Potato Nitrogen Study Report 2021
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Introduction:

Objective 1:

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 both 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-to-320-lb from samples 0-30 cm in depth. In a cursory examination of the data set, 130 to 180-lb of nitrogen appeared to be the beneficial amount of available soil nitrogen (N), 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-lb 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 lb 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.**

Objective 2:

The addition of nitrogenous fertilizers to the agricultural systems has an impact on the composition of air which is 79% nitrogen. The N in the air is present in the form of N_2 molecules, which is not directly available to the plants. That is why inorganic or mineral fertilizers are supplied to the plants to meet the crop nutrients demand. These fertilizers supply a form of N, called fixed nitrogen, that plants can easily uptake. In an inorganic fertilizer, N in the form of ammonium ion (NH_4^+) is converted into nitrite ions (NO_2^-) by soil bacteria of the

Nitrosomonas species through biological oxidation (Nitrification). The nitrite ions are further converted into nitrate ions (NO_3^-), the plant available form, at soil temperature above 10 ºC by the Nitrobacter species. Nitrate is highly soluble and eventually leaches down into the deeper soil layers because of its low adsorption capacity in the soil. If soil becomes water saturated causing anaerobic conditions, Nitrate-Nitrogen (NO_3-N) may be lost to the atmosphere through a reduction process called denitrification. Complete conversion from NH_4^+ to NO_3^- takes place within a month of application.

$$NH_4^+ \leftrightarrow NO_2^- \leftrightarrow NO_3^-$$

Like all other crops, a substantial amount of fertilizer-N is required to get the optimum yield and quality of potato tuber and to tolerate the diseases as well. In addition to nitrogenous fertilizers, irrigation management also plays a significant role in improving the crop yield. Potato tubers are very sensitive to water stress. Yield may be significantly reduced by water deficit. On the other hand, excessive water application may result in respiration stress and denitrification. Maximum potato production is achieved when the soil moisture is sustained at an optimum level and N is frequently available during the peak demand period within the potato root-zone. In order to achieve high potato yield with minimum water quality impact, both nitrogen and water management should be taken into account.

A combination of fertilizer application and irrigation management during the early growth stages of potato affects the tuber yield. Both over- and under-application of irrigation water and nitrogenous fertilizers, affect the nitrogen dynamics within the potato root-zone. The highly soluble NO_3-N will be leached below the root-zone due to excessive water application. That is why over-application of irrigation water causes contamination of ground water and surface water by leaching and surface run off, respectively. However, the total N uptake by plants is also substantially restricted by water deficits.

Intensive over-application of fertilizer is one of the main contributors to lower yield and elevated NO_3-N concentrations in groundwater. If the excess N is not utilized by the crop, N may accumulate within the root-zone in the form of NO_3-N which can leach below with a rainfall or supplemental irrigation event causing an increase in the NO3-N concentrations in the groundwater. If the soil becomes saturated, this nitrogen may be lost to the atmosphere in the form of nitrous oxide (N_2O) gas by denitrification, which destroys the stratospheric ozone contributing to global warming.

Nitrate leaching in the agricultural soil is influenced by many factors such as the irrigation system/applicator, irrigation management, N fertilizer management (N rate, application method, and splitting), soil characteristics, and rainfall patterns. Soil thickness and distance between the bottom of the root-zone and groundwater table also plays a role in determining the potential for ground water contamination. If the plant roots are closer to the water table, nitrate leaches into the groundwater more easily.

The results from numerous studies have proven that excessive irrigation and heavy rainfall are the main drivers of NO_3-N losses from plant root-zone. This loss can be controlled by irrigation management (that subsequently governs the volume of subsurface drainage water) and fertilizer management. The timing and scheduling of irrigation directly affects nitrate leaching. A proper water management can minimize N losses from the plant root-zone and improve the N uptake. If there is a significant difference between the irrigation supplies and the evapotranspiration demand of the crop, the application of N fertilizers assessed for full irrigation may result in "unintentional" over application of N fertilizers causing the potential for N losses. Soil type and soil physical properties also affect nitrate leaching potential.

Impact of different nitrogen application treatments on nitrate dynamics within the potato root-zone was studied in Carberry, Manitoba. The objective of this study was to examine the effects of different nitrogen application rates on nitrogen dynamics within the potato root-zone in a loamy sand soil, and to analyze the nitrate leaching potential below the root-zone.

Conclusions:

Objective 1:
MHPEC's 2018 to 2020 small plot 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 lb 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-to-180-lb of nitrogen are found in the top 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 general, the treatments of ESN and urea where 40-or-130-lb were expected by row closure ended up having far more soil nitrogen than anticipated. Treatments of ESN and urea where 180-lb were targeted by row closure appeared to be on target on average between all the replicates, but the large error bar indicates that some individual plots could be off from the target by 50-lb or more. Neither fertilizer treatment could achieve targets of 280-lbs. of nitrogen in a soil test by row closure. An unexpected, unrepeated observation came from the urea 180-lb treatment, which had more >12-oz percentage of tubers than urea treatments with either more or less nitrogen (280-and-40-lb, respectively). More study on this subject would be required to identify if this was a spurious event or something more meaningful, but the results are muted by the fact that soil targets by row closure were generally not met.

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 field needs and the consultant. **Answering the original research question requires going back to the community to 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 and can overcome the deficiencies outlined in the first two years of this study.

MHPEC's 2020 and 2021 field study was an observational study to achieve just such a goal of identifying promising candidate treatments and practices to address deficiency of row closure soil nitrogen. Some low nitrogen points were connected to the soil organic matter and texture where there was high leaching potential.

Based off average of all 8 points in 2021:
3/11 growers were above 200 lbs N at row closure
4/11 growers were between 120 and 180 lbs N hitting 130 lb target at row closure
1/11 growers were between 100 and 110 lbs
3/11 growers were under 100 lbs of N
2 growers top dressed to hit target or were above target using a dry or liquid product (ESN & UAN)
The lowest fields at row closure had an average of 35 lbs and 47 lbs. Lowest point was 16 lbs at row closure.
The highest fields at row closure had an average of 243 lbs and 227 lbs. The highest point was 390 lbs. at row closure.

Nitrogen Fertilizer Info:
Some were just general spring dry blends with no specifics on N products
2 growers used just urea for preplant
1 grower did a mixture of urea and ESN
2 growers did just liquid fertilizer 1 just UAN and 1 UAN/ATS 2:1 mixture
2 did just ESN
1 grower relied heavily on fertigation with 60% of applied N and all upfront was with N containing P & S fertilizer applied in the fall or in the planter

General Fertilizer Info
All producers used 10-34-0 at planting
Most used ammonium sulfate and MAP for dry blends

Fertigation Info
Avg fertigation passes was 4. Most 7 and least 2. *This is for info given
Most fertigaton programs used both UAN and ATS. Some mixed together others different passes.

Objective 2:
The importance of fertilizers in improving the crop yield and quality can never be underestimated. Nitrogen (N), potassium (P) and phosphorus (K) are the predominant fertilizers, generally applied to meet the crop nutrients demand, if the native soil supplies of these nutrients are limited. Nitrogen (N) is one of the essential fertilizers that affects plant growth and plays a

significant role in optimizing the crop yield. Like all other crops, a substantial amount of fertilizer-N is required to get the optimum yield and quality of potato tuber and to tolerate the diseases as well. In addition to nitrogenous fertilizers, irrigation management also plays a significant role in improving the crop yield. Potato tubers are very sensitive to water stress. Yield may be significantly reduced by water deficit. On the other hand, excessive water application may result in respiration stress and denitrification. Maximum potato production is achieved when the soil moisture is sustained at an optimum level and N is frequently available during the peak demand period within the potato root-zone. In order to achieve high potato yield with minimum water quality impact, both nitrogen and water management should be taken into account.

Intensive over-application of fertilizer is one of the main contributors to lower yield and elevated NO3-N concentrations in groundwater. If the excess N is not utilized by the crop, N may accumulate within the root-zone in the form of NO3-N which can leach below with a rainfall or supplemental irrigation event causing an increase in the NO3-N concentrations in the groundwater.

Potatoes require comparatively less N during the early part of the growing season i.e., sprout development, and vegetative growth stages compared to the later part i.e., tuber initiation, and tuber bulking stages. Excessive N application during the early part of the growing season leads to delay onset of the tuber initiation stage and decrease the yield. Potato requires an adequate and steady supply of N from tuber formation to bulking. Therefore, potato growers apply approximately 25 to 50 % of the total recommended N at the beginning of the growing season and the remainder is applied at the tuber initiation stage. Although this scheduling improves the yield and quality of tuber, it is costly and labor intensive. Controlled release nitrogen (CRN), also known as polymer coated urea (PCU), and environmentally smart nitrogen (ESN) is a cost effective N application source. A micro-thin polymer coat facilitates the release of N at a controlled rate and minimizes N losses from the soil. The rate of N release from PCU is controlled by soil temperature and soil water content. When water is applied to the soil by supplemental irrigation and/or rainfall, it enters into the polymer coated fertilizer granule and dissolves the N into soluble form within the granule. As temperature increases, this nitrogen solution moves out through the polymer coated fertilizer granule into the soil solution in the plant available form.

Methods:

Objective 1:

CMCDC small plot experiment 2018-2020: A factorial randomized complete block design was enacted with four blocks in 2020. 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 Carberry, 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 to 26-lb of soil nitrogen available at the start of each season.

Plot scale experimental size and fertilizer calculations: The entire experiment was 57869.28-ft^2 (1.33-acres). Each plot was 3.6-m 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 preplant at the equivalent of 40, 130, 180 and 280-lb 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	Target lb by row closure (lb/acre)	lb/acre fertilizer rate applied preplant	Fertigation Fertilizer and Formulation	Fertigation rate (lb)
46-0-0	Urea	40	180	UAN-28	60 lb
46-0-0	Urea	130	325	UAN-28	60 lb
46-0-0	Urea	180	400	UAN-28	60 lb
46-0-0	Urea	280	500	UAN-28	60 lb
44-0-0	ESN	40	180	UAN-28	60 lb
44-0-0	ESN	130	325	UAN-28	60 lb
44-0-0	ESN	180	400	UAN-28	60 lb
44-0-0	ESN	280	500	UAN-28	60 lb
No Preplant Nitrogen			0	UAN-28	60 lb

Table 1. Nitrogen fertilizer products employed in the study are listed to display the amount of each product necessary to achieve the goal lb of nitrogen available at row closure, as determined at a 0-30 cm soil test conducted by Agvise, Inc. (Northwood, North Dakota). Fertigation was applied at 20 lb N/acre (6.67 gals UAN 28 lb/acre). Two fertigation events were required in 2020, as determined by petiole testing from Agvise Inc. All plots received 115 lb/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 lb/acre.

Small plot experimental design: Only the cultivar Russet Burbank was used for the study. Experimental plots were prepared by cultivating on April 22nd 2020 and preplant fertilized on April 29th. 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 lb/acre to 584 lb/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 to 3 oz, average 2.5 oz (data not shown)) was planted on May 5th, 2020, with no gaps between plots, 36 inches between rows, 13 inches between seed pieces within row, and 6-to-7-inches deep (from top of hill). Seed was treated with Titan Emesto (Bayer, Leverkusen, Germany) at a rate of 20.8 mL/100 kg of seed. Pesticide applications and irrigation schedule were typical for the potato growing region in Carberry, Manitoba (data not shown).

Hills were created as plants emerged on June 2nd using a power hiller attached to a tractor. Row closure was observed on June 30th 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-lb 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). 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 to 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 (28-0-0) 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. 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 14th and was completed using a 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 lb harvested, as well as the lb of each tuber size category (less than 3-oz, 3-to-5.9 oz, 6-to-9.9 oz, 10-to-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).

Small plot statistical methods: 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-to-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.

MHPEC's 2020-2021 observational study: This study was based in grower fields consisted of selections that were chosen for exhibiting yield or quality limitations due to soil type, topography, limited water holding capacity, compaction, or for unknown reasons. Fields destined for French fry processing were planted with potato cultivar 'Russet Burbank'. Eight sampling points were established in each study field each May of the study year. Sampling points were determined in consultation with each grower and their consultants using all available information: aerial imagery, variability, Veris, and yield maps, as well as producer and agronomist knowledge of the field. The sampling points will be chosen to represent the range of field conditions and capture the areas of historical potato yield and/or quality variability within a 30-to-50-acre section of the field. Sample sites were recorded with a Trimble receiver with a 5-to-9-cm variance.

Determining Verticillium propagule levels. Soil samples were collected in the spring at row closure for each of the sampling points. Row closure was anticipated to occur by early July of each year. Sampling at each collection date for all fields in the project did not vary by more than two weeks. Composite soil samples (Seven cores per sampling point) were taken from 0-10 cm depths from the centre each collection point. The soil samples were ground to fine powder to prepare them for DNA extraction and eventual *V. dahliae* quantification. Two sub-samples of 0.25-g each were taken from each ground soil sample after it was well mixed between each sub-sampling. DNA was extracted from the sub-samples using DNeasy PowerSoil Kit (QIAGEN) following the manufacturer's instruction. Two extracted DNA samples were combined and mixed as the stock DNA to represent the original soil sample for the next step. The target DNA was amplified using the qPCR markers developed by Wei et al. (2015) http://dx.doi.org/10.1094/PHYTO-05-14-0139-R for *V. dahliae*. A model was developed and validated based on the relation of the numbers of microsclerotia per gram soil and threshold cycle threshold (Ct) of DNA amplification. Both parties of Pest Sustainability Initiative (PSI) labs and MHPEC were satisfied the model validation and agreed to their application on the real soil samples. The model was MSVd = 4*10^(9.019 – 0.2721*Ct) for *V. dahliae*.

Soil and plant nutrient evaluation: Soil and petiole samples were collected at row closure to determine in-season nutrient availability. Soils were collected from each of the 8-sampling points per field. Soils were sampled five times with a probe at 0-15 cm and 15-30 cm, and composite soil samples from both depths at each sampling point were tested through Agvise for N, P-Olsen, K, and S. Soil samples in the project were generally taken a 'V' pattern from sampling rows 1 to 3, and soil samples in the project were taken from within 6-inches of the plant, but never where the consultant had banded fertilizer (if fertilizer was not broadcast or fertigated). These samples were not dried before submission.

Potato petiole samples were collected on the same day as soils at row closure for analysis of percentage NO_3, P, K and S levels in plants. The data were used to assess the nutrient status of the plants at the various field sampling points through the season. Thirty-petioles were collected from sampling rows 1-to-3-in each collection site of each field. Petiole collection was done through the following method:

- Fields should not have been sprayed with pesticides or foliar nutrients for 3 to 5 days before sampling whenever possible.

- Sample from all 8-sites using rows 1 and 2 and 3, 30-petioles per site, go in a zig zag pattern down the rows.
- Select plants without an inflorescence if possible.
- Attempt to maintain similar sizes of petiole throughout sample, attempt to maintain petiole length of a minimum of three inches after stripping leaves
- Do not include snapped, torn, crushed, or otherwise damaged petioles
- Select 4th petiole from the top of the meristem, samples should not come in contact with dirt.
- Samples must be maintained in as cool temperatures as possible and not be exposed to sunlight.
- Samples should be delivered for processing immediately.

Objective 2:
Water level sensors (WLS) (Solinst Levelogger Junior 3001, Solinst Canada, Ltd., Georgetown, Ontario, Canada) were used to monitor the groundwater level in each plot throughout the season. These sensors were set to take a reading at half an hour interval. These sensors were hung inside the piezometers installed at the center of each plot. The piezometers were made from 2.5-m long steel pipes with an inner diameter of 41-mm. In order to avoid any hindrance to farming operations, such as hilling and spraying, all the piezometers were installed along the crop rows. The piezometers were mechanically installed using a mechanical auger. Manual readings of ground water level were also taken using a water level sensing tape as a check. A barometric pressure sensor (Solinst Barologger Gold) was used for subsequent barometric correction of the water level sensor data.
The stage of plant growth and rooting depth were the main factors considered in determining the nitrogen dynamics within the potato root-zone. Representative soil samples within 1.0-m below the ground surface were taken at 0.2-m intervals to determine the soil nitrate concentration (NO_3-N) at the beginning of each growth stage. Soil samples were stored in a refrigerator before sending them to soil testing lab (Agvise Laboratories Inc.) for analysis.

Results:

The 2020 nitrogen study indicated that the amount of available soil nitrogen, in lb, at row closure form 0-6 inches ($P = 0.0666$) and 6-12 inches ($P = 0.0883$) trended towards significance between treatments (Figs 2 and 3). There was a significant difference between the lb of nitrogen found in the soil prior to nitrogen fertilizer application at the start of the season ($P = 0.9615$, data not shown) with 10-to-18-lb of residual nitrogen in October of 2019. In general, the treatments of ESN and urea where 40-or-130-lb were expected by row closure ended up having far more soil nitrogen than anticipated. Treatments of ESN and urea where 180-lb were targeted by row closure appeared to be on target on average between all the replicates, but the large error bar indicates that some individual plots could be off from target by 50-lb or more. Neither fertilizer treatment could achieve targets of 280-lb of nitrogen in a soil test by row closure.

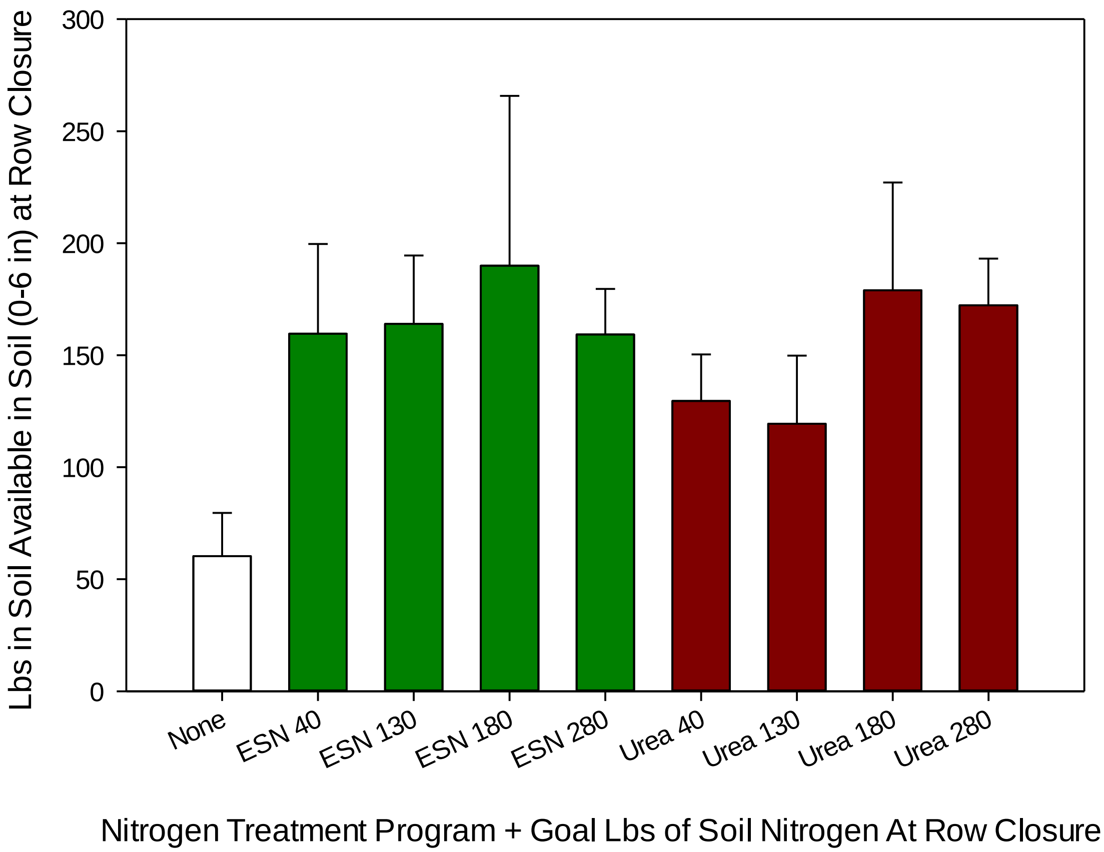
Lbs in Soil Available in Soil (0-6 in) at Row Closure
300
250
200
150
100
50
0
None
ESN 40
ESN 130
ESN 180
ESN 280
Urea 40
Urea 130
Urea 180
Urea 280
Nitrogen Treatment Program + Goal Lbs of Soil Nitrogen At Row Closure

Fig. 2

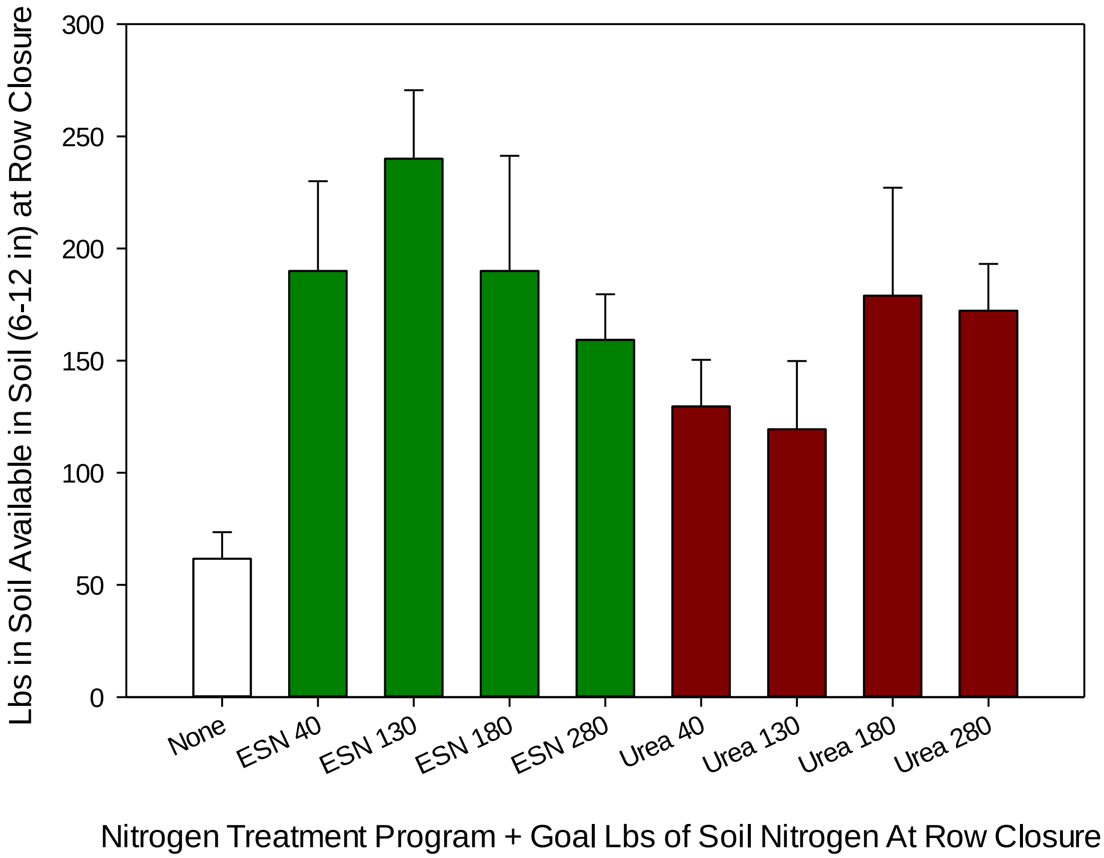
Lbs in Soil Available in Soil (6-12 in) at Row Closure
300
250
200
150
100
50
0
None
ESN 40
ESN 130
ESN 180
ESN 280
Urea 40
Urea 130
Urea 180
Urea 280
Nitrogen Treatment Program + Goal Lbs of Soil Nitrogen At Row Closure

Fig. 3

There was a significant effect of soil nitrogen treatment on the percentage of petiole nitrate at row closure ($P < 0.0001$, Fig. 4). Any nitrogen treatment significantly improved petiole nitrate availability compared to the negative control. There were no differences in petiole nitrate between any nitrogen fertilizer and/or treatment.

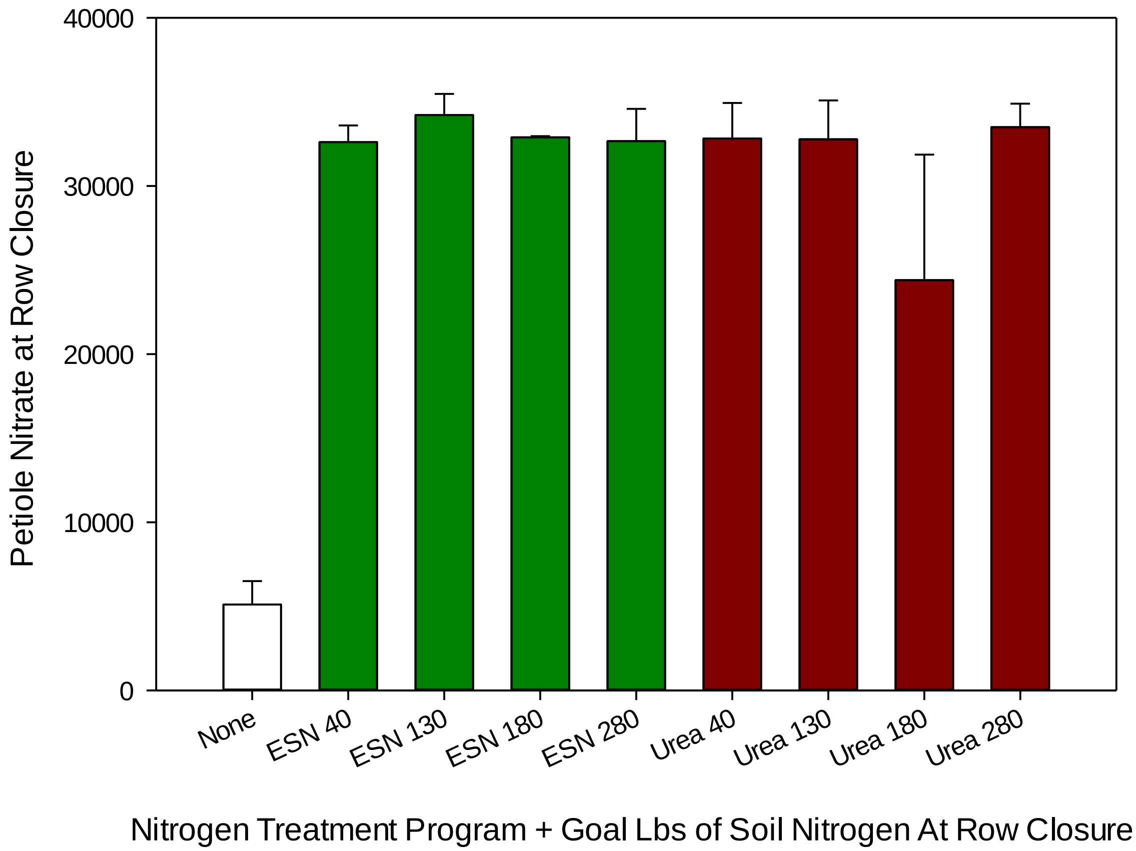

Fig. 4

Greater Fertilizer Treatment	Lesser Fertilizer Treatment	*P*- value
ESN 40	No added nitrogen	$P < 0.0001$
ESN 130	No added nitrogen	$P < 0.0001$
ESN 180	No added nitrogen	$P < 0.0001$
ESN 280	No added nitrogen	$P < 0.0001$
Urea 40	No added nitrogen	$P < 0.0001$
Urea 130	No added nitrogen	$P = 0.0021$
Urea 180	No added nitrogen	$P < 0.0001$
Urea 280	No added nitrogen	$P < 0.0001$

Table 2: The specific pairwise comparisons from proc mixed listed by the treatment with more petiole nitrate first, the lesser treatment second, and the P-value third. All other pairwise comparisons that are listed are nonsignificant ($P > 0.05$).

There was a nonsignificant effect of nitrogen treatment on total yield (*P* = 0.1549, Fig. 5). A curious observation is that the extreme ESN treatment (ESN 280-lb, where 500-lb of ESN were applied preplant with the intent of having 280-lb residual by row closure) has a numerical decrease in total yield when compared to the ESN 40-lb treatment or the treatment with no additional nitrogen.

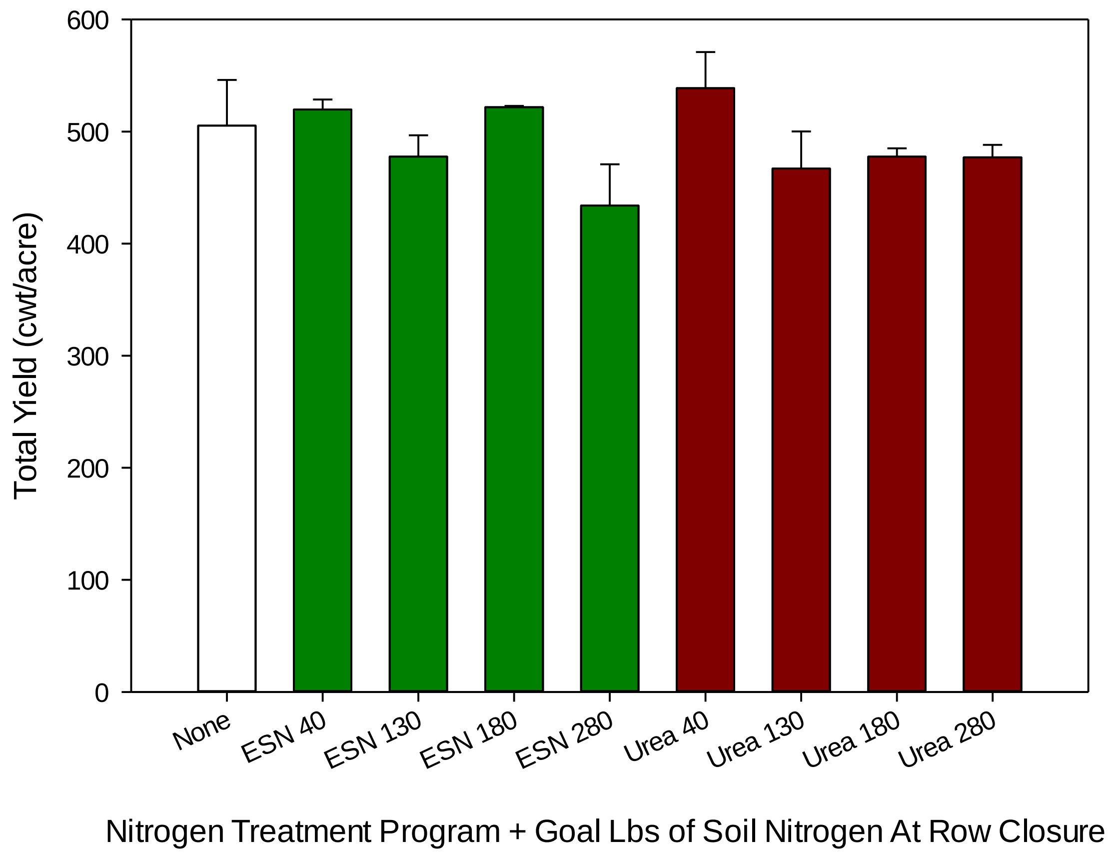

Fig. 5

There was nearly a significant trend (*P* = 0.1017) of nitrogen treatment and rate upon specific gravity (Fig. 6). While not technically significant, most nitrogen treatments appeared to numerically decrease specific gravity, albeit most of these decreases would not have incurred a penalty for low specific gravity by most French fry processors by being below 1.08. The most consistent trend is that the extreme rates of ESN and urea, where 500-lb were applied preplant with the intent to have 280-lb by row closure, dropped the specific gravity compared to lower rates of each fertilizer or the plots that received no supplemental nitrogen preplant.

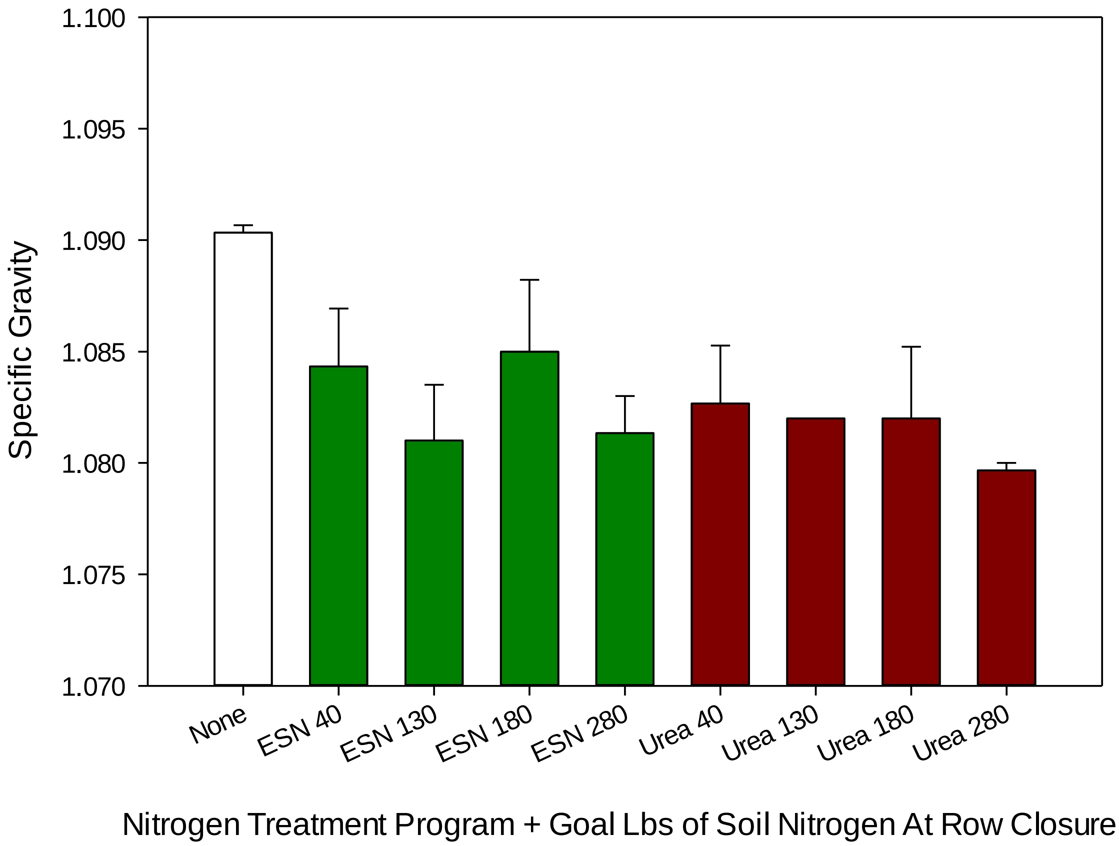

Fig. 6

There was a significant impact (*P* < 0.0001) of nitrogen treatment and rate on the cwt/acre of 3-to-6-oz tubers harvested from the experiment (Fig. 7). All fertilizer treatments decreased 3-to-6-oz yield compared to the negative control regardless of fertilizer rate or source (Table 3). There were no differences between the 3-to-6-oz yield between any of the fertilizer treatments and rate.

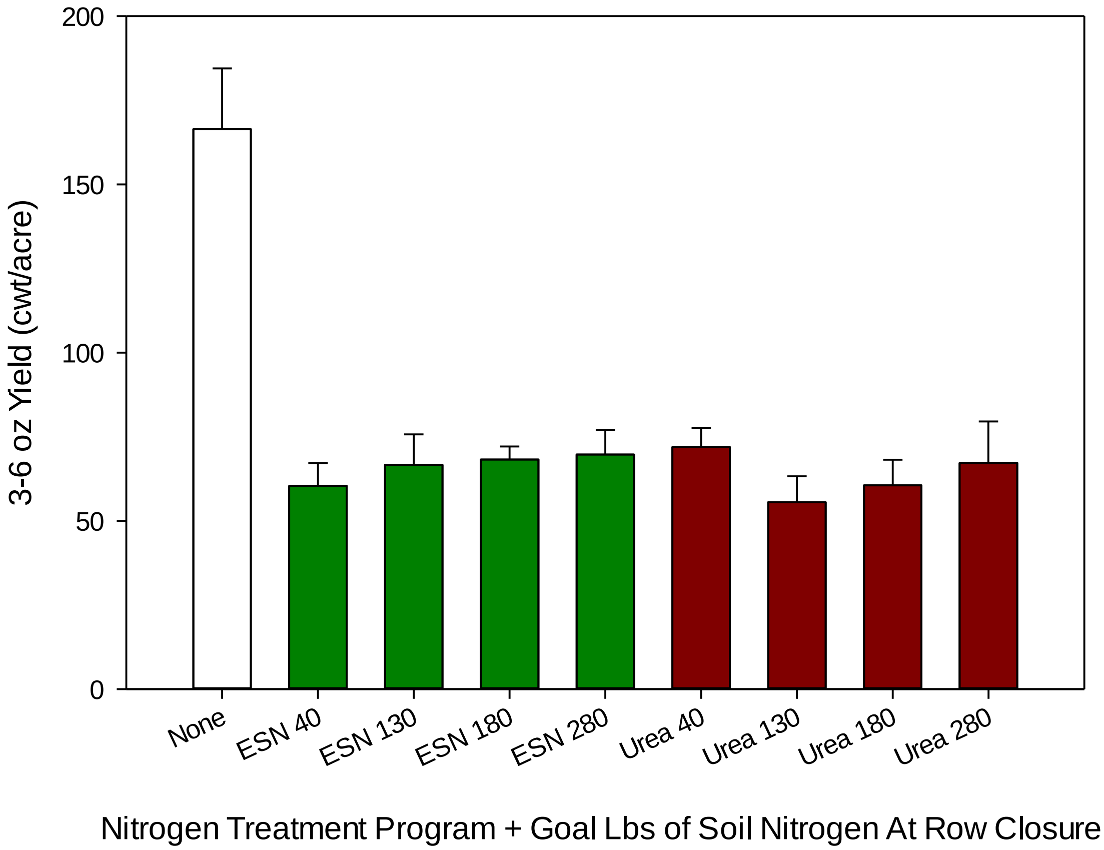

Fig. 7

Greater Fertilizer Treatment	Lesser Fertilizer Treatment	*P*- value
ESN 40	No added nitrogen	*P* < 0.0001
ESN 130	No added nitrogen	*P* < 0.0001
ESN 180	No added nitrogen	*P* < 0.0001
ESN 280	No added nitrogen	*P* < 0.0001
Urea 40	No added nitrogen	*P* < 0.0001
Urea 130	No added nitrogen	*P* < 0.0001
Urea 180	No added nitrogen	*P* < 0.0001
Urea 280	No added nitrogen	*P* < 0.0001

Table 3: The specific pairwise comparisons from proc mixed listed by the treatment with greatest 3-to-6-oz yield first, the lesser treatment second, and the *P*-value third. All other pairwise comparisons that are listed are nonsignificant (*P* > 0.05).

There was a significant impact ($P < 0.0001$) of nitrogen treatment and rate on the percentage of 10-to-12-oz tubers harvested from the experiment (Fig. 8). The treatments where 40-lb of nitrogen were targeted by row closure had the greatest percentage of 10-to-12-oz tubers when compared to the negative controls or higher rates of fertilizer, such as 280-lb of nitrogen by row closure.

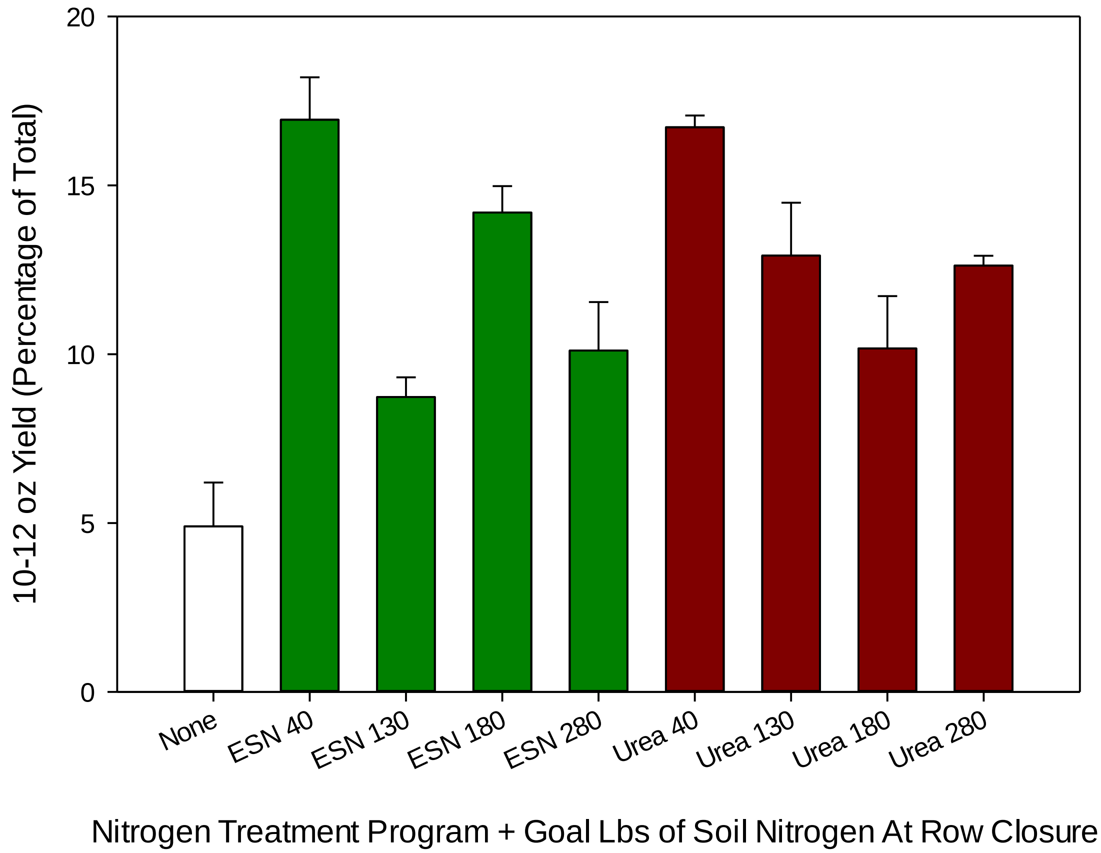

Fig. 8

10-to-12-oz %

Greater Fertilizer Treatment	Lesser Fertilizer Treatment	*P*- value
ESN 40	ESN 280	$P = 0.0104$
ESN 40	ESN 130	$P = 0.0018$
ESN 40	No added nitrogen	$P < 0.0001$
ESN 40	Urea 180	$P = 0.0112$
ESN 180	No added nitrogen	$P = 0.0005$
Urea 40	Urea 180	$P = 0.0148$
Urea 40	ESN 130	$P = 0.0024$
Urea 40	ESN 130	$P = 0.0137$
Urea 40	No added nitrogen	$P < 0.0001$
Urea 130	No added nitrogen	$P = 0.0023$

Urea 280	No added nitrogen	*P* = 0.0034

Table 4: The specific pairwise comparisons from proc mixed listed by the treatment with greatest 10% to 12% of yield first, the lesser treatment second, and the *P*-value third. All other pairwise comparisons that are listed are nonsignificant (*P* > 0.05).

There was a significant impact (*P* = 0.0007) of nitrogen treatment and rate on the percentage of 10 to 12-oz tubers harvested from the experiment (Fig. 9). All treatments improved >12-oz percentage yield compared to the negative control that had no additional nitrogen. There were no differences in >12-oz percentage yield between ESN fertilizer treatments. Conversely, the urea 180 treatment had more >12-oz tubers than urea treatments with more or less nitrogen (280 and 40, respectively).

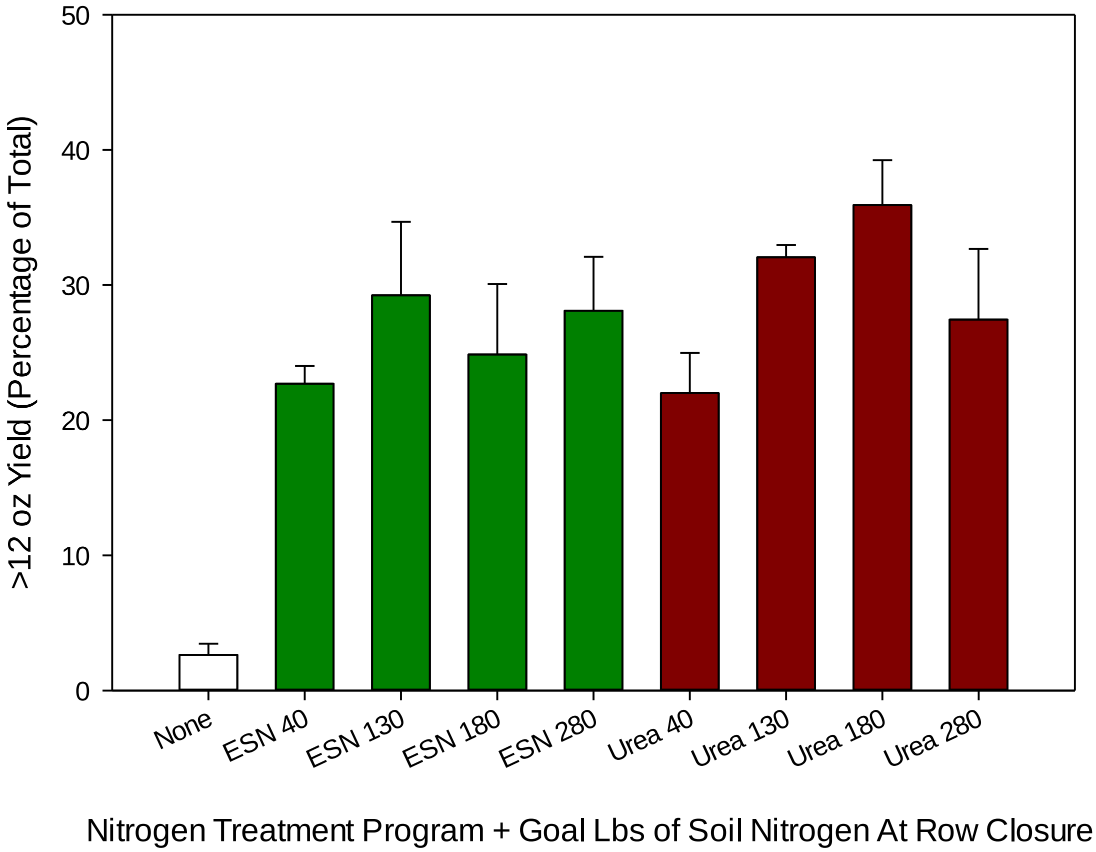

Fig. 9

Greater Fertilizer Treatment	Lesser Fertilizer Treatment	*P*- value
ESN 40	No added nitrogen	*P* = 0.0016
ESN 130	No added nitrogen	*P* = 0.0074
ESN 180	No added nitrogen	*P* = 0.0156
ESN 280	No added nitrogen	*P* = 0.0285
Urea 40	No added nitrogen	*P* = 0.0176
Urea 130	No added nitrogen	*P* = 0.0074
Urea 180	No added nitrogen	*P* = 0.0156
Urea 180	Urea 40	*P* = 0.0355
Urea 180	Urea 280	*P* = 0.0022

Urea 180	ESN 40	*P* = 0.0480
Urea 280	No added nitrogen	*P* = 0.0349

Table 4: The specific pairwise comparisons from proc mixed listed by the treatment with greatest >12-oz percentage of yield first, the lesser treatment second, and the *P*-value third. All other pairwise comparisons that are listed are nonsignificant (*P* > 0.05).

Nitrogen Dynamics within the Potato Root-Zone:

Impact of different nitrogen application treatments on nitrate dynamics within the potato root-zone was studied in Carberry, Manitoba. The objective of this study was to examine the effects of different nitrogen application rates on nitrogen dynamics within the potato root-zone in a loamy sand soil, and to analyze the nitrate leaching potential below the root-zone.

The nitrate concentrations at 0.2,-0.4,-0.6,-0.8-and-1.0-m depths from ground surface at vegetative growth, tuber initiation, tuber bulking, and maturation stages during the 2020 growing season is shown in figure 10 to 17. The plots with supplemental nitrogen application showed a trend of higher nitrate content within the potato root-zone compared to the no-supplemental nitrogen application treatment. Nitrogen was applied in the form of Urea and ESN also called as polymer-coated urea (PCU). ESN is a controlled release nitrogen fertilizer source. It has nitrogen granules covered in a thin/semi-permeable polymer coating. Soil water is absorbed by the granule which dissolves the nitrogen inside to releases it at a specific temperature and soil moisture level. About 80% of the nitrogen is released from PCU/ESN urea between 40 and 90 days after application. This period spans over the beginning of tuber initiation stage to mid of tuber bulking stage.

In the 2021 growing season, nitrogen treatments of ESN 280 lb/A, ESN 180 lb/A, and No Supplemental Nitrogen were compared under adequate irrigation application to track nitrogen dynamics within the potato root-zone under adequate irrigation application. (Fig. 18 and 19).

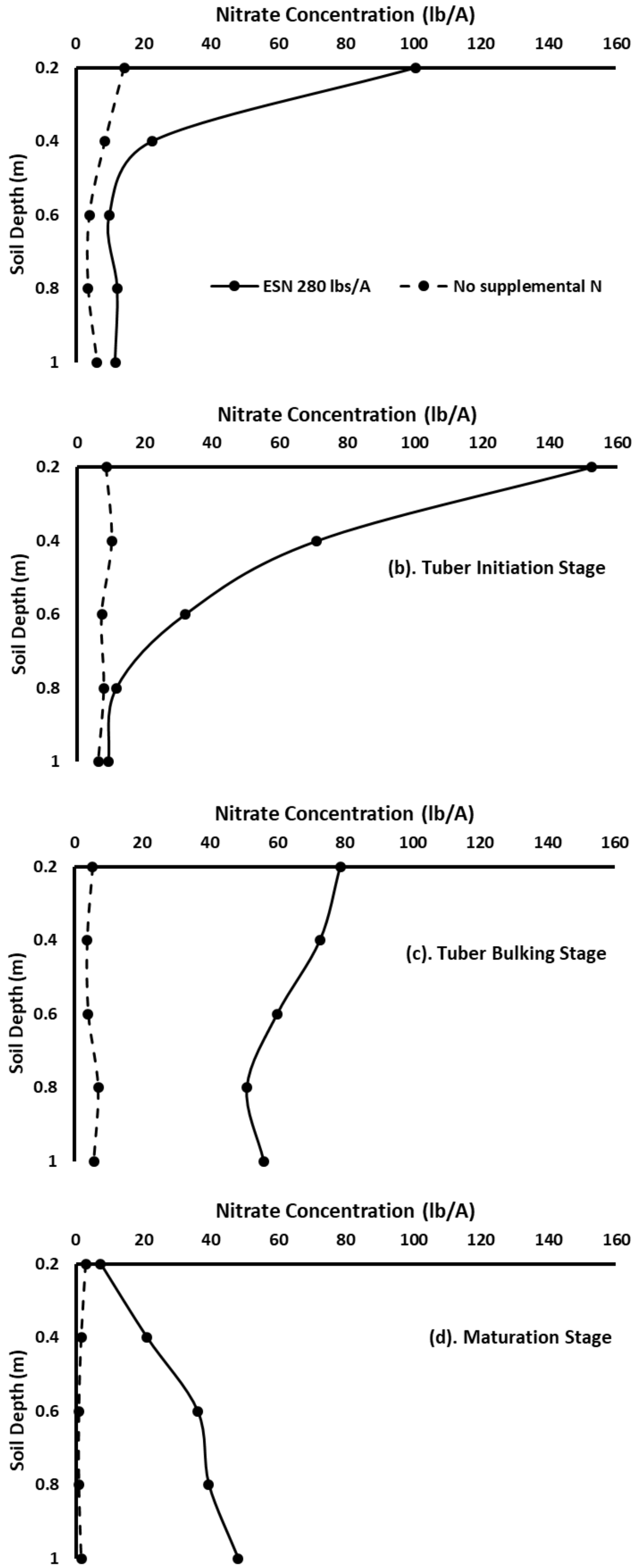

Fig. 10 Comparison of N application rate of ESN = 280 lb/A and no-supplemental N

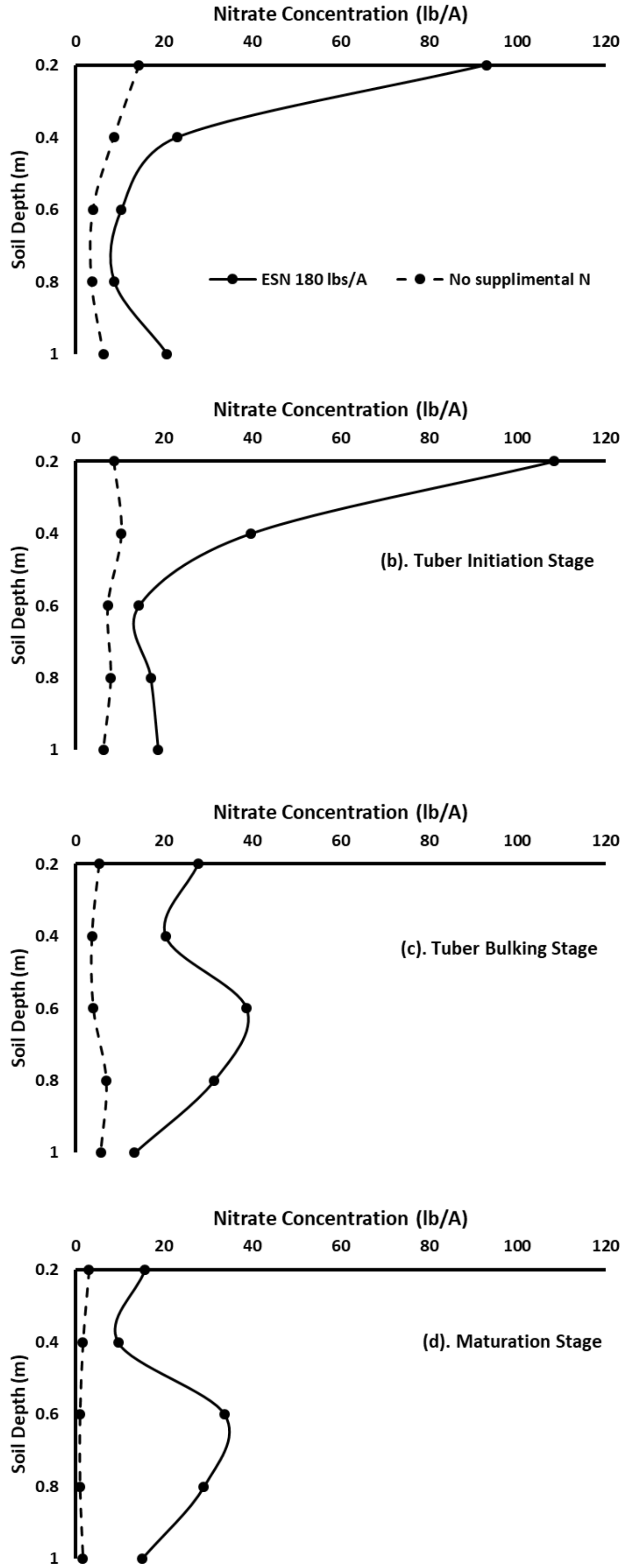

Fig. 11 Comparison of N application rate of ESN = 180 lb/A and no-supplemental N

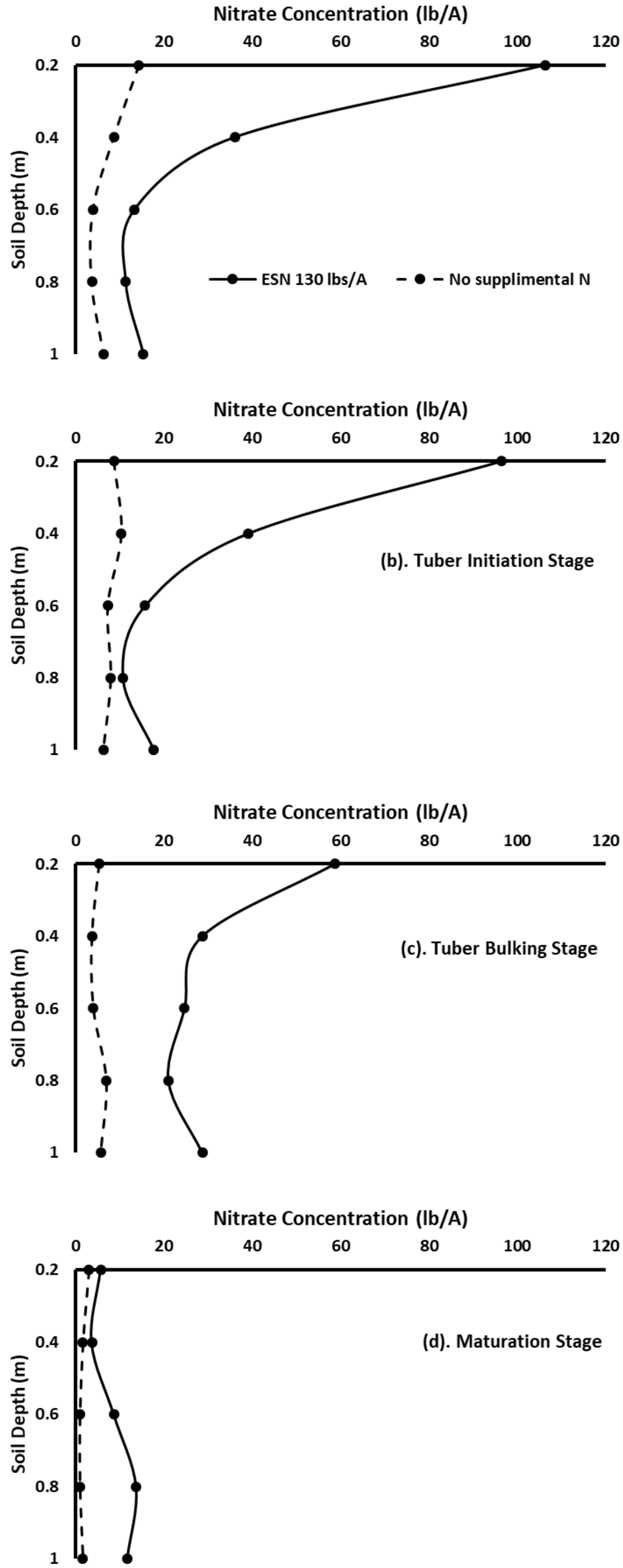

Fig. 12 Comparison of N application rate of ESN = 130 lb/A and no-supplemental N

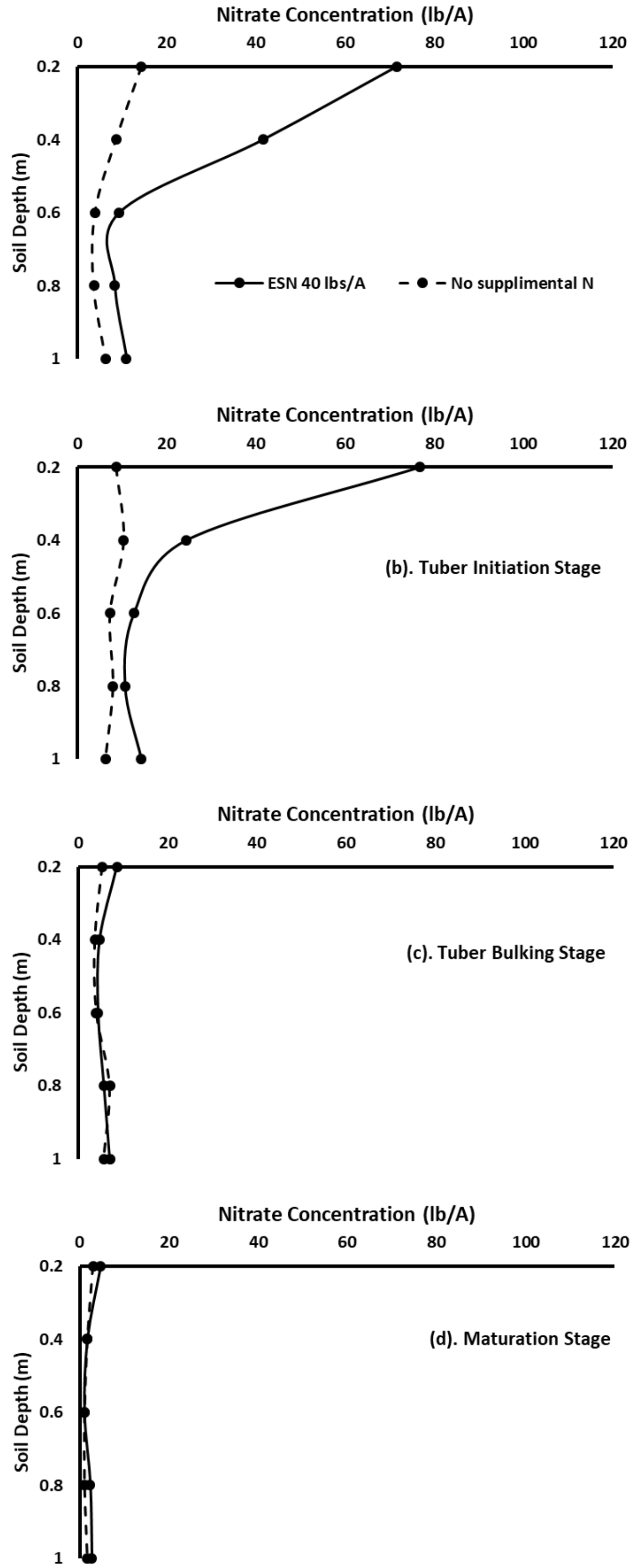

Fig. 13 Comparison of N application rate of ESN = 40 lb/A and no-supplemental N

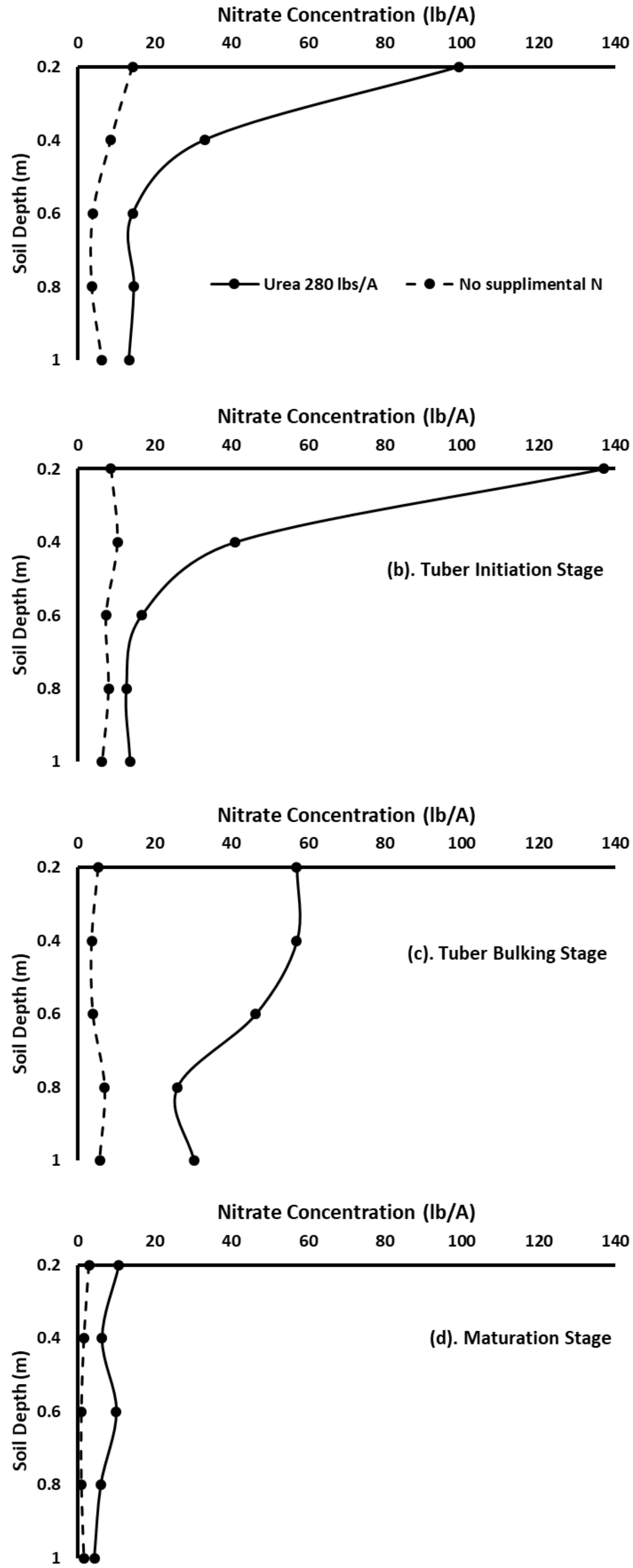

Fig. 14 Comparison of N application rate of Urea = 280 lb/A and no-supplemental N

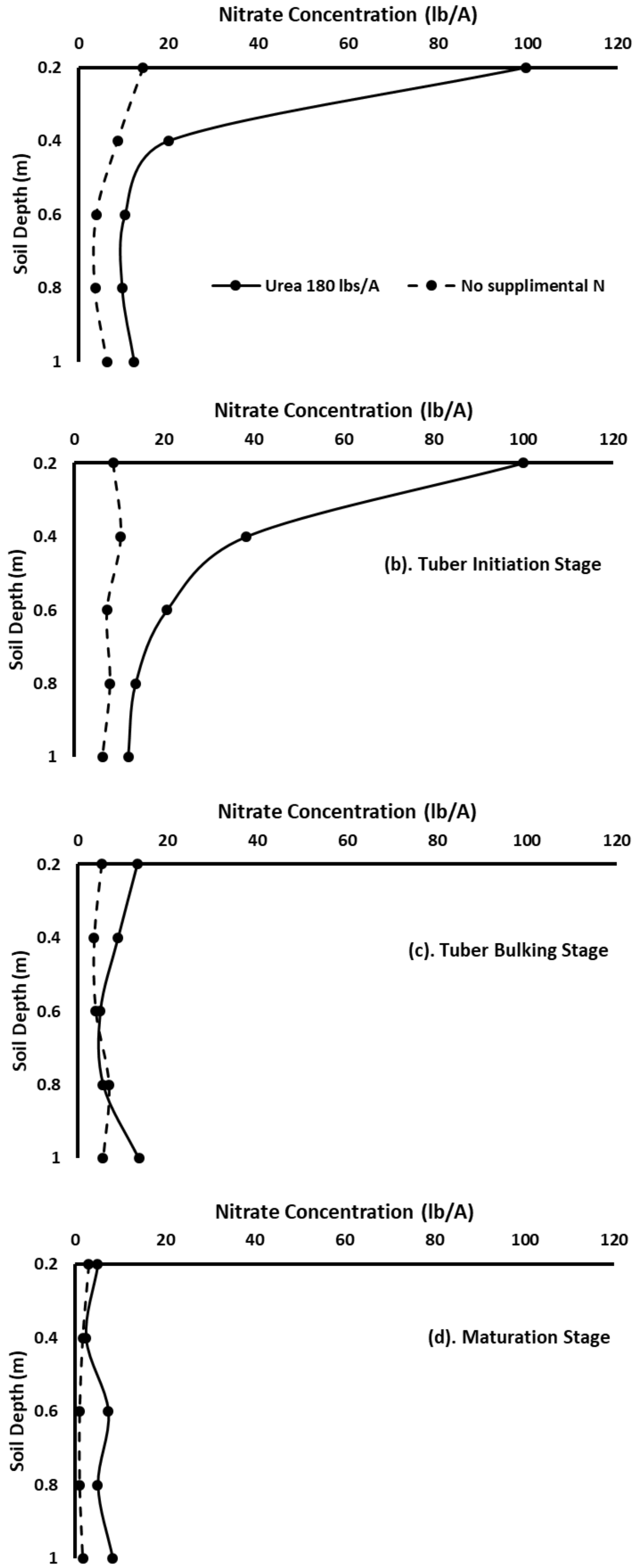

Fig. 15 Comparison of N application rate of Urea = 180 lb/A and no-supplemental N

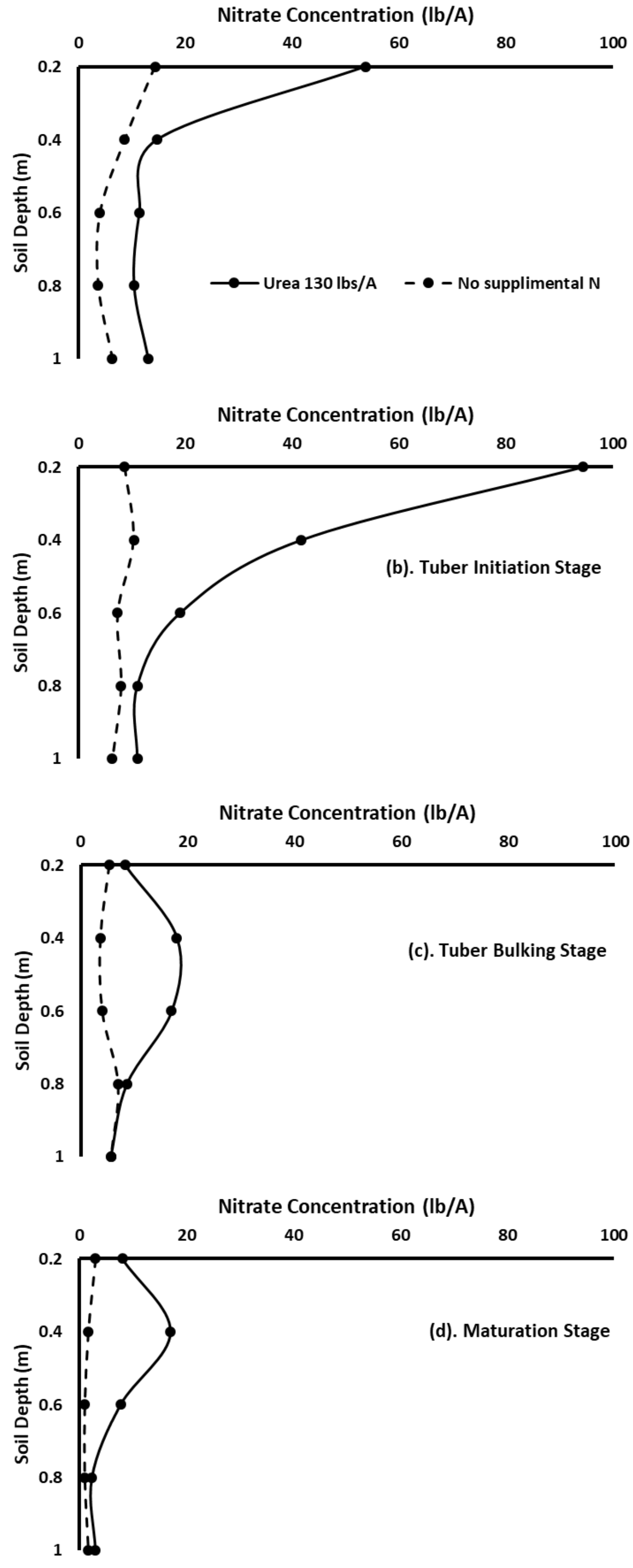

Fig. 16 Comparison of N application rate of Urea = 130 lb/A and no-supplemental N

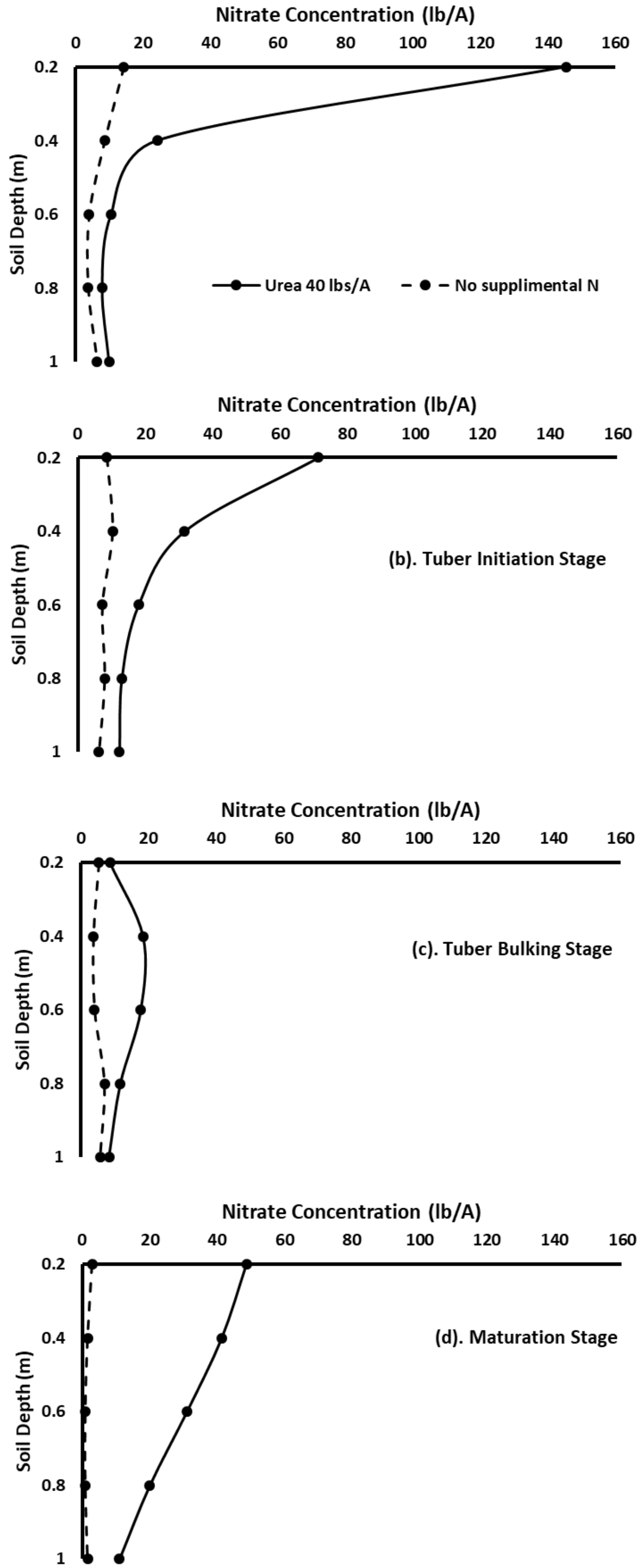

Fig. 17 Comparison of N application rate of Urea = 40 lb/A and no-supplemental N

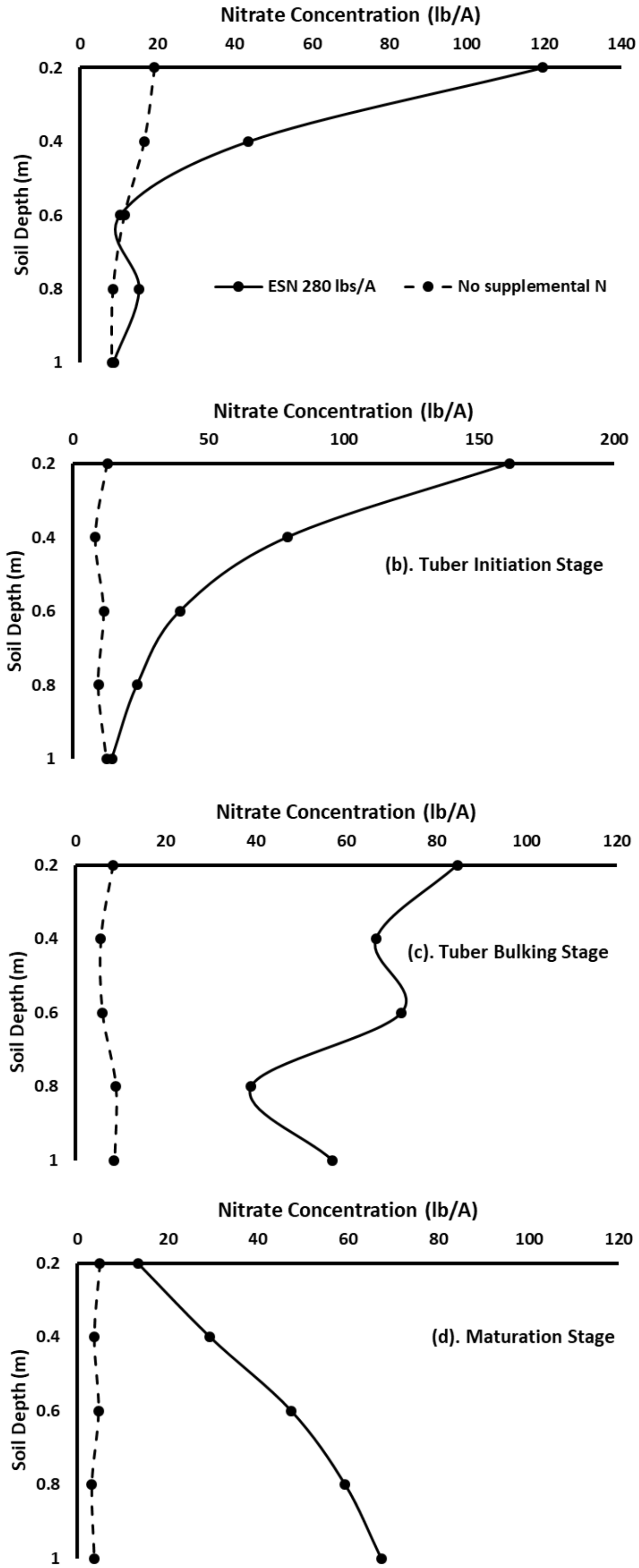

Fig. 18 Comparison of N application rate of ESN = 280 lb/A and no-supplemental N (2021)

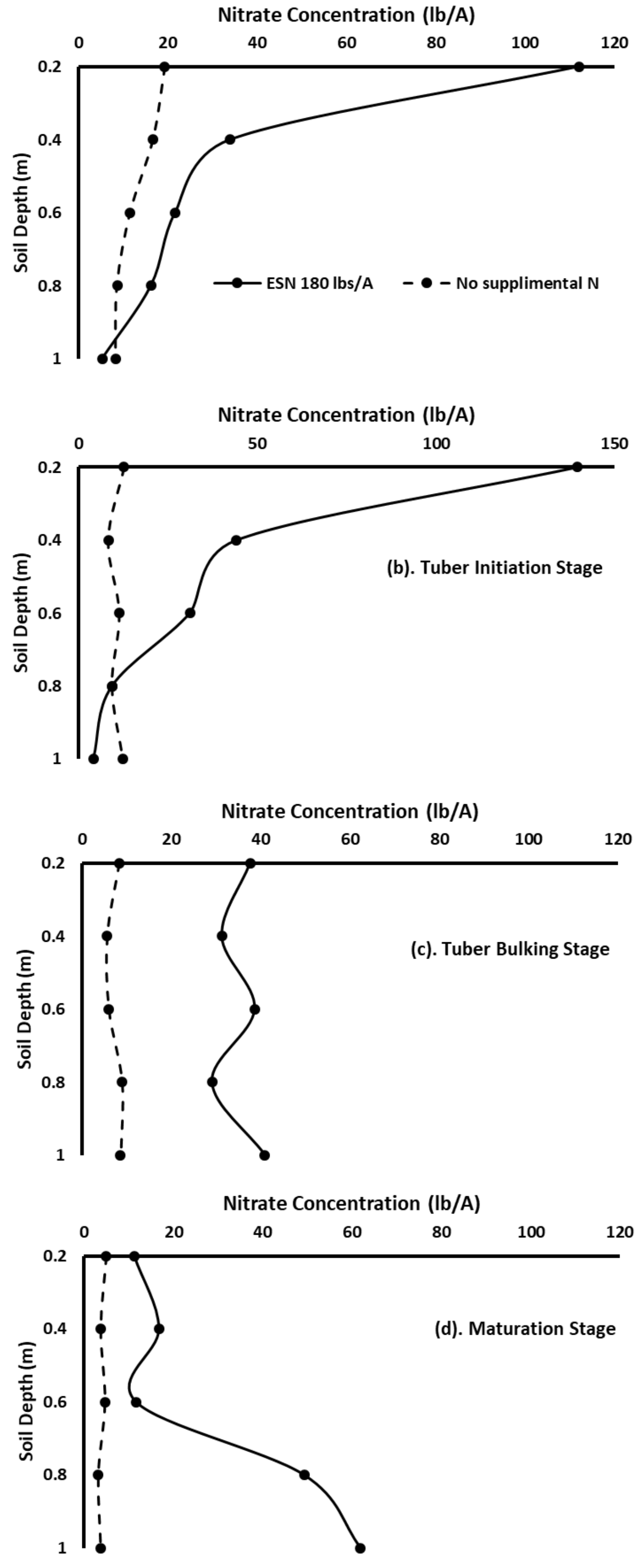

Fig. 19 Comparison of N application rate of ESN = 180 lb/A and no-supplemental N (2021)

Potato requires modest nitrate and soil moisture in the beginning of the growing season i.e. at sprout development and vegetative growth stages compared to the subsequent growth stages. An adequate amount of supplemental irrigation was applied during tuber initiation, and tuber bulking stages which facilitated the release of nitrogen from ESN. A comparatively higher nitrate content within the 0.2 m depth shows an adequate application of nitrogenous fertilizers. However, a trend of nitrate leaching was observed within the potato root-zone with the progression of growth stages. It resulted in higher nitrate contents in the deeper depths compared to shallow depths in some ESN applied treatments.

Polymer coated urea may release a maximum of 80% of the total nitrogen during the period of sprout development to mid-bulking stage and remaining is released after that. Since the potatoes do not need as much water during the maturation stage, no supplemental irrigation was applied during this stage. About 20% of the total PCU nitrogen may have been released during this stage. The decrease in nitrate content at 0.2 m depth and increase at 1.0 m depth in ESN = 280 lb/A treatment may be attributed to leaching down of unutilized nitrogen with percolation caused by irrigation and rainfall. As nitrates are readily soluble in water, nitrate leaching potential is directly linked to soil water dynamics within the effective root-zone. The potential risk of nitrate leaching increases with the accumulation of excessive nitrates within the root-zone combined with excessive irrigation and/or intense rainfall on well-drained sandy soils having low water-holding capacity.

Fig. 20 and 21 show that a higher amount of nitrogen application in sandy loam soil system facilitate the availability of nitrogen for plant growth. However, the application of a higher rate of slow released nitrogen is comparatively beneficial than Urea for better nitrogen use efficiency. Nitrate leaching potential from the effective root-zone was found significantly higher at tuber initiation stage, and tuber bulking stage. Tuber initiation and tuber bulking stages are sensitive to irrigation and nutrients stress. In 2021, supplemental irrigation was applied to the irrigated treatment during the tuber initiation, and tuber bulking stages. Overhead irrigation and rainfall coupled with favorable temperature facilitated the release of nitrogen from PCU/ESN granules in the plant-available-form. This accumulated nitrate may have been available to leach below the root-zone with the irrigation and rainfall events.

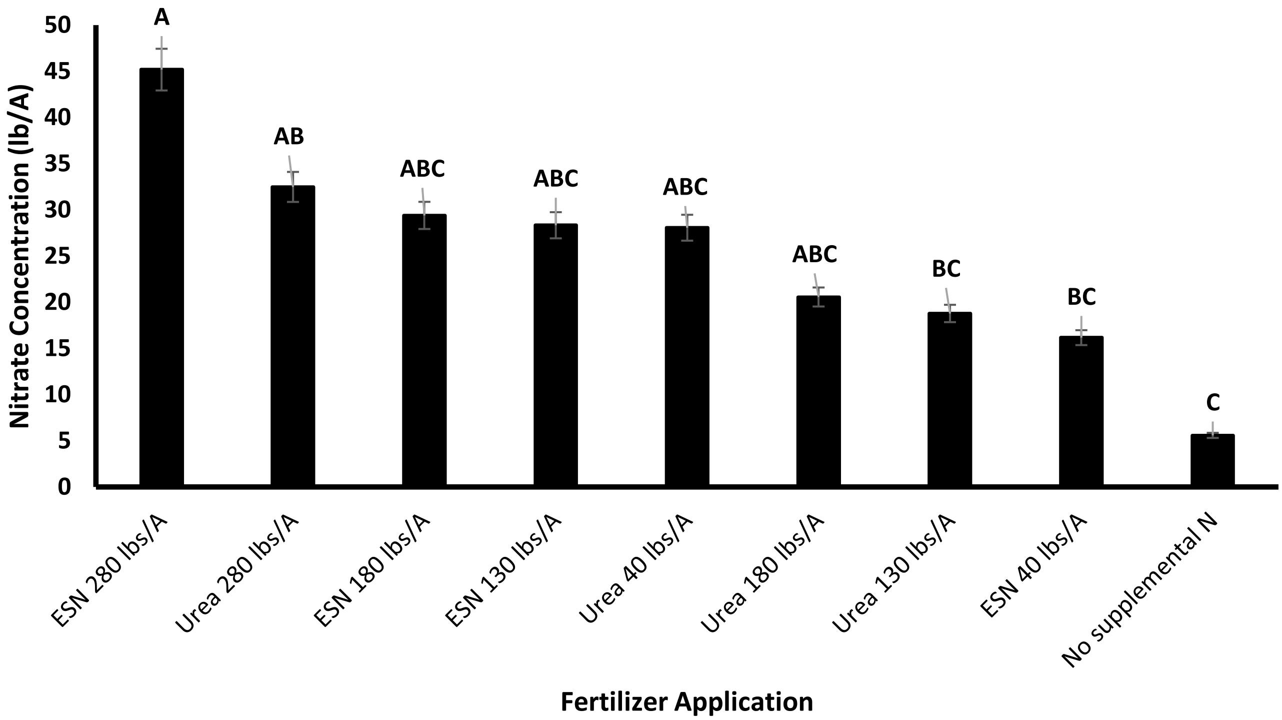

Fig. 20 Nitrogen availability within the potato root-zone throughout the growing season (2020)

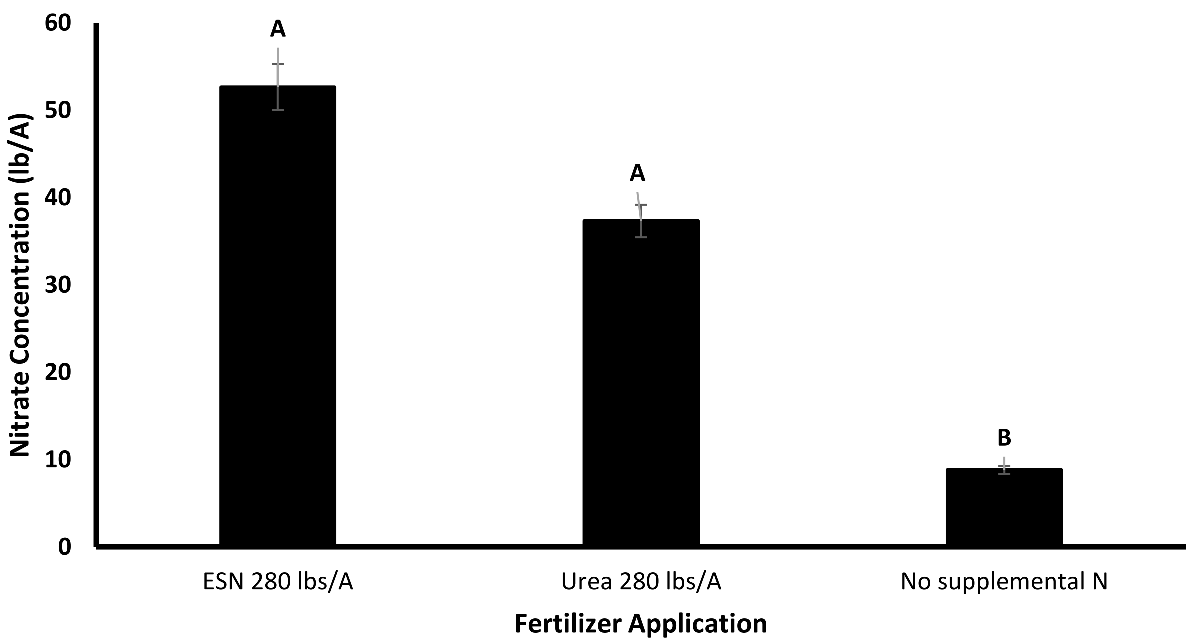

Fig. 21 Nitrogen availability within the potato root-zone throughout the growing season (2021)

Project findings:

Nitrate leaching can have a direct impact on groundwater quality. Nitrate is very mobile and easily leaches with water. Heavy rains and supplemental irrigation applications can cause nitrates to leach downward in the soil below the potato root zone. Whether nitrates continue to leach downward, and into groundwater, depends on underlying soil and/or bedrock conditions, as well as depth to groundwater. If depth to groundwater is shallow and the underlying soil is sandy, the potential for nitrates to enter groundwater is relatively high. However, if depth to groundwater is deep and the underlying soil is heavy clay, nitrates will not likely enter groundwater. In some cases where dense hardpans are present, nitrate leaching will not progress beyond the depth of the hardpan. The unavailability of nitrogen within the potato root-zone, due to nitrates leaching effect, causes negative impacts on potato yield and quality.

Acknowledgements:

The authors would like to thank Alan Manns and Alex Christison for their time and skill in applying the fertigation treatment to specific plots with the meticulousness and repeatability demanded by the principle investigator. 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)[68].

		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.

Above: 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

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

TABLE 24

****

Potato-Petioles (tubers <3/4)

****

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

****

Potato-Petioles (tubers <3/4-2)

****

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

****

Potato-Petioles (tubers > 3.5

****

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

Field Designation	Total NPKS Applied
NVS-1	213-6-168-35-4.26Mg
NVS-2	194-100-300-67
NVS-3	172-130-316-30
NVS-4	226-105-252
NVS-5	313-91-382-38
NVS-6	183-80-300-68
NVS-7	181-89-240-48
NVS-8	185-100-232-42
NVS-9	237-101-222-62
NVS-10	212-50-245-34
NVS-11	224-125-198-48
NVS-12	214-122-149-47-9.8Mg
NVS-13	190-150-210-35-1Zn
NVS-14	291-91-362-28
NVS-15	173-93-180-45
NVS-16	197-80-225-41
NVS-17	176-91-210-35
NVS-18	178-91-210-35
NVS-19	287-221-288-50

	Soil Analysis at Row Closure					Petiole Analysis at Row Closure				
Field Designation	**Total N lb**	**Rating**	**Phosphorous ppm**	**Potassium ppm**	**Sulphur lb**	**NO_3 ppm**	**Rating**	**Phosphorous %**	**Potassium %**	**Sulphur %**
NVS-8	243	Possible excess	43	399	132	15321	sufficient	0.32	10.07	0.19
NVS-9	101	v. high	18	329	54	18831	sufficient	0.27	9.44	0.20
NVS-10	47	mod	30	296	212	11114	low	0.32	8.70	0.23
NVS-11	84	v. high	32	266	86	24558	sufficient	0.47	9.30	0.21
NVS-12	149	v. high +	33	355	86	25583	high	0.44	10.25	0.21
NVS-13	227	Possible excess	18	267	28	20928	sufficient	0.40	10.37	0.20
NVS-14	180	v. high +	26	493	118	26230	High	0.37	11.51	0.02
NVS-15	203	Possible excess	35	555	36	25175	High	0.34	12.03	0.20
NVS-16	36	low	24	385	108	10085	low	0.34	9.57	0.20
NVS-17	140	v. high +	20	270	128	21627	sufficient	0.46	10.55	0.23
NVS-18	121	v. high +	27	315	108	18957	sufficient	0.36	10.56	0.21

Avg nutrient Content of 8 points. Mobile Nutrients Nitrogen and Sulphur 0-30 cm soil sample. Non-mobile nutrients Phosphorous and Potassium are 0-15 cm soi samples.