments 9 (75% urea/ESN split) and 10 (100 %split urea) both resulted in greater fluctuation. Only the split urea treatment (Trt #10) showed a consistent increase in nitrate concentration relative to the background level by the end of the season. Data presented are the mean of four replicate samples. None of the nitrate values were significantly different from one another in 2007.

2008: For all of the treatments, median nitrate levels decreased between the June 20 and the July 7 sampling dates in all of the treatments (Fig. 8). The pattern of nitrate concentrations under each treatment was similar. Sampling was discontinued after the August 15 sampling date because ground water samples were not recovered from over 50% of the lysimeters on Aug 15. As of August 15, there was no indication that any of the treatments resulted in a consistent increase in ground water nitrate concentrations. Data presented are the means of four replicate samples. None of the nitrate values were significantly different from one another in 2008.

2009: The median nitrate concentration decreased in the check treatment and in the ESN treatments for dates that samples were analyzed (Fig 9). Unfortunately, data was not available for samples collected July 27 and Aug 20 as there was turn-over in the ownership of the analytical laboratory. Sampling was discontinued after the August 20 sampling date because ground water samples were not recovered from over 50% of the lysimeters on Aug 12. As of August 12, there was no indication that any of the treatments resulted in a consistent increase in ground water nitrate concentrations. Data presented are the means of up to four replicate samples. None of the nitrate values were significantly different from one another in 2009.

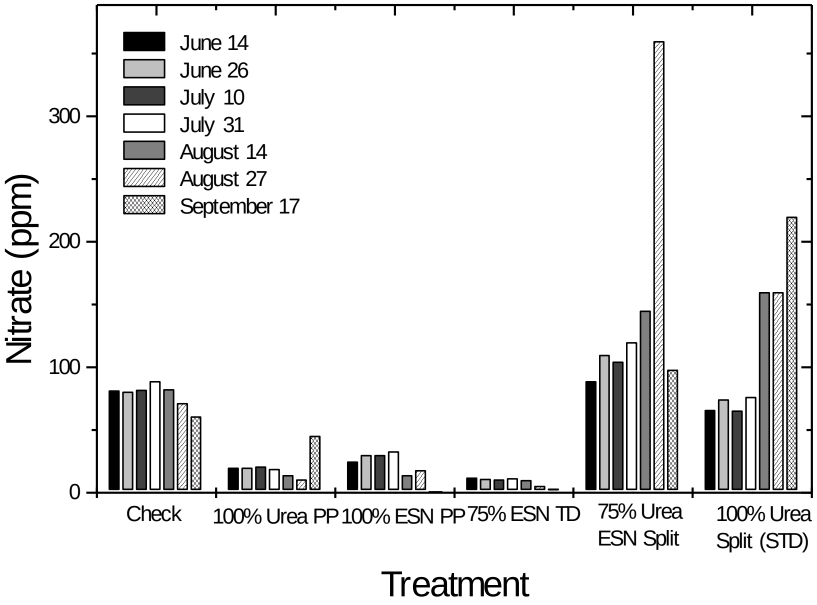

Figure 7: Nitrate concentration in samples of ground water recovered from lysimeters installed within treated areas of the field in **2007**.

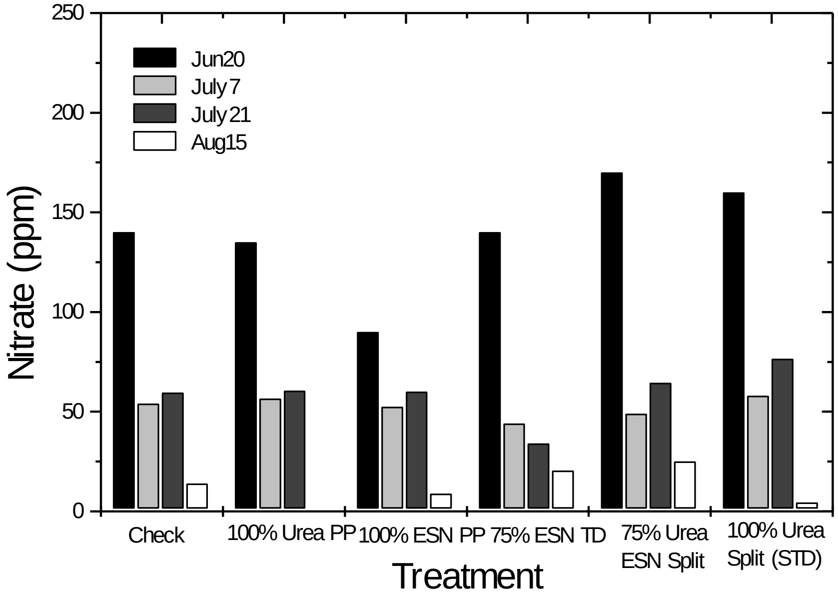

Figure 8: Nitrate concentration in samples of ground water recovered from lysimeters installed in **2008** within treated areas of the field.

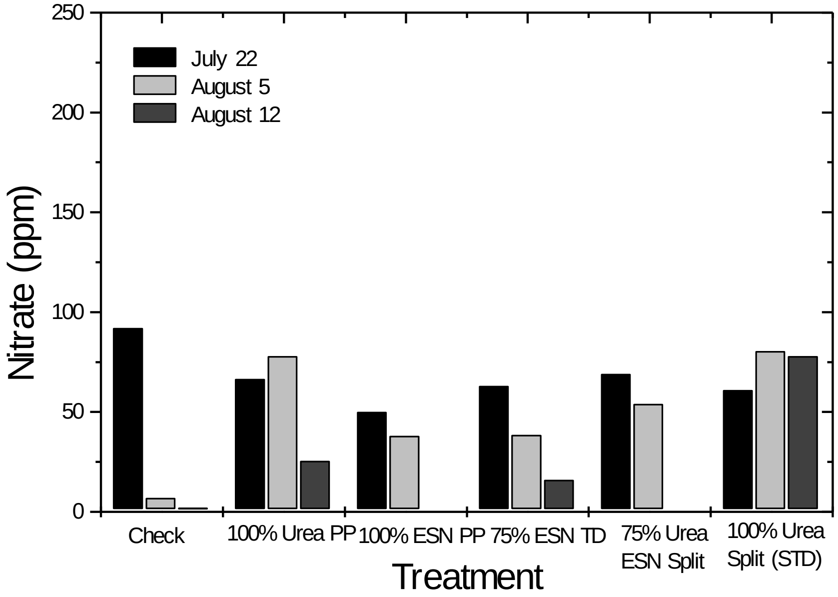

Figure 9: Nitrate concentration in samples of ground water recovered from lysimeters installed in **2009** within treated areas of the field.

Petiole Nitrates

Petiole nitrate concentrations in all treatments decreased throughout the growing season each year in **Brooks.** The first petiole sampling date was selected to coincide with the maximum release date of pre-plant ESN, approximately 45 to 50 days after incorporation. At the first sampling date in 2007, nitrate levels in the petioles ranged from about 16,000 ppm for the check to over 20,000 ppm for treatments with optimal nitrogen applied (Table 11). By the first sampling date in 2008, nitrate levels in the petioles ranged from just over 10,000 ppm for the check to over 17,000 ppm for the split urea (STD) treatment. In 2009, petiole nitrate concentrations at the first sampling date ranged from around 17,000 ppm for the check to over 20,000 ppm for treatment with adequate N. With the exception of the check treatments, the petiole nitrate concentrations at the beginning of each season fell within recommended levels for Russet Burbank production in southern Alberta (Woods et al., 2008).

In 2007, petiole nitrates collected at the Brooks location dropped off gradually throughout the growing season. In 2008 and 2009, petiole nitrates fell rapidly between the first and the second sampling dates even though no leaching events occurred during the season. This may reflect rapid vegetative growth of the plants rather than any deficiencies in N availability. By the second sampling date in 2009 and the third sampling date in 2008 and 2009, petiole nitrates for most treatments fell below recommendations by Woods et al. (2008) for southern Alberta. As expected, treatments with less N applied pre-plant started out with lower petiole nitrate levels and treatments with the greatest applied N levels, whether ESN or urea, maintained the highest petiole nitrate concentrations throughout the season. Split N applications typically maintained petiole nitrates at higher levels through the season than pre-plant applications, although some exceptions were observed. Wilson et al. (2009) also noted higher petiole nitrate concentrations as N rate increased and higher petiole nitrate concentrations with split N applications.

Table 11: Petiole nitrate levels for each treatment at the Brooks, AB and **Vauxhall, AB** locations. Samples were taken from the fourth petiole from up to eighty stems at three times during each growing season:

Treatment	**Brooks, AB**			**Vauxhall, AB**		
2007	July 4	July 25	Aug 8	July 5	July 26	Aug 10
Check	15600 b	10600 a	6760 a	11160 e	12100 b	5200 a
100% urea PP	20640 a	12800 a	8260 a	19120 ab	16880 ab	7800 a
75% urea PP	19440 ab	12220 a	6300 a	18960 b	17400 ab	7880 a
50% urea PP	17600 ab	9500 a	5760 a	13360 de	14040 ab	4480 a
100% ESN PP	19040 ab	13200 a	8360a	17840 abc	18960 a	8400 a
75% ESN PP	18840 ab	12560 a	6600 a	17260 abc	16520 ab	8240 a
50% ESN PP	18240 ab	10380 a	6460 a	14560 de	15360 ab	6160 a
75% ESN TD	17720 ab	14340 a	9000 a	15360 cd	16460 ab	7440 a
75% urea/ESN split	19360 ab	12800 a	9980 a	17660 abc	16080 ab	6720 a
100% urea split (STD)	20440 a	13800 a	9920 a	20320 a	20440 a	10800 a
2008	Jun 26	July 18	Aug 8	June 27	July 22	Aug 6
Check	10460 b	3215 d	383 a	4500 d	394 a	1564 b
100% urea PP	15640 ab	9386 ab	2297 a	13360 ab	2758 a	5084 ab
75% urea PP	12700 ab	6821 bcd	383 a	12620 abc	394 a	5476 ab
50% urea PP	11460 b	4489 cd	383 a	7860 cd	591 a	1956 ab
100% ESN PP	15820 ab	8261 abc	1531a	14880 a	2364 a	4302 ab
75% ESN PP	14480 ab	5403 bcd	766 a	11420 abc	591 a	3129 ab
50% ESN PP	12680 ab	4680 cd	766 a	8740 bcd	591 a	1760 ab
75% ESN TD	13980 ab	8969 ab	1531 a	12460 abc	6697 a	7822 ab
75% urea/ESN split	13240 ab	8582 abc	766 a	13680 ab	1576 a	3716 ab
100% urea split (STD)	17320 a	11093 a	8040 a	16280 a	6697 a	7822 a
2009	July 7	July 21	Aug 11	July 9	July 23	Aug 13
Check	18560 b	1160 c	1620 a	7980 a	4540 b	1400 a
100% urea PP	22720 ab	6760 abc	6000 a	14260 a	8520 ab	6600 a
75% urea PP	22880 ab	4020 abc	3140 a	12000 a	6440 ab	3100 a
50% urea PP	19280 b	1280 c	2140 a	5750 a	4160 b	8000 a
100% ESN PP	23840 ab	9260 ab	6480 a	12725 a	8080 ab	2900 a
75% ESN PP	26360 a	3000 cb	2600 a	9775 a	6925 ab	2350 a
50% ESN PP	21920 ab	2440 c	2300 a	10580 a	4025 b	1000 a
75% ESN TD	22700 ab	3250 bc	1700 a	11500 a	6650 ab	3100 a
75% urea/ESN split	23360 ab	5620 abc	4200 a	13420 a	5080 ab	1400 a
100% urea split (STD)	22760 ab	9780 a	6800 a	16740 a	15800 a	11600 a

Petiole nitrate levels in Vauxhall followed a different pattern in each year of the trial. In 2007, petiole N levels from the Vauxhall plots ranged from 11,000 to 20,000 on the first sampling date in early July (Table 11). As we observed in Brooks, treatments with the highest pre-plant applications of nitrogen had the highest petiole nitrate levels. Petiole nitrates remained high for the second sampling date and decreased by the third sampling date. Petiole nitrates appeared to be somewhat independent of the amount of N applied in 2007. Additional nitrogen may have become available during the growing season as a result of mineralization of organic matter.

In 2008, petiole nitrate levels ranged from around 4500 ppm for the check to around 16,000 ppm for the split urea (STD) treatment (Table 11). As with samples from the Brooks location, petiole nitrate concentrations were higher for treatments with 100% N than 75% or 50% N. In Vauxhall, the 100% treatments, 75% urea treatment and the split applications had petiole nitrate concentrations in the recommended range at the first sampling date. The crop in Vauxhall was damaged by hail July 16, 2008 and the up to 40% of the foliage was damaged. Petiole nitrate levels at the second sampling date were much lower for all treatments, and lower than the nitrate levels observed from the third sampling event. The replacement of vegetative tissue likely resulted in a re-allocation of N within the potato plants. By the third sampling date, petiole nitrates were higher than similar treatments in Brooks. The interruption of growth and development caused by the hail storm affected the nitrate concentration in the fourth petiole. Petiole nitrate concentrations for most of the treatments were below the recommended range in early August (Woods et al., 2008).

In 2009, petiole nitrate levels from the Vauxhall plots decreased throughout the season (Table 11). Nitrate levels ranged from around 8,000 ppm for the check to around 16,000 ppm for the split urea (STD) application treatment in early July. As with the samples from the Brooks location, petiole nitrate concentrations were generally higher for treatments with 100% N than 75% or 50% N. In Vauxhall, the 100% treatments, 75% urea treatment and the split applications had sufficient petiole-N at the first sampling date. Petiole nitrate levels at the second sampling date were lower for all treatments than the first sampling date and only petioles from the split urea (STD) treatment had sufficient nitrate based on southern Alberta recommendations (Woods et al., 2008). By the third sampling date, only petioles from the 100% urea pre-plant, 100% ESN pre-plant and the STD had nitrate levels within recommended levels. The check and treatments supplied with 50 to 75% N had inadequate N based on the 2008 recommendations.

Potato Yield and Grade

Potato yield, grade and estimated crop value relative to the STD are presented in Table 12 for each treatment harvested in **Brooks** during the three year trial. There were no significant differences in marketable yield or average tuber size between treatments in 2007 or 2009 and a few significant differences in 2008. Polymer-coated urea products have been shown by others (Wilson et al. 2009, Hopkins et al. 2008, Shoji et al. 2001) to produce similar or greater yields than soluble N at equivalent rates. Average tuber size in 2007 was quite small and a high percentage of tubers were undersized. In 2008, however, some statistical differences were observed in marketable tuber yields and yields of specific size categories. Pre-plant application of urea at 75% of the STD rate yielded the most marketable tubers, while the check and the 50% ESN pre-plant treatments yielded the least. Wilson et al. (2009) reported that an increase in the N rate applied resulted in a greater percentage of tubers over 6 oz., an economically important size class. Average tuber size was lower with pre-plant or top-dressed ESN applications in 2008 than with pre-plant urea or the urea/ESN split. The split urea application resulted in average tuber sizes that were not significantly different from the ESN treatments, while the urea/ESN split application resulted in an average tuber size similar to the check and the urea pre-plant treatments. In general, urea treatments resulted in a higher percentage of tubers over 10 oz compared to ESN treatments in 2008. In 2009, around 10% of the tubers were small (under 3 oz.) and fewer than 20% of the tubers were over 10 oz. The weather may have played a role in the size distribution of the crop. There were delays in the spring as a result of cool weather, August was more moderate and September was warmer than usual. Our trial was desiccated September 11 and we likely lost 2 weeks of potential bulking that might have helped differentiate between treatments.

All of the treatments in 2007 resulted in a lower net crop value than the STD treatment. In 2008, all of the treatments yielded a higher net crop value than the STD treatment, and in 2009, all treatments in Brooks, except the check treatment, gave similar or better gross economic return on a sample contract than the STD (Table 12). The greatest net crop value in 2008 was achieved with 75% urea applied pre-plant. For economic return in 2009, the best treatment in Brooks was 50% ESN applied pre-plant. Applying ESN (75%) at emergence and the urea/ESN split application gave better economic returns than the STD. Wilson et al. (2009) provided a simple economic analysis for their work with various rates of polymer-coated urea and split applied N treatments. Their analysis suggests that the use of polymer-coated urea could reduce or eliminate the need for fertigation on coarse-textured soils. In this study, each of the treatments with a better economic return than the STD used a reduced rate of N. The best economic return may shift with urea price changes.

Specific gravity of tubers was affected by N source and timing each year as well as by environmental factors (Table 12). Wilson et al. (2009) reported that N treatments did not significantly affect specific gravity, but that other factors, such as temperature or irrigation, may have contributed to differences between years. In this study, and in work reported by Belanger et al. (2002), the greater the quantity of N applied, the lower the specific gravity. The highest specific gravity tubers were usually observed in the check treatment and the 50% rate of urea and ESN. The lowest specific gravity was observed from treatments with 100% N applied whether pre-plant or split application (STD). Pre-plant N had a greater impact on specific gravity than top-dressed N. The trend was that urea reduced specific gravity more than ESN, although differences between treatments were not always statistically significant.

Table 12: Yield and grade of potatoes harvested from plots in **Brooks, AB** grown with different nitrogen sources in **2007, 2008 and 2009.** Data in each column followed by the same letter in a given year are not significantly different from one another.

Treatment	% under-sized	Mkt Yld (ton/ac)	>10 oz. (%)	Avg Tuber size (oz)	Tuber count (10 kg)	SG	Crop Value (% of STD)
2007							
Check	19.5 ab	21.8 a	3.7 a	3.9 a	86.8 ab	1.085 abc	83.1
100% urea PP	14.5 ab	24.2 a	4.2 a	4.5 a	89.4 ab	1.079 c	87.4
75% urea PP	10.4 b	26.1 a	4.6 a	4.8 a	83.6 ab	1.082 bc	96.3
50% urea PP	16.3 ab	22.4 a	4.2 a	4.3 a	80.6 ab	1.089 a	86.0
100% ESN PP	11.7 ab	26.7 a	4.5 a	4.5 a	84.6 ab	1.082 bc	97.7
75% ESN PP	13.8 ab	22.8 a	3.9 a	4.4 a	92.0 ab	1.086 ab	86.8
50% ESN PP	15.4 ab	24.1 a	4.2 a	4.2 a	78.4 b	1.083 abc	89.2
75% ESN TD	21.6 a	20.7 a	3.6 a	3.9 a	81.4 ab	1.082 bc	75.9
75% urea/ESN split	15.6 ab	23.3 a	3.5 a	4.3 a	74.4 b	1.085 abc	87.5
100% urea split (STD)	10.9 ab	26.7 a	4.9 a	4.8 a	98.6 a	1.084 abc	100.0
2008							
Check	4.3 abc	27.2 b	51.5 ab	8.9 a	40.6 b	1.094 a	100.4
100% urea PP	2.9 c	32.1 ab	49.6 abc	8.9 a	39.8 b	1.088 abc	117.1
75% urea PP	2.6 c	33.8 a	51.5 ab	8.7 a	40.6 b	1.088 bc	124.2
50% urea PP	2.5 c	32.0 ab	59.6 a	9.3 a	38.0 b	1.093 a	117.9
100% ESN PP	6.1 a	32.4 ab	40.1 cd	7.2 c	49.2 a	1.088 abc	117.7
75% ESN PP	5.0 ab	30.4 ab	37.2 d	7.2 c	49.6 a	1.093 ab	111.3
50% ESN PP	4.9 ab	27.3 b	46.3 bcd	7.6 bc	47.2 a	1.093 ab	100.6
75% ESN TD	4.4 ab	30.9 ab	41.5 bcd	7.2 c	48.8 a	1.089 abc	112.3
75% urea/ESN split	3.7 bc	32.3 ab	51.5 ab	8.4 ab	42.0 b	1.088 abc	117.8
100% urea split (STD)	5.4 ab	28.0 b	47.0 bcd	7.6 bc	47.2 a	1.085 c	100.0
2009							
Check	12.3 a	21.4 a	18.6 a	4.53 a	80.0 a	1.096 ab	98.7
100% urea PP	11.1 a	22.7 a	17.3 a	4.79 a	75.7 a	1.091 bcd	102.1
75% urea PP	11.7 a	22.9 a	17.1 a	4.67 a	75.8 a	1.092 bcd	104.6
50% urea PP	10.4 a	23.7 a	18.8 a	4.87 a	73.5 a	1.099 a	104.5
100% ESN PP	13.6 a	22.9 a	12.7 a	4.37 a	81.2 a	1.088 d	101.8
75% ESN PP	9.6 a	23.6 a	17.1 a	5.06 a	71.4 a	1.094 abcd	105.4
50% ESN PP	8.8 a	25.4 a	16.9 a	4.57 a	77.7 a	1.095 abcd	115.8
75% ESN TD	10.4 a	24.4 a	16.1 a	4.49 a	78.9 a	1.095 abc	110.8
75% urea/ESN split	11.5 a	24.1 a	19.1 a	4.76 a	75.5 a	1.095 abcd	107.8
100% urea split (STD)	9.6 a	22.3 a	19.8 a	4.83 a	73.5 a	1.089 cd	100.0

Potato yield, grade and estimated crop value relative to the STD are presented in Table 13 for each treatment harvested in **Vauxhall** during the three year trial. Potato yields from the Vauxhall site were lower than yields at the Brooks site all three years of the trial, possibly a result of the different irrigation strategies between the two locations. In 2007, the greatest marketable yield in Vauxhall was observed with the urea/ESN split application. The split urea application resulted in the greatest yield of undersized tubers, and the smallest yield of marketable tubers. There was good separation between treatments in data from the Vauxhall plots in 2008 in spite of higher background N (Table 13) and a hail event in mid-July. In 2008, the greatest marketable yield was observed when ESN was applied at emergence (ESN 75% TD). The 100% ESN pre-plant and split application treatments also resulted in very good marketable yield in 2008. In 2008 and 2009 marketable yield for the check was not significantly different from the 50% urea and ESN treatments because of high background N levels. The check and 50% N treatments resulted in the fewest tubers over 10 oz in 2008, while split treatments and ESN at emergence resulted in the greatest yield of tubers over 10 oz. The largest average tuber size was observed with the split application treatments, the 75% ESN treatment and when ESN was applied at emergence. This treatment (ESN 75% TD) was similar to the ESN recommendations developed in Idaho for Russet Burbank production. There was some separation between treatments in data from the Vauxhall plots in 2009 in spite of higher background N. In general, the more N applied, the better the yield and size profile (fewer smalls, higher mean tubers size, etc.). In 2009, the greatest marketable yield was observed with 100% urea pre-plant and the split urea application (STD). Relative to the check, the STD resulted in significantly greater yield, greater mean tuber size, and more tubers over 10 oz. Many of the differences observed between other treatments were not statistically significant.

Specific gravities of tubers from the various nitrogen treatments were not significantly different from the check in 2007, although some treatments showed significant differences from one another (Table 13). In 2008, generally the higher the N applied, the lower the specific gravity. The highest specific gravity values were observed from the check and the 50% urea and ESN treatments, while the lowest specific gravity values were observed with the STD treatment and when ESN was applied at emergence. In 2009, the highest specific gravity values were observed from the check, the 50% and 75% treatments, while the lowest specific gravity values were observed with the STD treatment, 100% pre-plant urea and 100% pre-plant ESN. As with samples from the Brooks location, the trend indicates that urea affects specific gravity more than ESN.

In 2007, the best economic return in Vauxhall was observed when 75% ESN was applied at emergence and with a split urea/ESN application was used. Economic return depends in part on the yield and profile of the crop, and in part on the price for urea and ESN fertilizers. In 2008, most of the treatments at Vauxhall resulted in a lower economic return than the STD treatment. Overall, the best economic return in Vauxhall was observed when urea (100%) was applied pre-plant. In this case, other agronomic factors, such as irrigation, likely played a greater role than the source and timing of N in the yield and grade of the crop.

In 2009, only the 100% urea pre-plant treatment resulted in an economic return greater than the STD split urea application. The check resulted in the lowest economic return. Although efforts were made to improve the irrigation practices at Vauxhall throughout the trial, irrigation efficiency was still quite variable. In the event that irrigation is not optimized, it is unlikely that the timing and quantity of N applied will make significant improvements in the yield or quality the potato crop.

Table 13: Yield and grade of potatoes harvested from plots in **Vauxhall, AB** grown with different nitrogen sources in **2007, 2008 and 2009.** Data in each column followed by the same letter in a given year are not significantly different from one another.

Treatment	% under-sized	Mkt Yld (ton/ac)	>10 oz. (%)	Avg Tuber size (oz)	Tuber count (10 kg)	SG	Crop Value (% of STD)
2007							
Check	14.2 b	16.7 b	3.0 ab	4.1 ab	86.8 ab	1.095 ab	83.1
100% urea PP	14.6 ab	17.6 b	2.9 ab	4.0 ab	89.4 ab	1.094 ab	87.4
75% urea PP	12.9 b	18.1 ab	3.1 ab	4.3 ab	83.6 ab	1.094 ab	96.3
50% urea PP	12.7 b	19.7 ab	4.0 ab	4.5 ab	80.6 ab	1.098 ab	86.0
100% ESN PP	14.0 b	16.9 b	3.2 ab	4.4 ab	84.6 ab	1.096 ab	97.7
75% ESN PP	15.5 ab	16.8 b	2.8 ab	3.9 ab	92.0 ab	1.100 a	86.8
50% ESN PP	12.3 b	20.2 ab	4.1 ab	4.5 ab	78.4 b	1.098 ab	89.2
75% ESN TD	11.4 b	18.8 ab	3.0 ab	4.4 ab	81.4 ab	1.092 b	75.9
75% urea/ESN split	11.2 b	22.3 a	4.8 a	4.8 a	74.4 b	1.096 ab	87.5
100% urea split (STD)	19.3 a	16.4 b	2.1 b	3.7 b	98.6 a	1.094 ab	100.0
2008							
Check	9.0 ab	21.6 c	25.6 bc	6.2 ab	57.8 abc	1.088 abc	90.1
100% urea PP	6.3 ab	22.8 bc	34.5 abc	6.4 ab	55.6 abc	1.086 abc	93.2
75% urea PP	10.6 a	23.4 bc	26.0 bc	5.8 b	62.4 a	1.087 abc	96.0
50% urea PP	10.5 a	21.4 c	23.0 c	5.8 b	61.6 ab	1.090 ab	87.4
100% ESN PP	6.6 ab	25.7 abc	27.9 abc	6.5 ab	54.6 abc	1.086 bc	103.4
75% ESN PP	8.7 ab	22.7 bc	27.2 bc	7.1 a	61.0 ab	1.088 ab	93.7
50% ESN PP	10.3 a	21.2 c	26.6 bc	5.8 b	61.4 ab	1.090 a	88.8
75% ESN TD	5.4 b	29.3 a	42.1 a	7.1 a	49.8 bc	1.083 c	115.4
75% urea/ESN split	7.0 ab	27.5 ab	39.2 ab	6.9 ab	52.0 abc	1.086 bc	111.8
100% urea split (STD)	4.6 b	24.8 abc	41.6 a	7.3 a	48.6 c	1.083 c	100.0
2009							
Check	15.7 a	13.5 b	13.8 ab	4.2 b	84.9 a	1.088 abcd	76.5
100% urea PP	10.5 a	20.4 a	18.1 ab	4.9 ab	72.9 ab	1.084 d	107.3
75% urea PP	8.4 a	17.7 ab	20.2 ab	4.9 ab	71.6 ab	1.086 abcd	99.1
50% urea PP	13.8 a	17.4 ab	11.1 b	4.7 ab	76.1 ab	1.090 abc	98.4
100% ESN PP	13.7 a	17.9 ab	20.6 ab	4.8 ab	76.5 ab	1.084 cd	92.9
75% ESN PP	14.7 a	16.7 ab	15.7 ab	4.8 ab	74.5 ab	1.091 a	93.1
50% ESN PP	11.7 a	15.8 ab	20.3 ab	4.7 ab	74.9 ab	1.090 abc	89.3
75% ESN TD	7.9 a	16.7 ab	17.5 ab	5.0 ab	70.7 b	1.090 ab	93.1
75% urea/ESN split	10.2 a	16.1 ab	19.9 ab	5.0 ab	71.5 ab	1.087 abcd	89.6
100% urea split (STD)	8.0 a	19.1 a	22.6 a	5.10 a	69.9 b	1.085 bcd	100.0

Potato yield from the Brooks site was higher each year than yield at the Vauxhall site for all treatments. Very different responses to the nitrogen treatments were observed at the two research locations in 2007. These differences were thought to be related to different agronomic practices, soil types or environmental conditions. In 2008, a severe hail storm in mid-July in Vauxhall likely reduced yield relative to Brooks. Similar responses to the nitrogen treatments were observed at the two research locations in 2008 in spite of hail damage at the Vauxhall site. Soil moisture was monitored at both sites in 2008 and 2009 to try to ensure that irrigation management was more consistent between the two sites. In 2009, a combination of solid set and wheel move sprinklers was set up at the Vauxhall site which increased variability between replicates. The 2009 crop was smaller than expected at both locations. A significant amount of bulking may have taken place in September if the crops had not been desiccated. Differences between treatments would likely have been more apparent if the crop had additional time to bulk.

Yield variation was evident between years at each location as well (Tables 12 & 13). An initial evaluation of cumulative physiological days (P-Days, Sands et al. 1979) for each season did not reveal any clues, but P-day accumulation at key growth stages provided a plausible explanation. A higher percentage of small tubers were harvested from both locations in 2007 compared to 2008 and 2009. As reported earlier, there were 21 days over 30˚C in July of 2007, 3 days in 2008, and 4 days in 2009 (data not shown). The difference in temperatures is reflected in the P-days accumulated in June and July of each year Table 10). In 2007, approximately 25 to 30 more P-days were accumulated in June of 2007 than 2008 or 2009 and 20 fewer P-days were accumulated in July than in 2008 and 2009. Heat in June may have affected tuber initiation. Excessive heat in July likely reduced growth and development of the potato plants. September was also much cooler in 2007 and may have reduced tuber bulking.

7. Conclusions

ESN can be used in place of or in concert with urea as an N source for Russet Burbank production in southern Alberta. Six site years of data were generated during the trial. Lysimeters were installed within treatments at the Brooks location of the trial to monitor nitrate levels below the root zone in each treatment. Plots were irrigated to maximize yield rather than to encourage leaching and there were no significant leaching events during the trial. Few differences were observed between treatments.

Petiole nitrates were monitored each year of the trial. Petioles nitrates from all treatments except the check fell within the recommended range for processing potatoes in southern Alberta at the first sampling date in late June or early July. Depending on the year and the location, petioles often dropped below the recommended range by the second or third sampling date. As expected, treatments with less N applied pre-plant reflected lower petiole nitrate concentrations and treatments with the greatest applied N, whether ESN or urea, maintained the highest petiole nitrate concentrations throughout the season. Split applications typically maintained petiole nitrates at higher levels through the season than pre-plant applications, although some exceptions were observed.

Treatments involving ESN resulted in marketable yields that were greater or not significantly different than yields from the split urea (STD) treatment. Average tuber size and tuber count in a 10 kg sample were affected more by environmental conditions each year than by N treatments. Applying N as ESN at emergence tended to reduce average tuber size relative to other comparable treatments applied pre-plant or as split applications. In general, though, the more N applied, the lower the average tuber size and the fewer tubers over 10 oz. The more N applied, the lower the specific gravity of tubers. ESN had less of an effect on tuber specific gravity than the same quantity of urea. ESN applied at hilling reduced specific gravity more than pre-plant application of ESN.

In this study, tuber size profiles, specific gravity and price of fertilizer were all taken into account for the crop value calculations. Base price assumed November delivery and fry colour bonuses were not taken into account. Marketable yield had the greatest impact on relative crop value in this study. That is, the treatments resulting in the greatest marketable yield, also resulted in the greatest economic return. Treatments where only 75% of the STD N rate was applied gave better economic returns than the STD treatment 4 out of 6 site years. Based on the results of this trial, it is feasible to reduce overall N applications by 25%. It is also feasible to use ESN to eliminate the need for in-season N applications. Reducing the quantity of N applied and splitting N applications between pre-plant urea and ESN at emergence gave good marketable yields and good economic returns 4 out of 6 site years.

8. Project Reach

Processing potato growers in southern Alberta are one target audience for this research. Producers need tools to improve nitrogen use efficiency and reduce cost of production for potatoes to remain competitive. The Potato Growers of Alberta (PGA) comprises more than 106 potato producers, 70 of whom grow processing potatoes. The PGA sponsored a portion of the project. Information was provided annually to the growers via the AGM and producer meetings.

Potato processors may also benefit by keeping contract prices in a range that maintains their competitiveness in a global market. Improvements in crop quality may also be realized with timely nitrogen applications. One Alberta processing company, McCain Foods, is partnering with us in the evaluation of the potato crops. Other processors will be kept apprised of the results of the project via PGA meetings.

Indirectly, members of the public may benefit from the efficient use of resources and the prudent use of nitrogen fertilizers. The impact of the study on this group is difficult to estimate. The results of the trial may be disseminated via popular press articles at the end of the research project depending on the outcome of the trials.

9. Project Impact

For ESN to be a useful tool for potato N management in Alberta, local information for producers is essential. There is a need to determine the best approach to optimize potato yield and quality while refining costs of production. The data generated over the past three years of the trial will:

- be useful in BMP development for potato production in Alberta;
- determine whether polymer coated urea can reduce total nitrogen applied or reduce the number of in-season nitrogen applications required for optimal potato yield and quality
- provide economic evaluations of the use of polymer coated urea
- potentially reduce nitrogen losses to leaching and denitrification processes
- will address using the ESN technology under soil type and environmental conditions specific to southern Alberta.

The short and long-term outcomes depend heavily on the information generated from the trials. Adoption by growers can be monitored through ESN sales. Growers must be able to realize benefits to using ESN that exceed the price premium on ESN over urea fertilizer prices. Potato growers are asking questions about how to incorporate ESN in their nitrogen management strategy for potatoes and some early adopters have already experimented with polymer coated urea.

10. References

Hopkins, B.G., C.J. Rosen, A.K. Shiffler and T.W. Taysom. 2008. Enhanced efficiency fertilizers for improved nutrient management: Potato (*Solanum tuberosum*). Online. Crop Management doi: 10.1094/CM-2008-0317-01-RV.

Hutchinson, C.M. 2005. Influence of a controlled release nitrogen fertilizer program on potato (Solanum tuberosum L.) tuber yield and quality. Acta Hort. 684. 99-102.

Hyatt, C.R., R.T. Venterea, C.J. Rosen, M. McNearney, M.L. Wilson, M.S. Dolan. 2010. Polymer-coated urea maintains potato yields and reduces nitrous oxide emissions in a Minnesota loamy sand. Soil Sci. Soc. Am. J. 74: 419-428.

Love, S.L., J.C. Stark and T. Salaiz. 2005. Response of four potato cultivars to rate and timing of nitrogen fertilizer. Amer. J. Potato Res. 82: 21-30.

Munoz, F., R.S. Mylavarapu and C.M. Hutchinson. 2005. Environmentally responsible potato production systems: A review. J. Plan Nutrition. 28: 1287-1309.

Sands, P.J., Hackett, C. and H.A. Nix. 1979. A model of the development and bulking of potato (solanum tuberosum L.). I. Derivation from well managed field crops. Field Crop Research. 2: 309-331.

Shoji, S., J. Delgado, A. Mosier and Y. Miura. 2001. Use of controlled release fertilizers and nitrification inhibitors to increase nitrogen use efficiency and to conserve air and water quality. Commun. Soil Sci. Plan Anal. 32: 1051-1070.

Shock, C.C., A.B. Pereira and E.P. Eldredge. 2007. Irrigation best management practices for potato. Amer. J. Potato Res. 84:29-37.

Simonne, E.H. and C.M. Hutchinson. 2005. Controlled-release fertilizers for vegetable production in the era of best management practices: Teaching new tricks to an old dog. HortTech. 15: 36-46.

Stark, J.C. and D.E. Westermann. 2003. Nutrient Management. In: Potato Production Systems (eds. J.C. Stark and S.L. Love). University of Idaho Agricultural Communications.

Vos, J. 1999. Split application in potato: Effects on accumulation of nitrogen and dry matter in the crop and on the nitrogen budget. J. Agric Sci. 133: 263-274.

Waterer, D. and J. Heard. 2001. Fertility and Fertilizers. In: Guide to Commercial Potato Production on the Canadian Prairies (ed. B. Geisel). Western Potato Council.

Westermann, D.T. 2005. Nutritional requirements of potato. Am. J. Potato Res. 82: 301-307.

Wilson, M.L., C.J. Rosen and J.F. Moncrief. 2009. Potato response to a polymer-coated urea on an irrigated, coarse-textured soil. Agron. J. 101. 897-905.

Woods, S.A., L. Hingley and M.N. Konschuh. 2008. Petiole nutrient recommendations for Russet Burbank potatoes grown in southern Alberta (2004-2007). Research Report for Potato Growers of Alberta, Taber, AB. 50 pp.

Zebarth, B.J. and C.J. Rosen. 2007. Research perspective on nitrogen BMP development for potato. Amer. J. Potato Res. 84: 3-18.

Zvomuya, F. and C.J. Rosen. 2001. Evaluation of polyolefin-coated urea for potato production on a sandy soil. HortSci. 36: 1057-1060.

11. Summary

Recent work in other potato production areas with polymer-coated-urea products have demonstrated improved nitrogen-use efficiency and decreased nitrate leaching (Hopkins et al 2009, Hutchinson 2005, Shoji et al. 2001, Zvomuya and Rosen 2001). This project involved growing Russet Burbank potatoes at two southern Alberta research stations to evaluate the use of a polymer-coated urea product locally. The purpose of the trial was to determine whether environmentally smart nitrogen (ESN, Agrium) could be used in potato production to reduce the total amount of N or the number of N applications without sacrificing yield or processing quality. Various quantities of urea and ESN were applied pre-plant and compared with urea at planting followed by top-dressing at emergence. Marketable yields from treatments involving ESN were greater or not significantly different from the split urea (STD) treatment each year of the trial, even when 25% less N was applied. In general, the more N applied, the lower the specific gravity and the fewer tubers over 10 oz. When economic return was taken into account, marketable yield had a greater impact on crop value than fertilizer price, average tuber size or specific gravity bonuses. Each treatment with a better economic return than the STD used a reduced rate of N. Based on the results of the trial, it is feasible to reduce overall N applications by 25%. Employing a split application with urea pre-plant and ESN at emergence gave good results in 2008 and 2009 provided that irrigation was timely and sufficient.

Resources used in the project:

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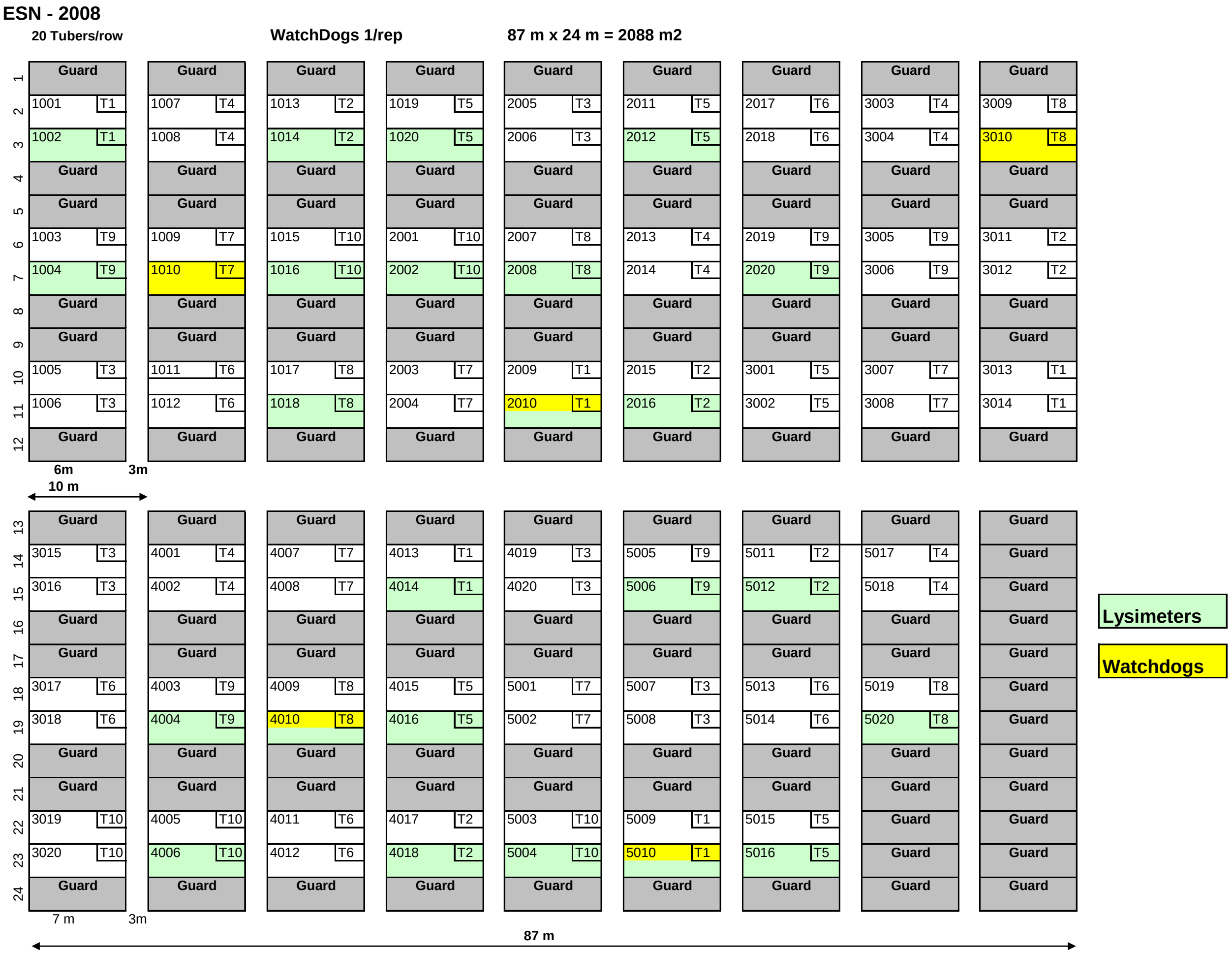
Year	Applicant / Industry Cash	Applicant / Industry In-kind	Provincial Government Cash	Provincial Government In-kind	Federal Government Cash	Federal Government In-kind
2007-08	18,000	2,500	0	14,500	15,800	9,500
2008-09	12,000	2,500	0	14,500	13,000	9,500
2009-10	12,000	2,500	0	14,500	13,700	9,500



ESN - 2008

20 Tubers/row

WatchDogs 1/rep

87 m x 24 m = 2088 m2

1	Guard	Guard	Guard	Guard	Guard	Guard	Guard	Guard	Guard
2	1001 T1	1007 T4	1013 T2	1019 T5	2005 T3	2011 T5	2017 T6	3003 T4	3009 T8
3	1002 T1	1008 T4	1014 T2	1020 T5	2006 T3	2012 T5	2018 T6	3004 T4	3010 T8
4	Guard	Guard	Guard	Guard	Guard	Guard	Guard	Guard	Guard
5	Guard	Guard	Guard	Guard	Guard	Guard	Guard	Guard	Guard
6	1003 T9	1009 T7	1015 T10	2001 T10	2007 T8	2013 T4	2019 T9	3005 T9	3011 T2
7	1004 T9	1010 T7	1016 T10	2002 T10	2008 T8	2014 T4	2020 T9	3006 T9	3012 T2
8	Guard	Guard	Guard	Guard	Guard	Guard	Guard	Guard	Guard
9	Guard	Guard	Guard	Guard	Guard	Guard	Guard	Guard	Guard
10	1005 T3	1011 T6	1017 T8	2003 T7	2009 T1	2015 T2	3001 T5	3007 T7	3013 T1
11	1006 T3	1012 T6	1018 T8	2004 T7	2010 T1	2016 T2	3002 T5	3008 T7	3014 T1
12	Guard	Guard	Guard	Guard	Guard	Guard	Guard	Guard	Guard
13	Guard	Guard	Guard	Guard	Guard	Guard	Guard	Guard	Guard
14	3015 T3	4001 T4	4007 T7	4013 T1	4019 T3	5005 T9	5011 T2	5017 T4	Guard
15	3016 T3	4002 T4	4008 T7	4014 T1	4020 T3	5006 T9	5012 T2	5018 T4	Guard
16	Guard	Guard	Guard	Guard	Guard	Guard	Guard	Guard	Guard
17	Guard	Guard	Guard	Guard	Guard	Guard	Guard	Guard	Guard
18	3017 T6	4003 T9	4009 T8	4015 T5	5001 T7	5007 T3	5013 T6	5019 T8	Guard
19	3018 T6	4004 T9	4010 T8	4016 T5	5002 T7	5008 T3	5014 T6	5020 T8	Guard
20	Guard	Guard	Guard	Guard	Guard	Guard	Guard	Guard	Guard
21	Guard	Guard	Guard	Guard	Guard	Guard	Guard	Guard	Guard
22	3019 T10	4005 T10	4011 T6	4017 T2	5003 T10	5009 T1	5015 T5	Guard	Guard
23	3020 T10	4006 T10	4012 T6	4018 T2	5004 T10	5010 T1	5016 T5	Guard	Guard
24	Guard	Guard	Guard	Guard	Guard	Guard	Guard	Guard	Guard

🟩 Lysimeters

🟨 Watchdogs

Figure A1: Sample plot plan of ESN Trial. Plot plans were similar for both locations each year of the trial.