<u>**Project Identification**</u>

1. **Project Title:** Improving nitrogen use efficiency in brassica (cole) vegetable production
2. **Project Number:** 20190421
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):** April 2020 to February 2021

6. **Project Contact Person & Contact Details:**

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Objectives and Rationale

7. Project objectives:
To demonstrate the impacts of enhanced efficiency products on the yield of brassica vegetables produced in north-central Saskatchewan. To assess the effects of efficiency products on short season, long season and continuous harvest cole vegetable crops of cabbage, brussel sprouts and kale, respectively.

8. Project Rationale:

In western Canada, crop response to N fertilizer and the 4R principles have been widely demonstrated for various grain crops. Enhanced efficiency formulations (EEF) slow down the rate at which N becomes plant available and is susceptible to losses, which can decrease overall N losses. The EEFs used in this demonstration are effective for their specific purposes, but their economic or agronomic benefits are dependent on the crop's response to the N and the local environmental conditions.

In 2019, the Conservation Learning Centre (CLC) completed a study of the effects of EEFs such as Nitrain, Super U, and ESN on carrots compared to urea. In this study, the EEFs performed just as well as urea, even when applied at a lower rate. Carrot yields were similar in treatments where 70 kg N/ha of EEFs were applied as in treatments where 100 kg N/ha of urea was applied, indicating that N use efficiency was better when N was applied as an EEF.
The 2019 CLC project drew from a similar 3-year study on EEFs in carrots conducted on Prince Edward Island (PEI). The PEI study found that using a product containing a urease and nitrification inhibitor could increase total yield by 7.5% and marketable yield by 18.7%. In this study, ammonium nitrate was applied at double the rate (100 kg N/ha) of the EEFs (50 kg N/ha). Other EEFs used in the study also had similar yields to the industry standard. EEFs improve the

efficiency of applied N, reducing the amount of N that needs to be applied. To justify switching to the costlier EEF product, there needs to be an economic benefit to the producer in the form of increased yields or reduced input costs.

Brassicas are a vegetable crop that perform well in Saskatchewan and are very responsive to soil N fertility. Yields of long-season storage cabbage have increased at N rates as high as 400 and 500 kg N/ha in Ontario and Quebec (Van Eerd, et al., 2018). Excess N can result in splitting of heads (Ministry of Agriculture), whereas the quality of cabbage can suffer from deficiencies of under 50 kg N/ha. Producers have successful yields with larger applications of N prior to planting, despite the risk of N losses. Multiple fertilizer applications are recommended to reduce the risk of N losses, but this raises the cost of application. EEFs may be a solution to better match N fertilizer timing to plant demand of cole crops. An Ontario study demonstrated that polymer coated urea was slower to dissolve than the ammonium nitrate industry-standard (Van Eerd, et al., 2018). Slow-release N products could better provide a consistent supply of N throughout the growing season.

The study in Ontario also compared the performance of EEFs applied pre-plant, and the industry-standard of ammonium nitrate applied as a split application and found no discernable differences. As a result, there were no environmental, economic, or agronomic benefits identified with the treatments used under Ontario's humid and temperate climate. There was no analysis comparing the performance of the EEFs, and the industry-standard applied pre-plant only. Most producers in Saskatchewan are likely pre-plant broadcasting their N, while larger producers are banding during planting. Split applications are likely not common, indicating that EEFs could still provide an environmental, economic and/or agronomic benefit compared to Saskatchewan's industry standard. Also, Saskatchewan varieties may respond differently, and EEFs could prove to be more beneficial for cole crops that have a shorter growing season or are continuously harvested.

Van Eerd, L.L., Turnbull, J.J.D., Bakker, C.J., Vyn, R.J., McKeown, A.W., and S.M. Westerveld. 2018. Comparing soluble to controlled-release nitrogen fertilizers: cabbage yield, profit margins, and N use efficiency. Can. J. Plant Sci. 98:815-829.

Methodology and Results

9. Methodology:

This trial was set up as a randomized complete block design with three 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, except for N with the application of monoammonium phosphate (MAP). The treatment list can be found in Table 1. Before seeding, the area was rototilled to prepare the area for planting. Fertilizer treatments and phosphorus were applied by hand broadcasting and incorporated with a rototiller. Nitrogen fertilizer rates were applied as per protocol (Table 1). A phosphorus rate of 139 kg/ha was applied based on a spring soil test (Table 6). Transplants of dagan brussels sprouts and bronco cabbage were planted by hand at a rate of 10 plants per row, with 50 cm spacing between plants and 60 cm spacing between rows. Winterbor kale seeds were also planted by hand, two seeds per hole, with the same plant and row spacing as the brussels sprouts and cabbage at a depth of 0.25 inches. Plots were approximately 5.5 m by 6 m, resulting in 9 rows per plot (3 rows of each brussels sprouts, cabbage, and kale). Replicates 2 and 3 of brussels sprouts and cabbage were planted May 29, 2020 and replicate 1 of brussels sprouts and cabbage and all the kale was planted on June 1, 2020.

Samples of the different types of fertilizer used in this study were placed in mesh bags and planted in the soil close to the plots to determine how much time it took for the fertilizers to break down. Four bags each of 7.5 g of urea, Nitrain, Super U and ESN were planted 15 cm deep on June 3, 2020. Four additional ESN bags were planted on August 5, 2020.

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

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

Table 2. Additional information for the cole crop trial.

Legal Land Location	SE-20-46-26-W2 RM 461
Soil Type	Clay loam
Soil Zone	Black

Drip irrigation was set up on June 3, 2020 and Prince Albert city water was used for irrigation. The middle row of cabbage, brussels sprouts, and kale of each plot was irrigated. The trial was irrigated to ensure the crop received at least 1 in of water per week when it was not met by precipitation. A full irrigation schedule can be found in Table 3. The flea beetle pressure on kale was very high, and many seedlings did not make it. Occasionally both kale seedlings planted survived, resulting in two kale seedlings per hole. One of the two kale seedlings were transplanted into a hole (within the same plot) that was missing a kale seedling. Extra kale seedlings had been started in pots and were transplanted into the plot where there were not enough double seedlings to transfer.

Table 3. Irrigation schedule for cole crop trial.

Date	Length of time (hours)
June 3, 2020	Replicates 1-3: 3.5
June 10, 2020	Replicates 1-3: 4
June 25, 2020	Replicates 1&2: 2.5
	Replicate 3: 2.5
July 17, 2020	Replicates 1&2: 2
July 24, 2020	Replicate 3: 2
August 7, 2020	
August 21, 2020	
August 24, 2020	
August 28, 2020	

Plots were monitored for pests and disease. A full schedule of fungicides and insecticides used in this trial can be found in Table 4. On July 7, 2020, the trial was sprayed with the insecticide Coragen® to control diamondback moths (*Plutella xylostella*) and imported cabbageworm (*Pieris rapae*). A few days later, on July 10th, 2020, cabbage root maggots (*Delia radicum*) were found. In response, a soil drench of the insecticide Citadel 480 EC (Chlorpyrifos) was applied. Coragen® was applied three more times and Pounce once to control imported cabbageworm throughout the growing season. Sclerotinia was detected in the cabbage, brussels sprouts, and kale around August 18, 2020. The fungicides Serenade and Luna were applied alternately every 1.5 weeks to the cabbage and brussels sprouts (Serenade two applications and Luna one application) starting August 26, 2020 to September 15, 2020 to provide effective protection against sclerotinia. Serenade and Luna were not applied to the kale because the sclerotinia on the kale was negligible.

Table 4. Chemical application information in cole crop trial.

Type	Name	Date	Rate	Comments
Fungicide	Serenade	August 26, 2020	5.86L/ha	Applied to brussels sprouts and cabbage only.
	Luna	September 4, 2020	560 mL/ha	
	Serenade	September 15, 2020	5.86L/ha	
Insecticide	Coragen	July 7, 2020	250mL/ha	For control of Imported Cabbage Moth, Diamondback Moth.
	Citadel	July 14, 2020	Soil Drench – 1.7L Citadel/1000L Water; 12.5L/100m row	For control of Cabbage Root Maggot.
	Coragen	July 27, 2020	250mL/ha	For control of Imported Cabbage Moth, Diamondback Moth.
	Coragen	August 4, 2020	250mL/ha	
	Coragen	August 20, 2020	250mL/ha	
	Pounce	September 1, 2020	180 mL/ha	

Kale was harvested by hand every week starting on July 30, 2020 (only replicates 1 and 2 were harvested on July 30, and the harvest of kale in replicate 3 began the following week) to September 25, 2020, by pinching off leaves that were as large or larger than a person's hand. Generally, about 50% of the plant leaves were picked off during harvest. Each week the row of kale that was irrigated was picked by hand, weighed, and cleaned. Replicates 1 and 2 of cabbage were harvested on August 25, 2020 and replicate 3 was harvested on September 1, 2020. From each plot, ten of the largest cabbage were picked by hand, cleaned, and weighed. The brussels sprouts were harvested by firstly cutting the plant leaves off, then the brussels sprouts/nodes of the plant were picked off by hand. In replicate 1, five brussels sprout plants per plot were harvested by hand on September 15, 2020, and five more per plot were harvested on September 28, 2020. For replicates 2 and 3, ten brussels sprout plants from each plot were harvested on September 25, 2020, except for plot 301, where ten brussels sprout plants were harvested on September 28, 2020. After the brussels sprouts were harvested, they were sorted into the categories; small (0-2.3 cm diameter), medium (2.3-4.1 cm diameter), oversize (>4.1 cm diameter), and rejects. These categories are based on a study by Cutcliffe et al. (1967). The medium brussels sprouts are considered the ideal size. The CLC successfully sold both the small and medium-sized brussels sprouts at the local farmer's market, so both small and medium brussels sprouts are considered marketable for this study. Brussels sprouts were often rejected because they were full of insects, moldy, very tiny, and/or had been eaten by insects. Once organized into these categories, the weights of the brussels sprouts per category were recorded.

10. Results

Weather

The spring and summer at the CLC saw adequate precipitation compared to past years (Table 5). Temperatures throughout the growing season were slightly cooler than in past years, but similar to 2019. The first fall frost occurred earlier than normal on September 8th (-3.6°C), and another hard frost occurred on September 16th (-5.3°C). Precipitation was lower in the fall months relative to the 2019 growing season. Overall, growing degree days were lower than the historical average. Growing degree days were especially low in May and June.

Table 5. Weather conditions in the 2020 growing season at the Saskatchewan Conservation Learning Centre.

	May	June	July	August	September	October	Average/Total
				--- Temperature (°C) ---			
2020	9.2	13.4	17.6	16.1	10.9	1.0	11.4
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) ---			
2020	68.4	91.4	32.2	33.2	31.6	10.1	266.9
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) ---			
2020	143.7	252.4	391.0	342.9	178.8	38.6	1347.4
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

Soil Test Results

Soil test results indicated that N and P levels were low (Table 6). 26 kg N/ha was available. The application of MAP resulted in an additional 30 kg N/ha, resulting in approximately 56 kg N/ha before applying nitrogen fertilizer. An additional 95 kg N/ha and 50 kg N/ha was applied in the urea and efficiency product treatments, respectively. Actual applied N was 206 kg N/ha for the urea treatment, 108.4 kg N/ha for the Nitrain and Super U treatments, and 113.4 kg N/ha for the ESN treatment. Cole crops require between 61 and 99 kg N/ha depending on the crop, according to Alberta Agriculture and Rural Development (2014).

Table 6. May 5, 2020 soil test results.

Depth (cm)	N (lb/ac)	P (ppm)	K (ppm)	S (lb/ac)	Zn (ppm)	OM (%)	pH	Salts (mm ho/cm)
0 – 15	10	5	187	10	1.55	4.8	6.4	0.14
15 – 45	13			26			7.0	0.18
0 – 45	23							

Throughout the growing season, replicates 1 and 2 of kale were harvested nine times and replicate 3 was harvested eight times (Table 7). The first harvest of the 3rd replicate was delayed as the plants were fewer and smaller than in the other replicates, likely due to significant weed pressure and early season flea beetle damage.

Table 7. Description of kale harvests per plot.

Treatments	Plot #	Kg N/ha	No. of plants in irrigated row	No. of harvests	Dates Harvested
Control	101	0	10	9	Jul 30, Aug 4, Aug 11, Aug 18, Aug 25, Sep 1, Sep 8, Sep 15, Sep 25
Urea	102	100	8	9	
Nitrain	103	70	7	9	
Super U	104	70	11	9	
ESN	105	70	11	9	
Nitrain	201	70	10	9	
ESN	202	70	9	9	
Control	203	0	12	9	
Urea	204	100	12	9	
Super U	205	70	8	9	
Urea	301	100	4	8	Aug 4, Aug 11, Aug 18, Aug 25, Sep 1, Sep 8, Sep 15, Sep 25
Nitrain	302	70	8	8	
Super U	303	70	10	8	
ESN	304	70	10	8	
Control	305	0	9	8	

There were no statistically significant differences in kale yield between treatments (Table 8). The average kale yield for the growing season was observably the highest in the urea treatment and lowest in the control. Yield peaked between August 25th and September 8th for all treatments (Table 8).

Table 8. The mean yields of kale throughout the growing season when using nitrogen efficiency products.

Treatment	Kg N/ha	Kale Yield (g/plant)									
		Jul 30	Aug 4	Aug 11	Aug 18	Aug 25	Sep 1	Sep 8	Sep 15	Sep 25	Avg. all yields
Control	0	24.8	27.1	38.3	51.8	61.3	49.1	58.2	18.5	25.7	35.4
Urea	100	72.1	50.9	68.6	75.3	90.2	66.9	84.9	20.8	27.0	50.3
Nitrain	70	28.8	23.1	43.5	49.9	62.5	54.3	74.6	19.6	24.6	39.3
SuperU	70	23.4	25.1	46.5	43.2	55.1	46.3	70.9	21.5	24.2	36.8
ESN	70	68.0	38.9	70.9	66.4	67.7	57.0	65.0	18.8	25.7	40.7
TRT means	N/A	43.4	33.0	53.6	57.3	65.4	54.7	70.7	19.8	25.4	46.8
P value		N/A	0.36	0.22	0.22	0.31	0.63	0.31	0.86	0.74	0.21
SD		N/A	11.4	35.2	25.2	28.2	21.5	15.6	3.95	2.58	17.2

Overall, replicate 3 had a significantly lower average yield than the first replicate (Table 9). Poor performance in replicate 3 due to weed competition and early season flea beetle pressure may have masked any treatment effects. There were no significant differences between replicates 1 and 2.

Table 9. Average kale yields for each of the three replicates.

Rep	Kale Yield (g/plant)									
	Jul 30	Aug 4	Aug 11	Aug 18	Aug 25	Sep 1	Sep 8	Sep 15	Sep 25	Avg. all Yields
1	52	51.8a	89.2a	70.1a	82.8a	65.5a	73.9a	21.8a	27.0a	59.2a
2	34.9	35.2ab	49.6b	69.1a	79.6a	65.4a	75.4a	16.7a	25.2a	50.3ab
3	N/A	12.0b	21.6b	32.7a	39.6b	33.3b	63.0a	21.0a	24.1a	30.9b
P value	N/A	0.02	0.002	0.01	0.01	0.02	0.13	0.32	0.13	0.01
SD	N/A	11.4	35.2	25.2	28.2	21.5	15.6	3.95	2.58	17.2

The average weight of cabbage and cabbage yield were not statistically significant between treatments (Table 10). Nitrain and SuperU treatments had observably larger cabbages and yielded more on average than the other treatments. All three efficiency product treatments produced larger cabbages and higher yields than the urea treatment, despite having a lower rate of N. The control produced the smallest cabbages and had observably the lowest yields.

Table 10. Average weight of each cabbage and cabbage yield with the use of nitrogen efficiency products.

Treatment	Kg N/ha	Avg. weight of cabbage (kg)	Yield (t ha^{-1})
Control	0	1.42	39.4
Urea	100	1.52	42.3
Nitrain	70	1.64	45.7
SuperU	70	1.71	47.4
ESN	70	1.55	43.1
	P value	0.87	0.09
	SD	0.34	9.55

There were no significant differences in brussels sprout yield and quality between treatments (Table 11). The urea treatment had observably the highest overall yield, but a larger proportion of oversize brussels and rejects than the other treatments. This could be due to the fact that the N in the urea became available more quickly than in the EEF product treatments, resulting in the production of more oversize brussels. The Nitrain treatment, on the other hand, observably produced the most brussels sprouts of ideal size (medium) and the fewest rejects. The ESN treatment and the control had very similar total yield, but the ESN treatment had a higher proportion of medium sized brussels sprouts than the control. The ESN broke down the most slowly of the EEF products, which may explain why the results were similar to the control.

Table 11. Breakdown of brussels sprout size and quality when nitrogen efficiency products are used.

Treatment	Kg N/ha	Brussels Sprout Yield (t ha^{-1})				
		Total	Small	Medium	Oversize	Rejects
Control	0	14.5	6.58	6.93	0.21	0.71
Urea	100	20.8	5.79	11.2	2.42	1.21
Nitrain	70	18.4	5.13	11.8	0.76	0.49
SuperU	70	18.2	5.15	10.5	1.29	1.1
ESN	70	14.7	6.5	10.3	1.04	0.86
P value		0.27	0.21	0.45	0.13	0.06
SD		3.97	1.1	3.36	1.24	0.49

The fertilized treatments of brussels sprouts produced observably higher marketable yields than the control treatment (Table 12). Marketable yields in the fertilized treatments were similar, but the urea treatment had higher unmarketable yields than any other treatment. The control had the lowest marketable yield.

Table 12. Yield of marketable and unmarketable brussels sprouts with the use of nitrogen efficiency products.

Treatment	Kg N/ha	Brussels Sprout Yield (t ha^{-1})	
		Marketable	Unmarketable
Control	0	13.5	0.93
Urea	100	17	3.64
Nitrain	70	17	1.25
SuperU	70	15.7	2.39
ESN	70	16.8	1.9
P value		0.53	0.09
SD		3.15	1.54

Samples of all fertilizer types were planted on June 3, 2020. Within the first week, all samples of urea, Nitrain and Super U had dissolved. The full list of ESN fertilizer bag weights can be found in Table 13. One bag of ESN was dug up every several weeks and disposed of, until there were only two bags left. One of the bags was dug up and replanted until August 13 when it was too dirty to be weighed. The last bag was left planted until it was dug up on August 5 and found to be empty. Samples planted on June 3 did not completely dissolve until the second week of August. Additional bags were buried in the soil on August 5 and all bags were marked 1-5. These bags of ESN were periodically dug up, weighed and replanted throughout the growing season. These bags had still not completely broken down by September 22. After being planted for several weeks, the fertilizer got muddy and was difficult to weigh accurately.

Table 13. ESN bag weights throughout the growing season.

Date	ESN Bag #	ESN Bag Weights (g)
June 10, 2020	1	7.5
June 30, 2020	1	7.2
July 16, 2020	1	5
July 29, 2020	1	3.3
August 5, 2020	1	3.2
	2	0
August 13, 2020	1	N/A*
	2	7.6
	3	8.1
	4	8.3
	5	7.8
August 21, 2020	1	7.1
	2	7.4
	3	7.2
	4	5.3
	5	7.3
August 28, 2020	1	6.3
	2	6.1
	3	5.7
	4	4.8
	5	4.7
September 4, 2020	1	5.9
	2	4.8
	3	5.4
	4	3.8
	5	5.2
September 15, 2020	1	4.4
	2	3.6
	3	2.9
	4	4
	5	2.4
September 22, 2020	1	4.5
	2	3.5
	3	3.8
	4	3.3
	5	3.8

*Sample was too dirty to be weighed.

References:

Alberta Agriculture and Rural Development. 2014. Commercial Vegetable Production on the Prairies. Available at: https://www.agric.gov.ab.ca/app08/ppslogin?pID=100104

11. Conclusions and Recommendations

There were no significant differences in yield between the control and the treatments and between the urea and EEF treatments for all three brassica crops. The yield difference between the control and the treatments were not significant likely because the residual soil P was very low, and therefore a lot of MAP was applied. The additional N within the MAP likely provided enough N to stimulate good cole crop growth, resulting in no significant differences between the control and treatments. Due to this additional N from MAP, no definitive answers about the effectiveness of EEF products on cole crops were drawn. The study should be repeated again under different soil nutrient conditions, where N is limited. Therefore, a difference between the control and treatments, and potentially a difference between the treatments can be detected.

The urea treatment resulted in the highest yield in the kale crops, though this difference was not significant (Table 8). For the cabbage, Nitrain and Super U resulted in observably the largest cabbages and the highest yield (Table 10). This could indicate that the cabbage responded well to the slower, continuous input of N from the EEF products. In the brussels sprout portion of the trial, the urea had the highest overall yield, although not significant, but a higher proportion of oversize brussels and rejects (Table 11). The quick input of N from the urea may have contributed to the production of oversized brussels sprouts. The Nitrain treatment had observably the highest number of ideal sized brussels sprouts, suggesting that EEF products may improve the quality of the crop. The ESN treatment of brussels sprouts had similar yields to the control. If the breakdown of the ESN was too slow, there might not have been enough N available for the crop.

Replicate 3 of the cole crop trial underperformed relative to the other replicates. No pre-emergent herbicide was applied in this trial, resulting in significant weed pressure. The 1st and 2nd replicates were weeded often, but due to time constraints the 3rd replicate was not weeded as often. Additionally, the kale was planted directly in the soil and faced significant flea beetle pressure during germination. Applying a pre-emergent herbicide or using mulch may have helped to reduce weed pressure and improve performance in the 3rd replicate. Growing the kale from transplants would have reduced seedling mortality from flea beetles.

The benefits associated with N efficiency are often weather dependent. Above-average spring precipitation likely contributed to our results. More testing under different weather conditions may be needed to determine if there are benefits to using N efficiency products on cole crops.

12. Acknowledgements:

The Conservation Learning Centre graciously acknowledged the Ministry's support through signage directly in field with the project, verbally during the walking tour and on the walking tour agenda handed out to all visitors.

13. Abstract:

This trial aimed to demonstrate the benefits of enhanced efficiency products on brassica vegetable yields in north-central Saskatchewan. The study examined three different brassica crops: a short season crop (cabbage), a long season crop (brussels sprouts), and a continuous harvest crop (kale). Treatments consisted of a control with 0 kg N/ha, urea at 100 kg N/ha, and three different efficiency products at 70 kg N/ha (Nitrain, Super U, and ESN). The control had lower yields for all crops than the fertilized treatments, although the control yields were not significantly different from the treatment yields for all three brassica crops. There were also no significant differences in yield between the fertilized treatments. This lack of results likely occurred because the residual soil P was very low and as a result, a large amount of MAP was applied. The N within the MAP likely supplied enough N to reduce the benefits of the N fertilizer treatments and result in no differences between the control and treatments. This trial was featured in a walking tour in lieu of the CLC's Annual Field Day in July of 2020. Approximately 10 people attended, including local producers and commodity group representatives. Walking tour attendance was restricted due to COVID-19.