MHPEC Nitrogen Study Report 2018-2019

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Summary:

MHPEC's nitrogen study was based upon statistical associations created from the larger field variability study that encompassed observations from 23 grower fields over five years. The goal of this study was to identify the exact range of lbs of soil nitrogen needed by row closure and possible products and rates needed to accomplish the task to ultimately improve yield and quality of processing potatoes. It is suspected that larger tuber size profiles are found when 130-180 lbs of nitrogen are found in 0-30 cm of soil at row closure based on this initial study, but this statistical association needs to be verified as cause and effect through further study.

While statistically significant observations were made for differences between fertilizer rates on available nitrogen at row closure, the targets for row closure soil tests were not met. Any discussion of statistically significant results does not encompass the biological phenomenon because treatment goals were not met in two years of study.

While negative results are generally undesirable in applied research, this study indicates that on this lighter soil type, unblended ESN and urea cannot possibly meet nitrogen goals by row closure at any of the rates evaluated.

The original research question remains unanswered using these four rates of ESN and Urea. Grower feedback has indicated that a blend of nitrogen fertilizers is often employed on-farm, and the exact blend varies by consultant. **Answering the original research question requires going back to the community monitor a wide range of nitrogen programs in order to select promising candidates to use in a study formatted much like the present study**. It is anticipated that other treatments may yield the desired result can overcome the deficiencies outlined in the first two years of this study.

Introduction:

The Field Variability Study (FVS) was conducted from 2015 to the present day with the overall goal of identifying and remediating factors responsible for variable processing potato yield. Approximately 55 soil, plant, and environmental factors have been identified in 23 grower fields and each factor has been ranked according to impact on potato yield. Lower petiole nitrate and soil nitrogen at row closure are associated with total yield negatively (i.e. lower petiole nitrate and/or lower soil nitrogen at row closure is associated with the lowest yielding sampling points). These yield associations were found at the mid-bulking and row closure growing stages of 'Russet Burbank' in Manitoba, which roughly approximates to early August and early July, respectively.

The FVS also offered insight into the amount of soil nitrogen typically seen in grower fields at row closure, which ranged from 4-320 lbs from 0-30 cm in depth. In a cursory examination of the data set, 130-180 lbs of nitrogen appeared to be the beneficial amount of available soil nitrogen, and compromised yields were observed when nitrogen test above or below this amount. The lowest yields appeared to be associated with sampling sites with under 50 lbs of nitrogen at row closure. This cursory examination did not have the benefit of any statistical test or association. **The goal of this study was to identify the exact range of lbs of soil nitrogen needed by row closure and possible products and rates needed to accomplish the task. Outcomes of this study are set in the context of small, controlled research plots to demonstrate the importance of a unique nitrogen fertilizer regime to potato growers in order to justify field-scale validation studies that are necessary for industry adoption.**

Methods:

A factorial randomized complete block design was enacted with four blocks in 2018 and 2019. The soil at the site was a Halboro series Orthic Black Chernozem with a loamy sand texture. The site has a typical crop rotation of potato-wheat-canola and is irrigated. All of these factors are a reasonable representation of lighter soils that potatoes are grown on in Manitoba, except the black chernozem exhibits greater organic matter content typical of lighter soils. Regardless of the organic content, the crop rotation resulted in low preseason soil nitrogen tests with approximately 8-26 lbs of soil nitrogen available at the start of each season.

The entire experiment was 57869.28 ft^2 (1.33 Acres). Each plot was 3.6m wide and 24 m long, or 86.4 m^2 (approximately 0.022 Acres). The experiment was constructed with two fertilizer treatments: urea and Environmentally Smart Nitrogen (ESN, Redfern Farm Services, Brandon, Manitoba). Each fertilizer treatment, except the negative control, was applied at the equivalent of 40, 130, 180 and 280 lbs of nitrogen expected in the soil by row closure (approximately early July). The total amount of each fertilizer needed to achieve the goal by row closure varied based on nitrogen content, with exact application rates displayed in Table 1 below:

Formulation (NPKS)	Fertilizer	Goal lbs by row closure	TOTAL Lbs of product per replicate (5 plots)	Lbs product applied preplant per replicate (5 plots)	Lbs product applied top dress per replicate (5 plots)	Fertigation Fertilizer and Formulation	Fertigation rate (lbs)
46-0-0	Urea	40	66.35	9.48	56.87	UAN-28	60 lbs
46-0-0	Urea	130	42.65	9.48	33.17	UAN-28	60 lbs
46-0-0	Urea	180	30.8	9.48	21.32	UAN-28	60 lbs
46-0-0	Urea	280	9.48	9.48	0	UAN-28	60 lbs
44-0-0	ESN	40	69.37	9.91	59.46	UAN-28	60 lbs
44-0-0	ESN	130	44.59	9.91	34.68	UAN-28	60 lbs
44-0-0	ESN	180	32.2	9.91	22.29	UAN-28	60 lbs
44-0-0	ESN	280	9.91	9.91	0	UAN-28	60 lbs
No Preplant or Top Dress Nitrogen			0	0	0	UAN-28	60 lbs

Table 1. Nitrogen fertilizer products employed in the study are listed to display the amount of each product necessary to achieve the goal lbs of nitrogen available at row closure, as determined at a soil test conducted by Agvise, Inc. (Northwood, North Dakota). Fertigation was applied at 20 lbs N/acre (6.67 gals UAN 28/acre). Three fertigation events were required in 2019, as determined by petiole testing from Agvise Inc. All plots received 115 lbs/acre of mono-ammonium phosphate (MAP, 11-52-0-0) and a Kmag mixture of 32% 0-0-60-0 and 68% 0-0-22-22 at 132 lbs/ acre.

Only the cultivar Russet Burbank was used for the study. Experimental plots were prepared by cultivating on April 29th and preplant fertilized on May 1st, 2019. Fertilizers were applied with a custom-modified R-tech Terra Mater fertilizer applicator that was set up to apply up to three different fertilizers in a single pass. Two sets of three Gandy Boxes were arranged in rows, and a single box of amazon cups was set up at the front in order to accommodate the three different types of fertilizer at possible rates of 6 lbs/acre to 584 lbs/acre (depending on fertilizer pellet size, vehicle speed, and gear combinations selected). The machine was set to broadcast all fertilizers over four potato rows at 36 inches between the rows. Each row of fertilizer applicators was calibrated for each pelleted formulation of fertilizer employed in the experiment and for every fertilizer rate in the treatment structure. Pre-plant fertilizer was immediately mixed into soil post-application with a Lely Rotterra 350-33 (Lely, Maassluis, Netherlands) to a depth of up to 10 inches.

Burbank seed (2-3 oz, average 2.5 oz (data not shown)) was planted on May 6th, 2019 with no gaps between plots, 36 inches between rows, 13 inches between seed pieces within row, and 6-7 inches deep (from top of hill). Seed was treated with Titan Emesto (Bayer, Leverkusen, Germany) at a rate of 20.8 mL per 100 kg of seed. Pesticide applications and irrigation schedule were typical for the potato growing region in Carberry, Manitoba (data not shown).

Prior to hilling, plots receiving more than 40 lbs of nitrogen before row closure were top dressed with the remaining nitrogen needed (Table 1), which was accomplished on June 7th in 2019. Hills were created as plants emerged on June 7th, 2019 using a power hiller attached to a tractor. Row closure was observed on July 15th, 2019, and five 0-15 cm soil and 30 petiole samples per plot were collected on the same day. Thirty petioles were collected weekly on every Friday in July from one replicate of each treatment to determine if a fertigation event was required the following week. The need for fertigation was determined by examining 130 and 180 lbs treatments for both Urea and ESN, and fertigation was conducted when these treatments were deficient in petiole nitrate as determined by Agvise Inc standards (Northwood, North Dakota). Finally, five 0-15 cm soil samples were taken from every plot for late bulking soil nitrogen assessment on the 20th of August. The lbs of nitrogen available in soils and the percentage of nitrate in petioles were determined by Agvise Inc (Northwood, North Dakota). The exact determination of sufficient soil nitrogen and petiole nitrate can be found in the supplemental materials at the end of this document.

Fertigation was conducted through a Hardi (Davenport, IA, USA) NL 80-26’ SB PT sprayer with three inline filters, triple nozzle bodies, and three boom controls using a minidrift 03-blue nozzle at approximately 41 PSI at 2-4 miles per hour. Applications were done in the early morning and diluted as quickly as possible to limit fertilizer burn. Thirty liters of UAN-28 was mixed with 35 imperial gallons of water and applied evenly to the entire experiment. This application was immediately diluted with ¼ inch of water from a linear irrigator (see Fig. 1 below). Fertigation was applied to entire experiment, negative controls included, because studying the impact of fertigation as an impact on final yield was not the intended purpose of the study because fertigation occurs after row closure, the key period identified in the field variability study. The authors also acknowledge that the amount of nitrogen fertilizer applied prior to row closure is insufficient for the entire season, necessitating fertigation. A flat rate of fertigation was selected instead of a variable rate due to technical limitations of the irrigation equipment onsite and the desire to have as minimal impact of fertigation as a factor on final yield. Likewise, fertigation was not applied through the linear irrigation system because an equipment limitation preventing fertigation of all potato experiments on the same site, including other fertigation experiments.

Fig 1. An example fertigation event demonstrating concentrate is applied directly to foliage and then immediately diluted to the correct ratio by a linear irrigator on a cloudy morning to prevent fertilizer burn.

Harvest occurred on September 16th, 2019 and was completed using 1-row digger on a 10m section of a designated harvest row that was unsampled and untrampled during the season. This harvest row was the innermost part of each plot to buffer it as much as possible from edge effects. The total yield of each plot was recorded as lbs harvested, as well as the lbs of each tuber size category (less than 3 oz, 3-5.9 oz, 6-9.9 oz, 10-11.9 oz, 12 oz and greater) and quality metrics were recorded (weight of rotted tubers, green tubers, hollow heart tubers in grams, as well as specific gravity). This information was used to calculate an approximate Canadian dollar value using these metrics to determine bonuses and deductions for a mid-season shipment of Burbank potatoes from a demonstration processor contract (data not shown).

Statistical tests were conducted with SAS v9.4 (SAS, Cary, NC). More specifically, proc mixed was employed to construct a linear regression model to compare the variables of fertilizer treatment and desired rate by row closure to a yield parameter (e.g. fertilizer and treatment effect determined for the 6-10 oz yield category). This analysis was completed for each yield parameter separately. In each case a Satterthwaite approximation is used to delineate limits for all variables that had a lower boundary constraint of zero. The blocking factor was used as a random effect as a vector for the mixed model. Because assumptions for the normal distribution of errors and homogeneity of variances were not met (data not shown), the repeated statement was used to model the variance. Finally, the lsmeans statement was used to determine significance of pairwise comparisons of a yield parameter between two fertilizer treatments (provided the type III test of fixed effects from the mixed model was significant with $P \leq 0.05$). Familywise type I error was controlled for the multiple comparisons in the lsmeans statement using a Tukey adjustment, with all subsequent reported *P*-values between specific treatments referring to this Tukey-adjusted *P*-value.

Results:

The first two years of study (2018-2019) have indicated that nitrogen treatments had a significant effect on the amount of available soil nitrogen, in lbs, at row closure ($P = 0.0003$) and late bulking ($P = 0.0028$). There was no significant difference between the lbs of nitrogen found in the soil prior to nitrogen fertilizer application at the start of the season ($P = 0.9615$, data not shown).

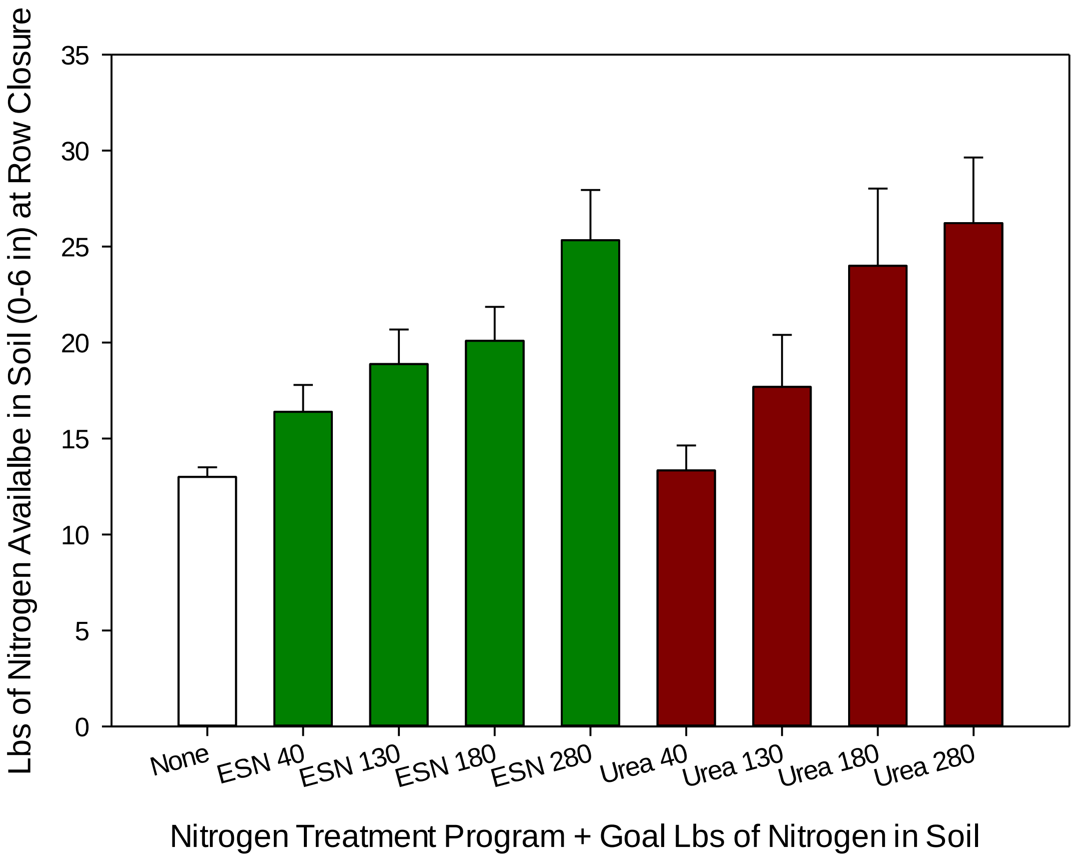

Fig 2. The effect of nitrogen treatment program (x-axis) on the availability of soil nitrogen (y-axis) at row closure. Bars indicate mean lbs of nitrogen and the standard error is above each bar. Two fertilizers were used, urea and ESN, and the number refers to the goal lbs of N in the soil sample at row closure (i.e. ESN 40 indicates an expected soil test of 40 lbs). Exact rates of fertilizer per plot can be found in Table 1.

Specific pairwise comparisons of nitrogen treatments on available soil nitrogen at row closure is as follows in Table 2. The greater column refers to the treatment with the largest amount of soil nitrogen, whereas the lesser has the smaller amount of soil nitrogen. Combinations of fertilizers that are not present were not significant ($P \leq 0.05$). This list does not include comparisons that trended towards significance ($P \leq 0.1$).

Greater Fertilizer Treatment	Lesser Fertilizer Treatment	*P*- value
ESN 280	No added nitrogen	$P = 0.0110$
ESN 280	Urea 40	$P = 0.0205$
Urea 280	No added nitrogen	$P = 0.0048$
Urea 280	Urea 40	$P = 0.0095$
Urea 180	No added nitrogen	$P = 0.0382$
Urea 180	Urea 40	$P = 0.0645$

In general, only the greatest rate (280 lbs/N per acre) of either fertilizer consistently increased soil nitrogen availability at row closure when compared to plots where no additional or a low rate (40 lbs/N per acre) of nitrogen was supplied. Despite the relative brevity of table 2, it is noteworthy to mention what was not observed to be significant. An interesting observation was noted in that same rate different fertilizer never significantly different in soil nitrogen (i.e. ESN 130 not different from urea 130). None of ESN rates were observed with significantly different row closure in soil nitrogen availability from one another (as in 40 lbs ESN by row closure not different from ESN 280 lbs at $P = 0.1684$). ESN treatment was not different from the treatment where no additional nitrogen was supplied in terms of the lbs of soil N at row closure UNTIL 280 lbs of ESN was applied. Finally, low levels of urea (40 and 130 lbs) were not different from not apply nitrogen fertilizer at all ($P = 1.0000$ and $P = 0.8737$), whereas higher levels of urea different from the no added nitrogen treatment (180 and 280 lbs at $P = 0.0382$ and $P = 0.0048$).

The availability of petiole nitrogen at row closure, expressed in the percentage of dry plant matter composed of nitrogen, was also significantly impacted by nitrogen treatment ($P = 0.0003$).

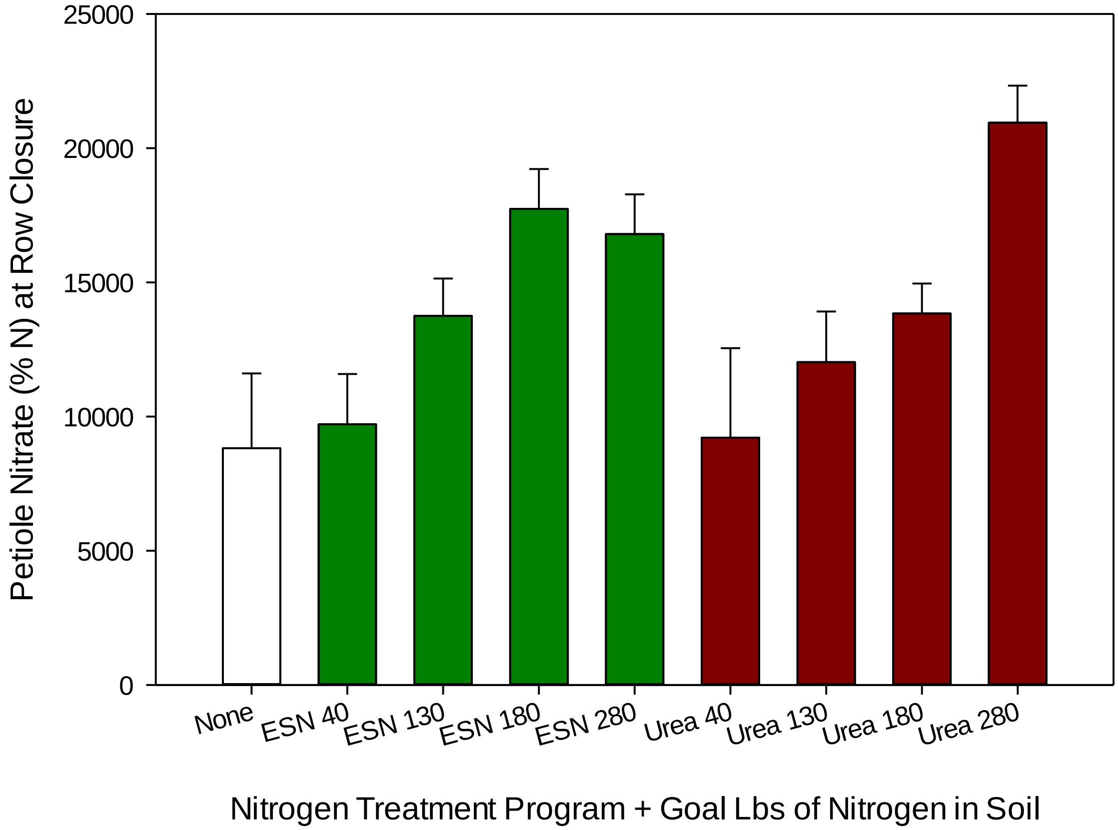

Fig 3. The effect of nitrogen treatment program (x-axis) on the availability of petiole nitrogen (y-axis) at row closure. Bars indicate mean lbs of nitrogen and the standard error is above each bar. All fertilizer rates for each treatment can be found in Table 1.

Specific pairwise comparisons of nitrogen treatments on available petiole nitrogen is as follows in Table 3. The greater column refers to the treatment with the largest amount of petiole nitrogen, whereas the lesser has the smaller amount of petiole nitrogen. Combinations of fertilizers that are not present were not significant ($P \leq 0.05$). This list does not include comparisons that trended towards significance ($P \leq 0.1$).

Greater Fertilizer Treatment	Lesser Fertilizer Treatment	*P*- value
ESN 180	No added nitrogen	$P = 0.0457$
ESN 180	ESN 40	$P = 0.0048$
ESN 180	Urea 130	$P = 0.0426$
ESN 180	Urea 40	$P = 0.0037$
Urea 280	No added nitrogen	$P = 0.0024$
Urea 280	Urea 40	$P = 0.0054$
Urea 280	ESN 40	$P = 0.0067$

In general, only the greatest rate (280 lbs/N per acre) of either fertilizer consistently increased petiole nitrogen availability at row closure when compared to plots where no additional or a low rate (40 lbs/N per acre) of nitrogen was supplied. The same general trend was observed in petiole and soil nitrogen availability by treatment.

Any potential response to yield or quality that was measured was not significantly impacted by nitrogen treatment. These nonsignificant responses included total yield ($P = 0.8044$), less than three oz cwt/A ($P = 0.3797$), three to six ounce cwt/A ($P = 0.4033$), six to ten ounce cwt/A ($P = 0.8357$), ten to twelve ounce cwt/A ($P = 0.7560$), over twelve ounce cwt/A ($P = 0.2515$), the calculated value per cwt ($P = 0.7823$), or the specific gravity ($P = 0.8715$).

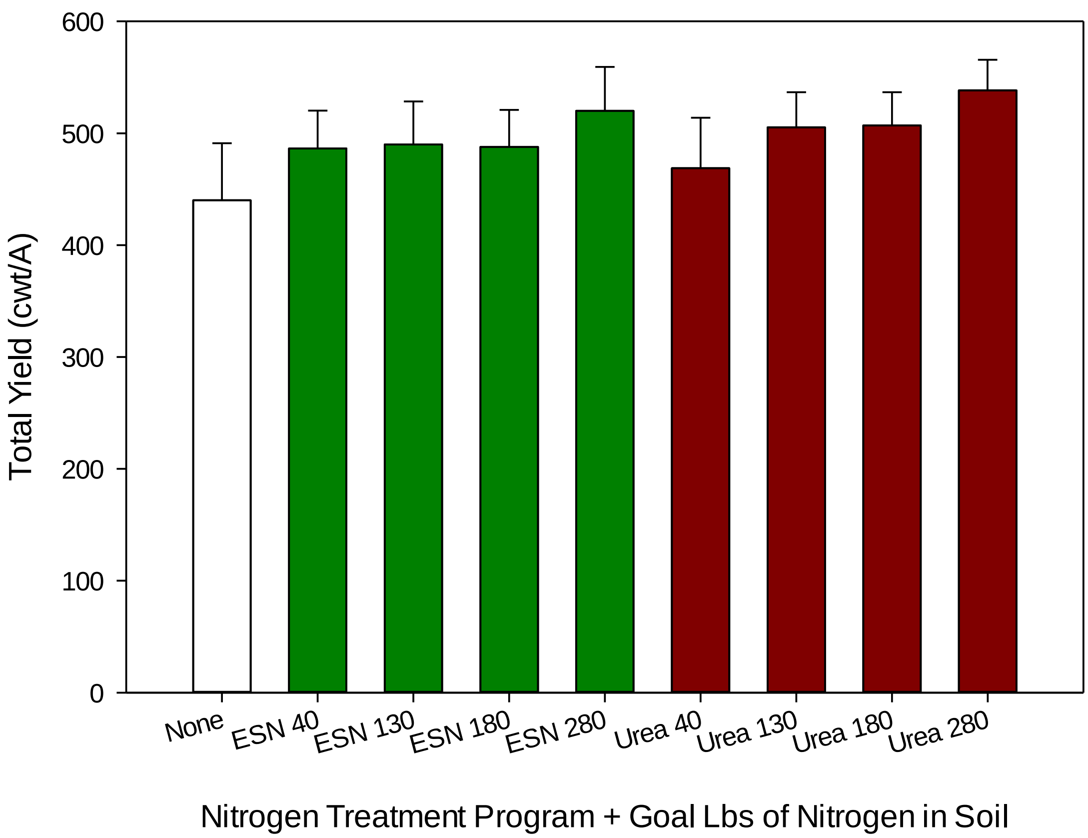

Fig 4. The effect of nitrogen treatment program (x-axis) on total yield(y-axis). Bars indicate mean lbs of nitrogen and the standard error is above each bar. All fertilizer rates for each treatment can be found in Table 1.

The raw data on the available soil nutrients, petiole nutrients, and yield potential was also evaluated by hand (without statistical analyses) using the references from the supplemental materials found at the end of this document. The following paragraphs contain the summary analysis for the 2018-2019 trials by fertilizer and rate:

ESN 40 lbs nitrogen available by row closure – preseason soil tests indicated that all plots generally started with low to very low soil nitrogen (8 to 22 lbs N). Row closure soil nitrogen was low to very low (25 lbs N to 10 lbs N) and row closure petioles were mostly low (14156 units) to deficient (1110 to 6604 units). Residual soil nitrogen at late bulk was 14-7 lbs soil N (very low). The plot yield from this treatment was exceptional (569 – 521 cwt) to low (313 cwt acre). The <3 to 6 oz yield was way to high (150-201 cwt/A). 6-12 oz yield was low to idea (93 – 223 cwt/A) and overall percentage of yield is far too low (45-29%) with no real bonus. Some plots didn't have any yield above 12 oz. The specific gravity from all plots was very high.

ESN 130 lbs nitrogen available by row closure – preseason soil tests indicated the season started with very low soil nitrogen (15 lbs N or less), Row closure tests had low soil N (29 lbs or less), Petioles came in sufficient (21197 units) to low (14010 units) with one deficient (7847 units). Very low residual soil nitrogen was observed by late bulk (13 or less lbs N in soil). The plot yield was exceptional from 626 cwt/A down to low (324 cwt/A), midrange of <3-6oz (166-230 cwt/A), 6-12 oz yield idea 239 cwt/A to low 127 cwt/A and generally percent 6-12 was far to small to make bonuses. <12 oz generally low percentage. Value is low (3415 per acre) to unrealistically high (6210 cwt/A). The specific gravity from all plots was very high.

ESN 180 lbs nitrogen available by row closure - preseason soil tests indicated very low soil N (19 lbs or less) was present at the start of the experiment. Row closure had low soil N (33 lbs or less), Petioles came in sufficient (24015 units) to low (12840 units) with one high (28110 units), with low residual by late bulk (24or less lbs N in soil) or very low late bulk (17 lbs N in soil). The plot yield was was exceptional from 642 cwt/A, sufficient from 434 cwt/A, to low to 343/A. The <3 to 6 oz yield is middle of the road with 128-234 cwt/A. 6-12 oz yield is idea at 257 cwt/A to low (125 cwt/A). The 6-12 oz percent is all over the place from far too small 35% to ideal at 50% to close to making money at 40%. >12 oz ranged from idea ranges like 49 cwt at 11% of total yield to rock bottom with no yield in this range. Yield value is generally average 3620-5056 $/acre. The specific gravity from all plots was very high and the percentage of high gravity tubers was sufficient to accrue a bonus.

ESN 280 lbs nitrogen available by row closure – the preseason generally started with low soil N (17 lbs or less). Row closure soil N ran low (35 lbs or lower) and petiole nitrogen generally runs sufficient (18314-22917 units) with one deficient (3740 units). All plots very low residual soil N at late bulk with 8-19 lbs. Yield ranges from sufficient to exceptional but differed from other plots in that yield trends were consistent. The <3 to 6 oz yield is midrange at around 160 cwt/A. The 6-12 oz range varies from seems low at 156 cwt/A to idea at 265 cwt/Acre. The percentage 6-12 oz range is not sufficient to earn a bonus (35-44%). Over 12 oz ranges from above average (66 cwt, 10% of yield). Total value is low end of average (3800 per acre) to unrealistic (6696 per acre). The specific gravity from all plots was very high and the percentage of high gravity tubers was sufficient to accrue a bonus.

Urea 40 lbs nitrogen available by row closure treatment had low preseason N (26 lbs or less), row closure N ran low (21 lbs or less), petiole N sufficient (22311) but usually ran deficient (3947 or less), lb N very low (15 lbs or less). Yield generally low (369 cwt or less) packing an average of 117-308 cwt/A of <3 to 6 oz tubers, with 27 270 cwt/A 6-12 oz (11-43% of yield, not getting bonus). >12 oz yield generally low or nonexistant. Dollar value ranged from 2562-5000 per acre. Gravity was high across the board and all plots got bonus with low stem count and vine length all over place.

Urea 130 lbs nitrogen available by row closure treatment had low soil N preseason (26 lbs N or less), low soil N at row closure (24 lbs or less), petiole nitrogen low to deficient (14780 units or less, 5541 units or less), very low soil N at late bulk (14-8 lbs N). Yield is generally exceptional to sufficient (636-402 cwt/A), 145 – 214 cwt is <3-6 oz (generally midrange to high), 150-240 cwt 6-12 oz (generally low to ideal) (32-47% and most generally don't make the bonus percent) and very low yield over 12 oz (6-50 cwt at 7-17%) with average value to points (4000-5000 $ per cwt). The specific gravity from all plots was very high and the percentage of high gravity tubers was sufficient to accrue a bonus.

Urea 180 lbs nitrogen available by row closure treatment had low preseason N (27 lbs or less), Row closure N ran low to very low (16-22 lbs N) in soil and low (14705 units or less) in petioles and low residual soil N at late bulking (16-9 lbs N). The yield response was highly variable from low to exceptional (346 cwt/A - 633 cwt/A). The yield composition was all over the place with each point. Yield was above average (5852 cwt/A at highest) to average (4206 cwt at highest). The specific gravity from all plots was very high and the percentage of high gravity tubers was sufficient to accrue a bonus.

Urea 280 lbs nitrogen available by row closure treatment had low preseason N (18 lbs or less), row closure N ran low (39 lbs or less), petiole N sufficient (24801 or less), lb N very low (23 lbs or less). Yield exceptional to sufficient (653-420 cwt/A), packing an average of 150 cwt/A of <3 to 6 oz tubers, with 160-280 cwt/A 6-12 oz (29-42% of yield, not getting bonus). >12 oz yield all over the place from 10-125 cwt/A that composes 3-21% of total yield (high end incurring penalty). Dollar value ranged from 4509-6738 per acre. The specific gravity from all plots was very high and the percentage of high gravity tubers was sufficient to accrue a bonus.

No nitrogen treatment has virtually no soil nitrogen available throughout season (less than 15 lbs), petioles run deficient, all over the place with one 600 cwt but most run low (250 cwt/A), 150 – 180 cwt is <3-6 oz, 50-150 cwt 6-12 oz (percentage too small to make bonus) and very low yield over 12 oz (<10 cwt or none at all) with low yielding points (2512 – 3108 $ per cwt). The specific gravity from all plots was very high and the percentage of high gravity tubers was sufficient to accrue a bonus.

Conclusions:

The present study was based upon statistical associations created from the larger field variability study that encompassed observations from 23 grower fields over five years. The goal of this study was to identify the exact range of lbs of soil nitrogen needed by row closure and possible products and rates needed to accomplish the task to ultimately improve yield and quality of processing potatoes.

While statistically significant observations were made for differences between fertilizer rates on available nitrogen at row closure, the targets for row closure soil tests were not met. Any discussion of statistically significant results does not encompass the biological phenomenon because treatment goals were not met in two years of study.

While negative results are generally undesirable in applied research, this study indicates that on this lighter soil type, unblended ESN and urea cannot possibly meet nitrogen goals by row closure at any of the rates evaluated.

The original research question remains unanswered using these four rates of ESN and Urea. Grower feedback has indicated that a blend of nitrogen fertilizers is often employed on-farm, and the exact blend varies by consultant. Answering the original research question requires going back to the community monitor a wide range of nitrogen programs in order to select promising candidates to use in a study formatted much like the present study. It is anticipated that other treatments may yield the desired result can overcome the deficiencies outlined in this study.

Acknowledgements:

The authors would like to thank Alan Manns for his time and skill in applying the fertigation treatment to specific plots with the meticulousness and repeatability demanded by the principle investigator. The authors also appreciate the efforts of Lindsey Andronak, Brian Baron, and Eric Claeys for their contributions to plot setup and maintenance as members of the Agriculture and Agri-Food Canada partner at the Canada Manitoba Crop Diversification Centre in Carberry, Manitoba, where this study was conducted. The authors would be remiss to not thank Jack Adriaansen for donating the ‘Russet Burbank’ seed used in the study.

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Supplemental Materials:

Appendix

Appendix Table 13. Nitrogen recommendations for potatoes (based on spring broadcast application)[69].

		NITROGEN RECOMMENDATIONS (lb/ac)			
Production system		Dryland		Irrigated†	
Target Yield (cwt/ac)		200	250	High (250-350)	Very High (400+)
Fall Soil NO_3-N					
lb/ac in 0-24"	Rating				
0	VL	140‡	170‡	200‡	260‡
20	L	80	110	140	180
40	M	60	90	120	160
60	H	40	70	90	130
80	VH	20	50	70	110
100	VH+	0	30	50	90
120	VH+	0	10	30	70
140	VH+	0	0	10	50
160	VH+	0	0	0	30
180	VH+	0	0	0	10
200	VH+	0	0	0	0

† Mineralizaton of soil organic N is substantial under irrigated production on most soils. However, Manitoba research on low organic matter, very sandy soils is limited; nitrogen rates required may be slightly higher than indicated.

‡ Soils testing very low in nitrogen may be infertile and require large applications of nitrogen. Nitrogen should be applied in split applications rather than entirely at planting.

Figure 2: Soil nitrogen recommendation for irrigated and dryland potatoes for Manitoba potato production from the Manitoba Soil Fertility Guide available from gov.mb.ca/agriculture/crops/soil-fertility/soil-fertility-guide/fertilizer-guidelines-for-soil-tests.html#table13

Table 2: Selected table from Agvise recommendations for potato (tuber ¾ = ¾ inch tuber, table 24 approximates row closure in most years).

TABLE 24
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Potato-Petioles (tubers <3/4)
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NO.	NAME	DEF.	LOW	SUFFICIENT	HIGH
1	NITRATE	<10000	10001 TO 15000	15001 TO 25000	25001 TO 30000
2	NITROGEN	< 0.0	0.1 TO 0.0	0.1 TO 0.0	0.1 TO 0.0
3	PHOSPHORUS	< 0.00	0.01 TO 0.29	0.30 TO 0.50	0.51 TO 0.99
4	POTASSIUM	< 0.0	0.1 TO 7.9	8.0 TO 11.0	11.1 TO 20.0
5	SULFUR	< 0.00	0.01 TO 0.19	0.20 TO 0.50	0.51 TO 0.99
6	CALCIUM	< 0.00	0.01 TO 0.39	0.40 TO 0.80	0.81 TO 2.00
7	MAGNESIUM	< 0.00	0.01 TO 0.19	0.20 TO 0.40	0.41 TO 0.99
8	SODIUM	< 0.00	0.00 TO 0.00	0.00 TO 0.10	0.10 TO 0.20
9	ZINC	< 0	1 TO 19	20 TO 30	31 TO 99
10	IRON	< 0	1 TO 19	20 TO 50	51 TO 999
11	MANGANESE	< 0	1 TO 19	20 TO 30	31 TO 99
12	COPPER	< 0	1 TO 1	2 TO 4	5 TO 99
13	BORON	< 0	1 TO 19	20 TO 30	31 TO 99
14	OTHER 1	< 1000	1001 TO 2000	2001 TO 5000	5001 TO 7000
15	OTHER 2	< 0	1 TO 0	1 TO 0	1 TO 0

Mid bulk
TABLE 25
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Potato-Petioles (tubers <3/4-2)

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NO.	NAME	DEF.	LOW	SUFFICIENT	HIGH
1	NITRATE	< 8000	8001 TO 12000	12001 TO 20000	20001 TO 30000
2	NITROGEN	< 0.0	0.1 TO 0.0	0.1 TO 0.0	0.1 TO 0.0
3	PHOSPHORUS	< 0.00	0.01 TO 0.24	0.25 TO 0.50	0.51 TO 0.99
4	POTASSIUM	< 0.0	0.1 TO 6.9	7.0 TO 10.0	10.1 TO 20.0
5	SULFUR	< 0.00	0.01 TO 0.19	0.20 TO 0.50	0.51 TO 0.99
6	CALCIUM	< 0.00	0.01 TO 0.39	0.40 TO 0.80	0.81 TO 2.00
7	MAGNESIUM	< 0.00	0.01 TO 0.19	0.20 TO 0.40	0.41 TO 0.99
8	SODIUM	< 0.00	0.00 TO 0.00	0.00 TO 0.10	0.10 TO 0.20
9	ZINC	< 0	1 TO 19	20 TO 30	31 TO 99
10	IRON	< 0	1 TO 19	20 TO 50	51 TO 999
11	MANGANESE	< 0	1 TO 19	20 TO 30	31 TO 99
12	COPPER	< 0	1 TO 1	2 TO 4	5 TO 99
13	BORON	< 0	1 TO 19	20 TO 30	31 TO 99
14	OTHER 1	< 1000	1001 TO 1600	1601 TO 3000	3001 TO 5000
15	OTHER 2	< 0	1 TO 0	1 TO 0	1 TO 0

Late Bulk
TABLE 27
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Potato-Petioles (tubers > 3.5
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NO.	NAME	DEF.	LOW	SUFFICIENT	HIGH
1	NITRATE	< 3000	3001 TO 4000	4001 TO 8000	8001 TO 12000
2	NITROGEN	< 0.0	0.1 TO 0.0	0.1 TO 0.0	0.1 TO 0.0
3	PHOSPHORUS	< 0.00	0.01 TO 0.19	0.20 TO 0.40	0.41 TO 0.99
4	POTASSIUM	< 0.0	0.1 TO 5.9	6.0 TO 9.0	9.1 TO 20.0
5	SULFUR	< 0.00	0.01 TO 0.19	0.20 TO 0.40	0.41 TO 0.99
6	CALCIUM	< 0.00	0.01 TO 0.39	0.40 TO 0.80	0.81 TO 2.00
7	MAGNESIUM	< 0.00	0.01 TO 0.19	0.20 TO 0.40	0.41 TO 0.99
8	SODIUM	< 0.00	0.00 TO 0.00	0.00 TO 0.10	0.10 TO 0.20
9	ZINC	< 0	1 TO 19	20 TO 30	31 TO 99
10	IRON	< 0	1 TO 19	20 TO 50	51 TO 999
11	MANGANESE	< 0	1 TO 19	20 TO 30	31 TO 99
12	COPPER	< 0	1 TO 1	2 TO 4	5 TO 99
13	BORON	< 0	1 TO 19	20 TO 30	31 TO 99
14	OTHER 1	< 800	801 TO 1200	1201 TO 2400	2401 TO 4000
15	OTHER 2	< 0	1 TO 0	1 TO 0	1 TO 0