<u>Project Identification</u>

1. **Project Title:** Improving Nitrogen Use Efficiency in Carrots
2. **Project Number:** 201894976
3. **Producer Group Sponsoring the Project:** Conservation Learning Centre
4. **Project Location(s):** SW 20-46-26 W2 RM #461 (Prince Albert)
5. **Project Start and End Dates (Month & Year):** February 20, 2019 to February 15, 2020
6. **Project Contact Person & Contact Details:**

A.Robin Lokken AAg
Manager
Box 1903
Prince Albert, SK
S6V 6J9
info@conservationlearningcentre.com
306-960-1834

B.Joanne Kowalski
BOD Chair
jkowalski@sasktel.net
306-980-8688

Objectives and Rationale

7. Project objectives:
The objective of this demonstration is to demonstrate how enhanced efficiency products could improve nitrogen use efficiency and impact carrot yield in north central Saskatchewan.

8. Project Rationale:

Enhanced efficiency fertilizer products have been proven effective for their specific purposes and are commercially available. Products have been developed to slow down the release of plant available N in order to ensure better crop uptake and to reduce losses to the surrounding environment. Some of these readily available products include SuperU, Agrotain, and ESN. Both SuperU and Agrotain are inhibitors, while ESN is a controlled release product. SuperU uses both a urease and nitrification inhibitor that slows the conversion of urea to ammonia, which reduces volatilization losses, and the conversion of ammonium to nitrate, which reduces leaching and denitrification losses. Agrotain only uses a urease inhibitor and as a result protects against volatilization losses, but not leaching and denitrification. ESN is urea with a polymer coating that allows moisture in. This moisture forms a N solution that moves out through the membrane at a rate controlled by soil temperature. Ideally the N solution is released when conditions are ideal for plant growth. Like SuperU, ESN reduces losses associated with denitrification, leaching and volatilization.

Whether these products are economically or agronomically beneficial depends on the environmental conditions and the crops response to N. Carrots have a high N demand but are also susceptible to excessive crop growth if too much N is available, which would reduce the growth and development of the marketable portion of the carrot, the root. Excessive crop growth can also create conditions that are more favorable for diseases like sclerotinia. Carrots were selected due to the likelihood of a N response and also because carrots are an important vegetable crop in Saskatchewan. Vegetable production is on the rise in Saskatchewan and carrots make up 8% of Saskatchewan's total vegetable acres, being the fourth most common vegetable grown.

A similar study was completed in Prince Edward Island and showed enhanced efficiency products could increase yields when applied at lower N rates than the industry standard (Sanderson, et al. 2012). The CLC study wanted to demonstrate if the same results could be achieved in the prairies. This project was anticipated to demonstrate 4 R nutrient stewardship in a horticultural setting and demonstrate methods that could be used to reduce fertilizer inputs and associated costs, increase yields, as well as provide environmental benefits through reduced fertilizer losses by water and in the form of greenhouse gas emissions.

Methodology and Results

9. Methodology:

This trial was set up as a randomized complete block design with 4 replicates. Three different nitrogen efficiency products were compared to an industry standard of 100 kg N/ha of urea. A control was also included where no additional N was added, with the exception of N with the application of monoammonium phosphate (MAP). The treatment list can be found in table 1. Prior to seeding, fertilizer treatments were applied by hand broadcasting and incorporated with a rototiller. Nitrogen fertilizer rates were applied as per protocol (Table 1). Phosphorus rate was 146 kg P_2O_5/ha based off of a spring soil test (Table 3). Royal Chantenay carrots were seeded June 4, 2019 at an approximate depth of 2 cm using an Earthway Precision Garden Seeder. Four rows were seeded per plot with a row spacing of 20 cm. Plot length was 4 m.

Drip irrigation was installed June 14, 2019 and Prince Albert city water was used for irrigation. The two inside rows of each plot were irrigated. Irrigation was used to ensure the crop received 1 in of water per week during peak use when it was not met by precipitation. Plant counts were completed July 12 and final stand counts were completed during harvest. Carrots were allowed to self thin. Plots were monitored for pests and disease. The disease aster yellows was detected by appearance of yellowing and bronzing of foliage, but was not severe to warrant any control. Centurion was applied June 26, 2019 for control of grassy weeds. Plots were relatively weed free for the remainder of the growing season. Any further weeding was completed by hand and a small rototiller was used to control weeds between plots.

Table 1. Treatment list of different N types and rates used in the carrot trial.

Trt #	N source	N rate (kg N/ha)
1	None (control)	0
2	Urea	100
3	Agrotain	70
4	Super U	70
5	ESN	70

Carrots were harvested by rep from October 2 – October 7. An inside 4 m length of row was harvested for each plot. All carrots were dug and the above ground biomass was separated by clipping and then immediately weighed. Roots were washed before weighing. Carrots were separated into 6 categories based on Canadian No. 1 grading standards and Prairie Fresh baby carrot standards. Midsize is not a typical category for Prairie Fresh baby carrot standards, but was added due to the large quantity of carrots that did not meet the length requirements to be considered regular. These categories are listed and described in table 2. After carrots were grouped into the different categories, both a count and total weight was recorded. The count was used as the final plant stand. Marketable carrots were considered carrots that fit into categories baby, regular, and midsize. Unmarketable included undersize, oversize and cull. Data was statistically analysed as an RCBD ANOVA using Statistix10. Tukey HSD was used to assign differences from multiple comparisons.

Table 2. Description of criteria used to categorize carrots.

Category	Description	
	Length (in)	Diameter (in)
Undersize	< 3 ½	<3/8
Baby	3 ½ - 6	3/8 – 1
Regular	> 6	1 – 1 ¾
Oversize		> 1 ¾
Midsize	3 ½ - 6	1 – 1 ¾
Cull	Misshapen, animal damage, cracked, miscoloured, excessive secondary roots, woody.	

10. Results

Soil Tests

Soil testing was completed spring of 2019 prior to seeding (Table 3). Based on soil test results 31.5 kg N/ha of N was available. The application of MAP resulted in an excess of approximately 30 kg N/ha applied to each treatment. As a result, all treatments would have approximately

61.5 kg N/ha available prior to the N fertilizer treatments. It was not deemed necessary to apply any other nutrients. Carrots require 110 kg N/ha, 120 kg P2O5/ha and 250 kg K/ha when grown on mineral soils (Saskatchewan Ministry of Agriculture). Carrots are sensitive to salt and can withstand up to 4 mS/cm. The salts at the trial were well below this level at 0.2 mS/cm.

Table 3. Soil test results.

Depth (cm)	N (lb/ac)	P (ppm)	K (ppm)	S (lb/ac)	OM (%)	pH	Salts (mm ho/cm)
0 – 15	17	9	265	16	6.2	5.7	0.2
15 – 30	11			16		6.8	0.25
0 – 30	28						

<u>Weather</u>

Similar to 2018, the spring and summer of 2019 was relatively dry (Table 4). CLC and producers in the area struggled with poor crop emergence due to dry soil conditions. Dry conditions during soil preparation resulted in a clumpier than desired seed bed; however, timely rains immediately following seeding of carrots and drip line installed on June 14, 2019 resulted in successful carrot emergence. The first frost did not occur until September 27th (-0.5°C), and the first hard frost occurred on October 9th (-7.2°C). September had a higher than average precipitation and October was colder than average (Table 4), which made it a wet and cold harvest. While growing degree days were lower than average at the CLC, this had no detrimental effect on carrots, which mature in approximately 65 days. Carrots were harvested by rep from October 2 – October 7. Carrots could have been harvested earlier, but due to the lack of frost and the urgency to complete other tasks at the research farm, carrots were harvested in early October. A later harvest was also chosen since frost can sweeten the taste of carrots.

Table 4. Weather conditions over the 2019 growing season at the Conservation Learning Centre.

	May	June	July	August	September	October	Average/Total
				--- Temperature (°C) ---			
2019	9.5	15.8	17.4	15.1	11.6	1.0	11.7
2012-2018	11.8	16.1	18.5	17.3	11.6	3.5	13.1
				--- Precipitation (mm) ---			
2019	30.0	54.4	57.4	16.8	59.6	11.6	229.8
2012-2018	36.4	80.6	96.1	48.0	25.8	26.0	310.5
				--- Growing Degree Days (base 5°C) ---			
2019	164.7	322.7	383.5	314.1	207.3	13.1	1405.4
2012-2018	211.1	332.7	419.0	381.6	203.2	38.2	1585.9

Royal Chantenay carrots were selected because they were incorrectly thought to be an intermediate choice between Nantes and an Imperator. Shapewise they are considered an intermediate (Saskatchewan Ministry of Agriculture), but Chantenay carrots are shorter and wider than other varieties of carrots. Chantenay carrots are typically grown for processing and canning due to their high yields. They mature in 65 days and grow to 10-12 cm (4-5 inch) in length and 5-6.4 cm (2-2.5 inch) in width. Due to their short roots, they grow well in heavy soils (Larum, 2018).

In order to provide more detail about the quality/size of carrot yield per treatment, the Prairie Fresh Baby Carrot guidelines were used. An extra category was added to accommodate the short nature of the Chantenay carrot variety. Chantenay is not a variety that would be used for the fresh baby carrot market. Since this variety is better suited for processing, size requirements are likely not as stringent. In retrospect, it would have been more meaningful to have selected a longer hybrid carrot such as Mokum or Bolero that is better suited to the grading guidelines used. No differences were detected between the treatments for various size categories used (table 5). Approximately half the carrots were sized as midsize and undersize, which is to be expected since the carrots are a wide and short variety.

Table 5. Breakdown of carrot size and quality when nitrogen efficiency products are used.

Treatment	Kg N/ha	Yield (t ha^{-1})						
		Total	Under size	Baby	Regular	Oversize	Cull	Midsize
Control	0	80.6	22.9	9.4	0.9	11.1	7.2	29.1
Urea	100	99.3	28.8	9.3	0.7	18.9	12.4	29.3
Agrotain	70	98.4	25.4	4.5	0.6	12.2	19.8	36.0
SuperU	70	109.0	26.5	10.5	0.3	21.9	15.6	34.2
ESN	70	112.6	20.3	5.3	1.4	26.6	23.9	35.0
P value		0.2188	0.3756	0.5170	0.6252	0.1239	0.2235	0.9012
SD		21.1	7.7	5.8	1.0	9.3	10.6	12.7

Although not statistically significant, the addition of fertilizer did increase total root yield by 20 – 32 t/ha dependant on the treatment (table 6). Final plant stands were similar across all treatments and no differences were detected between plant stand, root total, marketable and unmarketable yields ($p>0.05$) (Table 6). Due to the high amount of MAP applied to reach phosphorus fertility requirements and soil N, the control treatment did have an equivalent of 61.5 kg N/ha. While below the needed 110 kg N/ha, it should be noted that the control was not extremely limited. It should also be noted that the urea treatment N rate was equivalent to 161.5, and the efficiency products were 131.5 kg N/ha. The lack of response between the urea and efficiency products used at lower rates may be a result of all treatments having sufficient N available and maximum yield potential being reached. Alternatively, the yields of the efficiency products may be similar to the yields of urea when applied at 30% lower rate due to improved nitrogen use efficiency of the carrots. Although the efficiency products were applied at a lower rate, the N was released at a slower rate to better match the demand of the plants. While there are no differences in yield of carrots, less N was applied with the efficiency products and as a result less was available to be lost to the surrounding environment.

The lack of difference between the efficiency products used may be a result of the environmental conditions. Different efficiency products work best under different environmental conditions. Agrotain, which uses only the urease inhibitor, protecting against volatilization, works best under conditions that would favor high volatilization losses. These conditions occur when the fertilizer is applied close to the surface, soil has a high pH, high crop residue and warm and windy weather. Since the fertilizer treatments were incorporated into the soil, there was a reduced volatilization threat. If producers plan to broadcast fertilizer and not incorporate, efficiency products are highly recommended. SuperU contains both the urease inhibitor and a nitrification inhibitor, and as a result, can reduce volatilization losses like Agrotain, but can also protect against losses due to excessive moisture. Other than the applied drip irrigation, conditions were very dry at the CLC. ESN does not contain inhibitors, but the polymer coating slows down the release of urea and is also marketed as reducing losses from all three potential loss pathways of volatilization, leaching of nitrate and gaseous losses due to denitrification.

Table 6. Yield of carrots and final plant stands with the use of nitrogen efficiency products.

Treatment	**N rate**	**Yield**				**Plant stand**
		Above Ground	**Root Total**	**Marketable**	**Unmarketable**	
	(kg N/ha)	----------------------------**(t ha^{-1})**----------------------------				**(no. m^{-1})**
Control	0	28.7 b	80.6	39.4	41.2	53
Urea	100	50.0 a	99.3	39.2	60.1	63
Agrotain	70	41.8 ab	98.4	41.0	57.4	67
SuperU	70	48.3 a	109.0	45.0	64.0	61
ESN	70	47.4 a	112.6	41.8	70.8	52
P value		0.0120	0.2188	0.9854	0.0700	0.4446
SD		10.4	21.1	13.7	16.5	13.5

Over application of N can result in excessive above ground leaf growth, which can reduce the growth and development of the marketable root. This was clearly evident with this trial (table 6). All fertilized treatments had an excess of N greater than the required 110 kg N/ha and had greater above ground leaf growth than the control. SuperU, and ESN performed similarly to the urea that was applied at a higher rate. Of the fertilized treatments, Agrotain had the lowest above ground growth.

Table 7. Estimated cost analysis of efficiency products compared to industry standard of urea as of November 2019.

Treatment	Cost	N Rate	Actual Product rate		Total cost
	$/t	Kg/ha	Kg/ha	t/ha	$/ha
Urea	500	100	217	0.22	109
Agrotain	580	70	152	0.15	88
SuperU	630	70	152	0.15	96
ESN	625	70	159	0.15	99

Enhanced efficiency products at lower rates perform similar to standard N products, which helps reduce losses to the surrounding environment. The adoption of efficiency products will depend on the cost of the product, since the products can be costly ranging between 1.3–12X more than conventional fertilizer (Sanderson, et al. 2012). To address this, an economic analysis of the cost associated with the various treatments was completed. Since there were no differences found between total or marketable yields, total profits were not estimated. These estimates are based off of November 2019 fertilizer prices. The efficiency products used in the study were approximately 1.3X more expensive than urea, but since rates were lower, total cost per ha was less.

This demonstration was featured at the CLC Annual Field Day held July, 2019 with approximately 50 people in attendance and the Vegetable Growers AGM held in Saskatoon in January 2020 with approximately 20 people. This trial was also featured in a crop walk video posted through the Ministry of Agriculture Facebook page and has received over 1000 views. The carrot crop walk video was one of the most viewed and shared crop walk videos of 2019.

References:

Larum, D. (2018) Chantenay Carrot Info: Guide to Growing Chantenay Carrots. Retrieved January 17, 2020 from https://www.gardeningknowhow.com/edible/vegetables/carrot/chantenay-carrot-info.htm

Sanderson, K.R., and S.A.E. Fillmore. 2012. Slow release nitrogen fertilizer in carrot production on Prince Edward Island. Can. J. Plant Sci. 92: 1223-1228

11. Conclusions and Recommendations

This demonstration would have been more meaningful if a different carrot type had been selected that was meant for fresh markets. However, this demonstration showed how high N rates can increase above ground biomass that can be problematic for controlling disease if present. This can also lead to reduced below ground growth of the marketable root. Enhanced efficiency N products when used at lower rates were found to perform similar to the industry standard, implying improved nitrogen use efficiency, which reduces the loss of N to the surrounding environment. The use of enhanced efficiency products is a great option to help reduce losses to the environment and is a form of insurance in case weather conditions are favorable for N losses. Enhanced efficiency products can be expensive, but being able to apply at lower rates than urea can make the product more affordable and the practice to be more widely adopted. The 2019 growing season was relatively dry. Under a wetter scenario, SuperU and ESN may have had a better response compared to urea and Agrotain.

12.Acknowledgements:

The Conservation Learning Centre graciously acknowledged the Ministry's support through signage directly in field with the project, verbally during the Field Day and on the Field Day agenda handed out to all visitors. The CLC also thanks Nutrien Ag Solutions and Koch Fertilizer for providing the efficiency products used.

13. Abstract:

The objective of this project was to demonstrate how enhanced efficiency products could improve nitrogen use efficiency and impact carrot yield in north central Saskatchewan. Three different nitrogen efficiency products including Agrotain, SuperU and ESN were applied at a rate of 70 kg N/ha and compared to an industry standard of 100 kg N/ha of urea and a control of no additional N. Royal Chantenay carrots were grown and total yield, above ground yield, various sizing categories, and plant stands were measured. In order to meet P requirements, the addition of MAP and residual soil N resulted in the control treatment having 61.5 kg N/ha, industry standard 161.5 kg N/ha and efficiency products 131.5 kg N/ha. The addition of fertilizer increased total yield by 20 – 32 t/ha and increased above ground biomass. The efficiency products had similar yields as the industry standard even though they were applied at a rate that was 30% lower. This implies that there was improved nitrogen use efficiency and, or carrots had sufficient N available with all treatments and reached the possible maximum yield potential under 2019 growing conditions. There were no differences between the efficiency products, but the 2019 season was very dry and was not conducive to showcasing the potential for SuperU and ESN to reduce denitrification and leaching losses. The use of efficiency products at lower N rates implies less N loss to the surrounding environment. Based on November 2019 fertilizer prices, N use efficiency products when applied at a 30% lower rate than urea cost 21 –

10 $/ha less. N efficiency products can be costly, however, if applied at a lower rate due to expected improved nitrogen use efficiency, cost may no longer be a limitation. This trial was featured at the 2019 CLC Field Day, presented at the Saskatchewan Vegetable Growers Association Meeting in January and reached over 1000 viewers as a Ministry of Agriculture Crop Walk Feature.