ADOPT 20190450
4R Nitrogen Use in Mixed Forage Stands (part one)
Final Report

Project Identification

1. **Project Title:**
   - 4R Nitrogen Use in Mixed Forage Stands
2. **Project Number:**
   - 20190450
3. **Producer Group Sponsoring the Project:**
   - Saskatchewan Forage Council
4. **Project Location(s):**
   - Site 1 – Plunkett, SK, RM Viscount No. 341, LL NE36-35-25 W2, cooperating landowner was Harvey Welter
   - Site 2 – Outlook, SK, RM Rudy No. 284, LL NE4-31-6 W3, cooperating landowner was Marcel Vermette
   - Site 3 – Parkbeg, SK, RM Wheatlands No. 163, LL NE35-16-03 W3, cooperating landowner was JP Monvoisin
5. **Project start and end dates (month & year):**
   - Fertilizer spread in May 2020, hay was cut July 2020, soil sampling competed November 2020
6. **Project contact person & contact details:**
   - Catherine Lang, 306-694-3492, Moose Jaw, SK

Objectives and Rationale

7. **Project objectives:**
   - This project was intended to demonstrate and compare the benefits of fertilizing old hay stands with nitrogen loss inhibitors as part of a complete fertility stand in mixed forages
8. **Project Rationale:**
   - This project is of interest to local producers since livestock producers are looking to make the most feed with the lowest economic burden. With land prices increasing, it is becoming more important than ever to maximize productivity on their existing land base. Using nitrogen loss inhibitors is not typical in forage fertilizer blends, but if it makes economic sense to invest in these products to gain a higher yield, the uptake of these products could become common. The products have a really good fit in forage fertilizer blends as fertilizer applications on forage stands are almost always applied by broadcasting. In addition, nitrogen loss inhibitors produce less greenhouse gasses than traditional bare urea, so they are better for the environment.

Methodology and Results

9. **Methodology:**
   - The project was set up at three sites – Plunkett, Outlook, and Parkbeg. At each site, we were provided with 40 acres of the hay stand that was fairly consistent in terms of topography and plant establishment. These 40 acres were then divided into 10 acre treatments – untreated check (no fertilizer), bare urea, a urease inhibitor product, and a nitrification and urease inhibitor combination product. One composite soil test per 40-acre site was completed when the ground thawed (beginning of May) and were sent to A&L labs to be analysed. The decision was made to plan for two bales per acre as the yield target, and applied fertilizer to meet those requirements. We took the fertilizer needed to meet that yield (100-25-200-15) and subtracted the nutrients already present in the soil (as presented on the soil test) to calculate what fertilizer needed to be applied. A blend request was sent to a local Ag retailer and was then spread on the site when

conditions allowed (Plunkett – May 29, Outlook – May 3, Parkbeg - May 11). Rainfall was recorded in Plunkett and Outlook using weather data from environment Canada, but the Parkbeg site was recorded in a rain gauge after every rainfall. The sites were then monitored until the crop was ready to cut. Some of this monitoring was done by satellite imagery provided by Farmer's Edge. The producer then cut and baled the field when it was ready (Plunkett – cut July 21, baled July 28, Outlook – cut July 18, baled July 24, Parkbeg – cut July 22, baled July 27). Once bales were made, they were weighed to determine the forage yield. Forage samples were taken to determine forage quality, and these samples were also sent to A&L labs. Lastly, when the soil had cooled enough (in November) composite soil samples were taken again, but for each 10-acre treatment this time to compare any effects that the nitrogen protected fertilizer had on the soil nutrients. Once the trial was completed and the analysis results back, an economic analysis was completed.

10. Results

- The parameters of this project that we collected were rainfall, forage yield, forage quality, soil composition, and an economic analysis.

  i. In terms of rainfall, the was very low rainfall on all three sites (Plunkett 5.2 inches, Outlook 6.0 inches, and Parkbeg 5.5 inches) so the dry conditions severely impacted plant growth. This may explain some of the results we found regarding crop yield.

  ii. Satellite imagery gathered throughout the growing season measured three metrics on each of the sample sites. Imagery consisted of NDVI (a measure of healthy green vegetation), Scouting (showing areas of high and low NDVI relative to the field average for that day), and Variation (showing all present image bands, including soil, water, vegetation). Imagery taken early in spring near to when the fertilizer was applied show very low/no levels of vegetative biomass, which was to be expected. As imagery was gathered into mid-June it was apparent that the untreated check was far behind the fertilized treatments in all imagery metrics. On the final imagery pictures taken days before the fields were cut, there were extremely noticeable difference between the amount of healthy green vegetation of the untreated check and the fertilized treatments. Even variations such as when the spreader applied the fertilizer crooked or where the fertilizer ran out on a trial, were clearly shown on these maps. See Appendix A for a summary of these photos.

  iii. Forage yield was determined by calculating the distance between the bales and weighing the resulting bale. This was done on four random bales within each 10-acre treatment to get an average. The acreage was determined by calculating the average distance between bales (in feet) multiplied by the width of the swather (in feet) to give the resulting volune (in feet^2). This feet^2 calculation was then converted to an acreage. Then, the average pound of the bale was divided by the acreage previously calculated to result in the yield expressed as pounds per acre. To compare these sites appropriately, all values were converted to a dry matter basis.

  At the Plunkett site, the untreated check treatment yielded 911 lbs/ac, the urea treatment yielded 1806 lbs/ac (in increase of 98%), the urease inhibitor treatment yielded 1612 lbs/ac (an increase of 77%), and the urease and denitrification inhibitor treatment yielded 2152 lbs/ac (an increase of 136%).

  At the Parkbeg site, the untreated check treatment yielded 1811 lbs/ac, the urea treatment yielded 1980 lbs/ac (in increase of 9%), the urease inhibitor treatment yielded 2268 lbs/ac (an increase of 25%), and the urease and denitrification inhibitor treatment yielded 2296 lbs/ac (an increase of 27%).

  The Outlook site used slightly different products due to availability at the ag retailer. Instead of using urease and denitrification inhibitors, a polymer coated urea product and a sulphur enriched urea product were used instead. The untreated check treatment yielded 1264 lbs/ac, the urea treatment yielded 2032 lbs/ac (in increase of 61%), the polymer coated urea yielded 2504 lbs/ac (an increase of 98%), and the sulphur enriched urea yielded 2526 lbs/ac (an increase of 100%). Although the products have a different mode, the end result was consistent with the urease and denitrification inhibitors result.

  The results of forage yield show that no matter what, the yield increased by applying fertilizer, and increased even more when the nitrogen treatment products were used. The Plunkett and Outlook sites both showed a very high response to the fertilizer, whereas the Parkbeg site showed a very small response. This is likely because the Parkbeg site never got a large amount of rain at one time. Although the cumulative rainfall was similar, it almost always rained as a drizzle rather than a soaking rain. Seeing this response is very encouraging, but determining whether it was worth the additional cost of the nitrogen protection products needs to be analysed. See Appendix B for yield comparison graphs.

iv. Forage samples were collected and sent to A&L laboratories for analysis. This analysis looked at: dry matter (DM), crude protein (CP), soluble crude protein, acid detergent fibre (ADF), neutral detergent fibre (NDF), total digestible nutrients (TDN), net energy lactation, maintenance, and gain, calcium (Ca), copper (Cu), phosphorus (P), potassium (K), sulphur (S), magnesium (Mg), zinc (Zn), iron (Fe), manganese (Mn), sodium (Na), and relative feed value.

At the Plunkett site, the feed quality showed no change between treatments. The bale quality parameters of DM, CP, ADF, NDF, and TDN hardly changed. There were slight changes in the CP (11% untreated check/urease to 13% urea/urease and denitrification) and NDF (50% urea/urease and denitrification to 54% untreated check/urease), but not of these parameters changed enough to cause an effect on feed quality. The lack of CP increase shows that there was likely no additional alfalfa growth. The macronutrients of Ca, Mg, P, K, and Na also stayed relatively the same. The microminerals of Cu, Fe, Mn, S, and Zn also stayed unchanged.

At the Parkbeg site, the feed quality again showed no change major between treatments. The bale quality parameters of DM, CP, ADF, NDF, and TDN did not change. The lack of CP increase again shows that there was likely no additional alfalfa growth. The macronutrients of Ca, Mg, P, K, and Na also stayed relatively the same. The microminerals of Cu, Fe, Mn, S, and Zn also stayed unchanged except for iron. Iron showed a dramatic drop from the untreated check (712 µg/g) to all the other treatments (ranging from 147 µg/g to 255 µg/g). This drop is unexplained and we do not know what caused it. This might have been a sampling error.

The Outlook site also followed the same trends with no observable changed in the bale quality, macronutrient, or micronutrient parameters.

What these forage sample analyses are indicating are that although the forage yield was increased, the actual value of the feed did not. These samples are all testing adequate for livestock nutrition. If more fertilizer was applied to get the old alfalfa growing again it is possible that those plants could cause an increase in protein and energy. See appendix C for a summary of the feed analysis for all three sites.

v. Soil testing was complete both pre and post-trial. The soil samples that were collected before the trial provided the information needed to make the blends of fertilizer. Samples were collected as 40-acre composites as there was expected to be no spatial variability on nutrient levels within that 40-acre site pre-treatment. In addition, they gave a baseline of how deficient the soil was in nutrients. Interestingly, all of the site showed similar values in their pre soil sampling results averaging 3.2% organic matter, 2 ppm Nitrate-Nitrogen, 8 ppm Phosphorus Bicarbonate, 246 ppm potassium, and 7 ppm sulphur.

Once the trial was completed, repeat composite soil tests were done on all of the 10-acre treatments at each site to determine if the nitrogen was taken up by the crop, tied up in the soil, or lost to leaching/volatilization/erosion. We were hoping to see a residual effect of the soil nutrients to carry into the next year. In all three sites we saw a bump in organic matter. This bump is likely due to the time of year that the sampling was done and that there was more root matter present from the growing season that wasn't broken down yet. In addition, the phosphorus, potassium, and sulphur all remained unchanged, if not decreased slightly.

However, the nitrate-nitrogen was slightly different. At the Plunkett and Outlook sites, there was a slight increase in soil Nitrate-N on all of the sites that were fertilized. The Parkbeg site however showed a much greater response to the nitrogen fertilizer with value increase from 2 ppm to 8 ppm, and being even higher (10 ppm) in the trial that used the urease inhibitor. Although there was an increase, these values of soil Nitrate-Nitrogen are still classified as "low". See Appendix D for the cumulative soil analysis, both pre and post fertilizing.

vi. The economic component of these results may be of the most value to producers. If it doesn't make economic sense to fertilize an existing hay stand, it may be more beneficial to take that stand out of production and re-establish instead. When doing these economic comparisons, we are essentially looking at the total costs per acre to apply that fertilizer, the additional pounds of forage that fertilizer produced, and what that works out to as a cost per pound. This can then be compared to the cost of purchasing hay. In the fall of 2020, it was common for the price of hay to be around $0.07/lb. Please refer to appendix E for the full calculation breakdown.

At the Plunkett site, the costs of fertilizing the forages ranged from $62.23/ac to $68.88/ac. The additional pounds for forage produced caused the cost to be $0.06/lb for the urea, $0.09/lb for the urease inhibitor, and $0.05/lb for the denitrification and urease inhibitor.

The Outlook site followed a very similar trend, with the cost of fertilizing ranging from $72.04/ac to $84.56/ac. The additional pounds of forage produced cost $0.09/lb for urea, $0.06/lb for the sulphur enriched urea, and $0.06/lb for the polymer coated urea.

The Parkbeg site did not show as promising economic comparisons due to the lower yield differences between the treatments. The cost of fertilizer ranged from $54.12/ac to $58.56/ac. The additional pounds of forage produced using urea cost $0.32/lb, the urease inhibitor cost $0.12/lb, and the urease and denitrification inhibitor cost $0.11/lb.

Although the economic component did not show the same result, they did however show the same trend; that applying the nitrogen stabilizing products had a great enough yield bump that it justifies the cost of treating the urea. Ultimately, that was the goal of this project.

It is important to remember some other key takeaway from this analysis. For Plunkett and Outlook, the cost of fertilizing was less than the cost of purchasing feed (assuming feed to be around $0.07/lb). Although, that $0.07/lb does not always include other expenses like: trucking, bringing unwanted noxious weeds onto your land, and the unknown if you will be able to find feed that you can afford. However, since it was a dry year, it is likely that they would have been more yield if there was rain, and therefore more pounds of feed to divide the costs across, bringing the total cost per pound of additional feed down. Also, at the Parkbeg site in particular, there is additional Nitrate-N remaining in the soil that will likely cause a yield bump in the following year as well.

vii. This information has been presented at Ranch Management Forum on January 12, 2021. This was the last 15-minute presentation of the topic titled "Ranch Management Forum Forage Week: Session 2 – Rejuvenating a Perennial Forage Stand" had 177 people watch live and 184 views on the recorded webinar (as of January 26, 2021). In July, there was a social media "ADOPT update" post that featured this project in the video. We also have intentions of writing a SaskAg Now article and doing a radio interview in February to share the results of this project.

11. Conclusions and Recommendations

- From this demonstration we were able to see that fertilizing established forage stands following 4R practices (right source, rate, time, place) can lead to increased forage yields that provide a net positive economic benefit with no negative effects on feed quality. Producers that are looking to maximize productivity on their forage stands that are deficient in soil nutrients can use these results to build a fertilizer blend that will suit the yield increase they wish to achieve. Let it be noted that the exceptionally dry conditions during this trial likely lessened the difference between the untreated check to fertilized treatments, and if more precipitation was seen during the first half of the growing season there would have likely been larger differences between the bare urea and treated urea plots due to increased rates of urea hydrolysis.

- An application has been submitted to continue this project in 2021 at Moose Jaw, North Battleford/Meadow Lake, Swift Current, and Yorkton, to further expand on these results and demonstrate these practices in other soil zones and precipitation.

<u>Supporting Information</u>

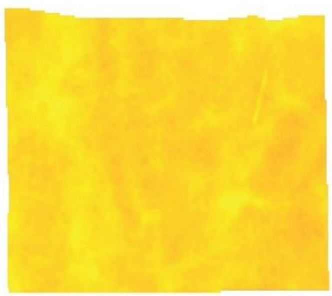
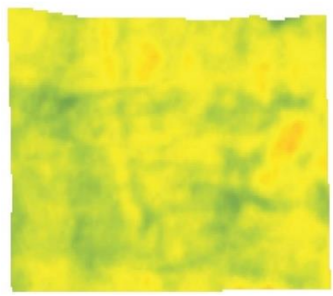
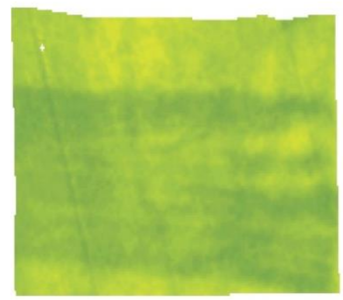
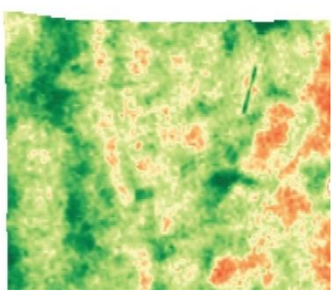
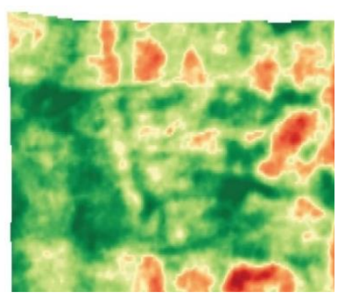
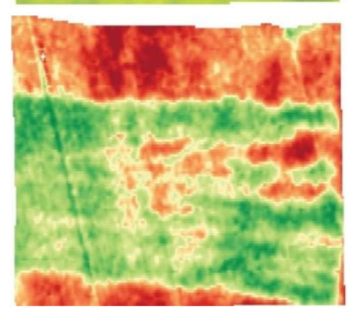
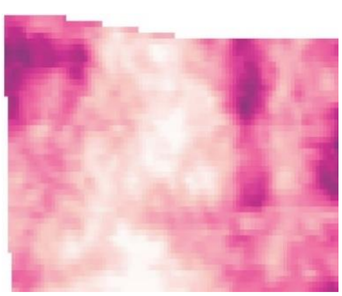
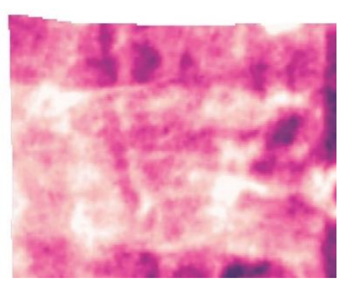
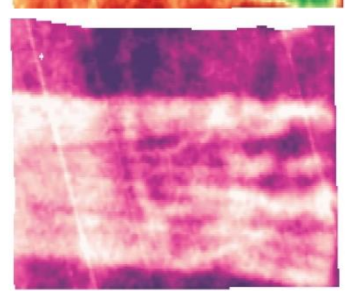
12. Acknowledgements

- We would like to acknowledge the Saskatchewan Forage Council, Shannon McArton and Chelsey Siemens, for their partnership on this project.

13. Appendices

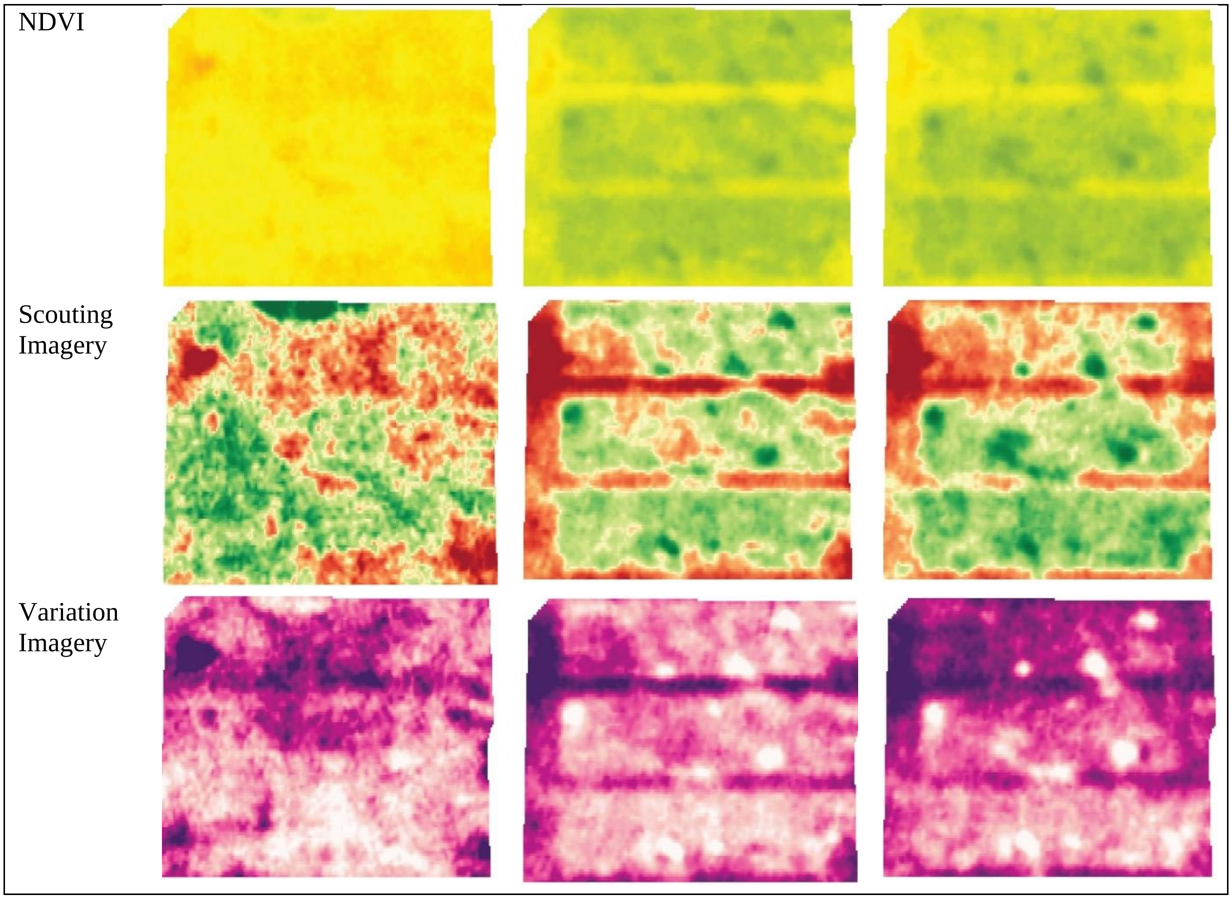
Appendix A – Satellite Imagery:

Plunkett Imagery. Treatment order (top to bottom): Control, urea, urease inhibitor, urease and denitrification inhibitor

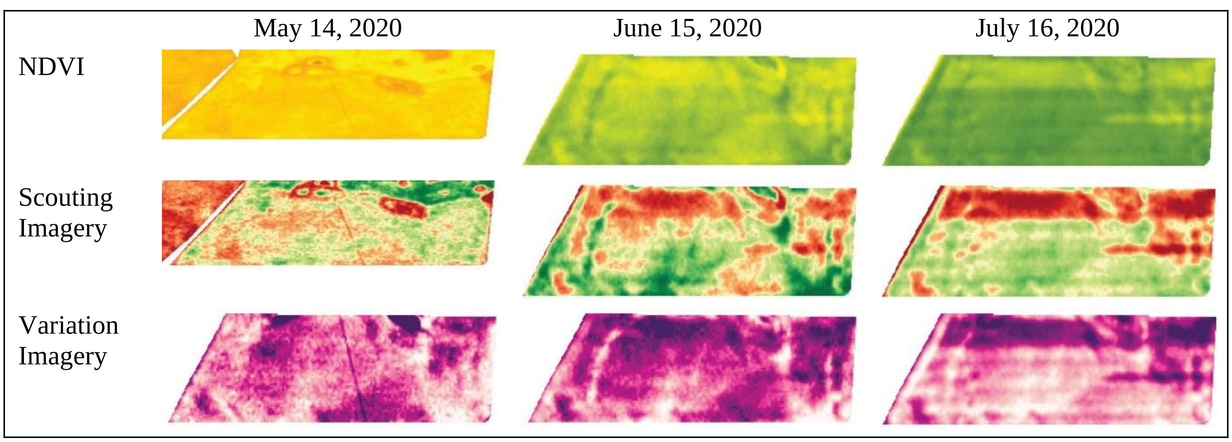
	May 30, 2020	June 22, 2020	July 14, 2020
NDVI			
Scouting Imagery			
Variation Imagery			

Outlook Imagery. Treatment order (top to bottom): Urea, polymer coated urea, sulphur enriched urea. Control is the surrounding border of the trial

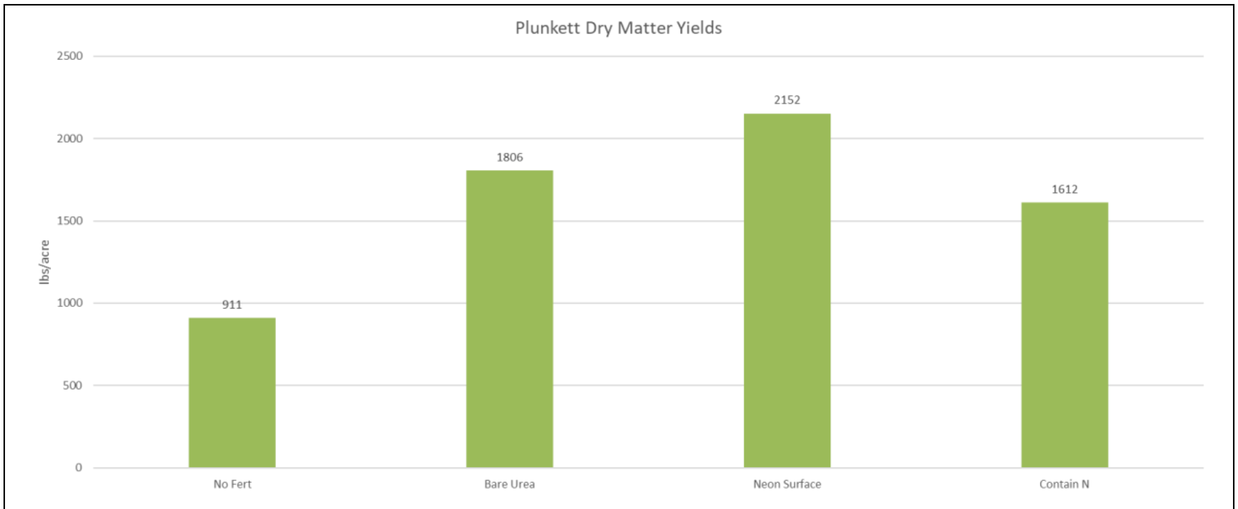
	May 7, 2020	June 22, 2020	July 16, 2020

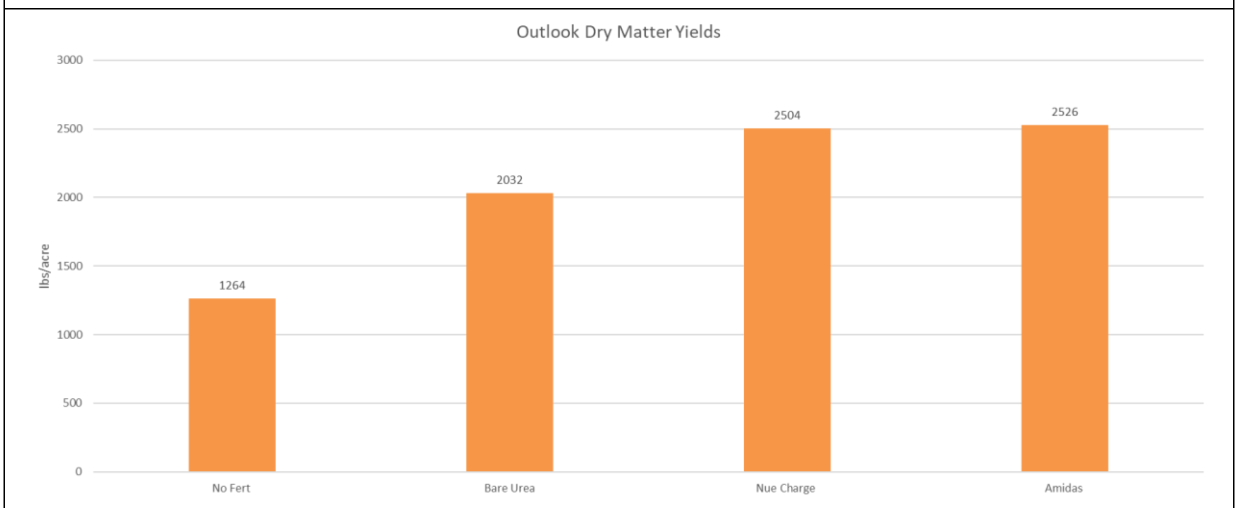


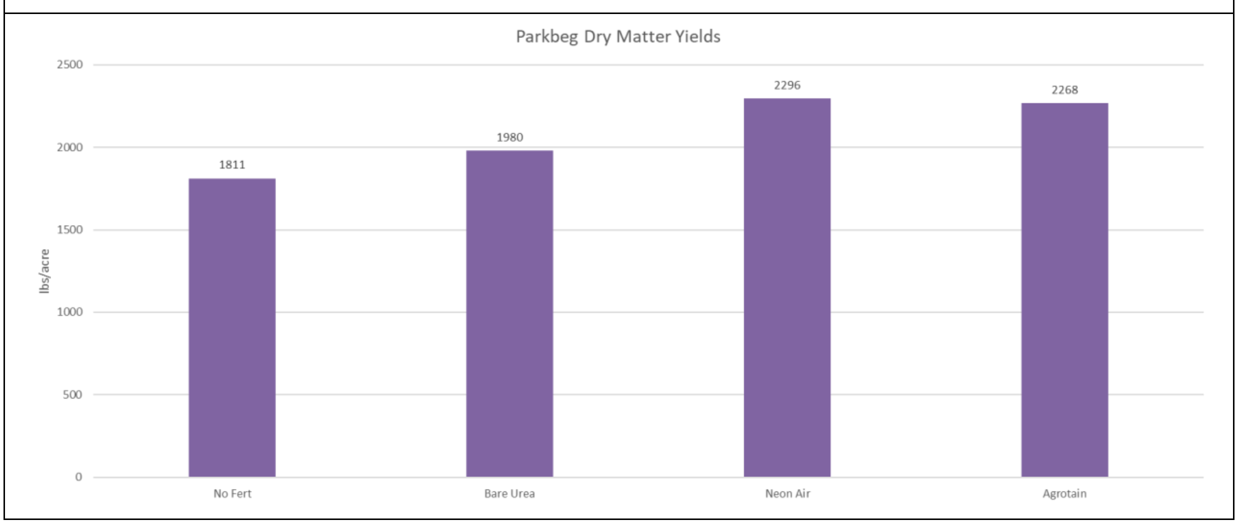
Parkbeg Imagery. Treatment order (top to bottom): Control, urea, urease and denitrification inhibitor, and urease inhibitor



Appendix B – Yield Comparison:







Appendix C – Summary of Feed Quality:

Plunkett Feed Analysis Results. All values (except dry matter) are reported in a Dry Matter basis

	Control	**Urea**	**Urease Inhibitor**	**Denitrification and Urease Inhibitor**
Dry Matter (DM) (%)	94.63	92.59	93.04	92.72
Crude Protein (CP) (%)	11.33	13.35	11.72	13.16
Acid Detergent Fiber (ADF) (%)	35.24	33.98	35.63	34.79
Neutral Detergent Fiber (NDF) (%)	54.04	49.99	53.99	52.44
Total Digestible Nutrient (TDN) (%)	61.45	62.43	61.14	61.80
Calcium (Ca) (%)	0.68	0.76	0.58	0.70
Phosphorus (P) (%)	0.14	0.15	0.14	0.15
Potassium (K) (%)	2.05	2.60	2.63	2.81
Magnesium (Mg) (%)	0.22	0.23	0.17	0.22
Sodium (Na) (%)	0.02	0.02	0.02	0.04
Sulphur (S) (%)	0.11	0.12	0.11	0.13
Copper (Cu) (µg/g)	3.97	4.45	3.82	4.57
Iron (Fe) (µg/g)	74.8	92.4	86.9	73.65
Zinc (Zn) (µg/g)	12.5	13.5	12.17	13.59
Manganese (Mn) (µg/g)	49.47	52.55	50.50	57.75

Outlook Feed Analysis Results. All values (except dry matter) are reported in a Dry Matter basis

	Control	**Urea**	**Polymer Coated Urea**	**Sulphur Enriched Urea**
Dry Matter (DM) (%)	94.53	93.62	94.52	93.99
Crude Protein (CP) (%)	7.32	7.01	7.22	8.42
Acid Detergent Fiber (ADF) (%)	35.97	37.27	36.74	37.00
Neutral Detergent Fiber (NDF) (%)	60.37	62.35	62.87	62.20
Total Digestible Nutrient (TDN) (%)	60.88	59.87	60.28	60.08
Calcium (Ca) (%)	0.35	0.36	0.36	0.40
Phosphorus (P) (%)	0.10	0.09	0.08	0.08
Potassium (K) (%)	1.63	1.84	1.75	1.67
Magnesium (Mg) (%)	0.12	0.10	0.11	0.12
Sodium (Na) (%)	0.02	0.02	0.02	0.02
Sulphur (S) (%)	0.11	0.09	0.09	0.09
Copper (Cu) (µg/g)	3.24	2.90	2.76	2.67
Iron (Fe) (µg/g)	76.55	66.70	58.40	86.25
Zinc (Zn) (µg/g)	14.06	11.33	12.44	13.54
Manganese (Mn) (µg/g)	26.63	27.10	30.30	27.66

Parkbeg Feed Analysis Results. All values (except dry matter) are reported in a Dry Matter basis

	Control	**Urea**	**Urease Inhibitor**	**Denitrification and Urease Inhibitor**
Dry Matter (DM) (%)	95.06	95.49	93.84	95.04
Crude Protein (CP) (%)	7.71	8.76	8.95	9.12
Acid Detergent Fiber (ADF) (%)	36.18	34.98	35.16	34.95
Neutral Detergent Fiber (NDF) (%)	52.56	53.49	51.02	52.85
Total Digestible Nutrient (TDN) (%)	60.72	61.65	61.51	61.67
Calcium (Ca) (%)	0.84	0.64	0.70	0.69

Phosphorus (P) (%)	0.10	0.10	0.10	0.10
Potassium (K) (%)	1.38	1.75	1.73	1.72
Magnesium (Mg) (%)	0.22	0.18	0.18	0.18
Sodium (Na) (%)	0.02	0.02	0.02	0.02
Sulphur (S) (%)	0.10	0.11	0.10	0.11
Copper (Cu) (μg/g)	4.06	4.18	4.30	3.62
Iron (Fe) (μg/g)	711.99	147.10	197.04	254.95
Zinc (Zn) (μg/g)	12.32	9.77	9.68	10.33
Manganese (Mn) (μg/g)	83.75	62.90	62.05	62.35

Appendix D – Summary of Soil Analysis

Plunkett soil test report, condensed.

	Spring (Pre-Fertilizer)	**Control**	**Urea**	**Urease Inhibitor**	**Denitrification and Urease Inhibitor**
Organic Matter (%)	3.7	4.3	4.4	4.8	4.5
Phosphorus Bicarbonate (ppm)	8	6	6	6	5
Potassium (K) (ppm)	205	249	238	269	263
Magnesium (Mg) (ppm)	558	582	638	533	618
Calcium (Ca) (ppm)	4920	3390	3490	3630	4050
pH	8.0	7.6	7.8	7.6	7.8
Sulfur (S) (ppm)	7	8	7	6	6
Nitrate Nitrogen (ppm)	1	1	3	2	2
Sodium (Na) (ppm)	14	12	8	8	10

Outlook soil test report, condensed.

	Spring (Pre-Fertilizer)	**Control**	**Urea**	**Polymer Coated Urea**	**Sulphur Enriched Urea**
Organic Matter (%)	2.1	2.5	2.4	1.8	1.7
Phosphorus Bicarbonate (ppm)	9	6	11	8	7
Potassium (K) (ppm)	252	249	296	245	221
Magnesium (Mg) (ppm)	231	297	211	214	219
Calcium (Ca) (ppm)	1420	1780	1380	1220	1430
pH	7.1	7.6	7.0	6.9	7.6
Sulfur (S) (ppm)	7	7	7	6	6
Nitrate Nitrogen (ppm)	3	2	3	1	3
Sodium (Na) (ppm)	13	7	8	4	3

Parkbeg soil test report, condensed.

	Spring (Pre-Fertilizer)	**Control**	**Urea**	**Urease Inhibitor**	**Denitrification and Urease Inhibitor**
Organic Matter (%)	3.9	3.9	4.0	4.2	4.4
Phosphorus Bicarbonate (ppm)	6	5	5	5	4
Potassium (K) (ppm)	281	305	329	356	321
Magnesium (Mg) (ppm)	497	700	549	776	625
Calcium (Ca) (ppm)	5390	6030	4780	5750	5020
pH	7.8	7.7	7.8	7.9	7.8
Sulfur (S) (ppm)	7	9	7	7	7
Nitrate Nitrogen (ppm)	2	8	8	10	8
Sodium (Na) (ppm)	21	21	13	14	12

Appendix E – Economic Analysis:

Plunkett economic analysis

	Fert	Additive	Tractor Rental	Total Costs/ac	Difference from no fertility	Cost/additional lb
Control	$0	$0	$0	$0		$0
Urea	$48.23/ac	$0	$14.00/ac	$62.23/ac	987.5 lbs	$0.06
Urease Inhibitor (ContaiN)	$48.23/ac	1.7 L total $5.44/ac	$14.00/ac	$67.67/ac	770 lbs	$0.09
Urease and Denitrification Inhibitor (Neon Surface)	$48.23/ac	1.9 L total $6.65/ac	$14.00/ac	$68.88/ac	1359 lbs	$0.05

Outlook economic analysis

	Fert	Additive	Spreading	Total Costs/ac	Difference from no fertility	Cost/additional lb
Control	$0	$0	$0	$0		$0
Urea	$62.04/ac	$0	$10.00/ac	$72.04/ac	813 lbs	$0.09
Sulphur Enriched Urea (Amidas)	$62.04/ac	$12.52/ac Product comes pre treated	$10.00/ac	$84.56/ac	1350 lbs	$0.06
Polymer Coated Urea (Nue-Charge)	$62.04/ac	1.1 L total $5.89/ac	$10.00/ac	$77.93/ac	1338 lbs	$0.06

Parkbeg economic analysis

	Fert	Additive	Spreading	Total Costs/ac	Difference from no fertility	Cost/additional lb
Control	$0	$0	$0	$0		$0
Urea	$46.62/ac	$0	$7.50/ac	$54.12/ac	168.3 lbs	$0.32
Urease Inhibitor (Agrotain)	$46.62/ac	1.9 L total $4.85/ac	$7.50/ac	$58.97/ac	511.2 lbs	$0.12
Urease and Denitrification Inhibitor (Neon Air)	$46.62/ac	1.3 L total $4.44/ac	$7.50/ac	$58.56/ac	509.9 lbs	$0.11

Abstract

14. Abstract/Summary

Rejuvenating an established forage stand with a fertilizer application instead of terminating and reseeding can prove to be an economically feasible practice. This project aimed to demonstrate that fertilizing for a yield goal of two bales per acre using 4R practices (right source, rate, time, place) with bare urea or enhanced efficiency fertilizers could increase yields and have positive economic benefit without sacrificing any nutritional quality based on a hay cost of $0.07/lb. Soil samples showed all sites were deficient in soil nutrients and fertilizer application rates targeting the two bale per acre yield goal showed yield increases in a range of 9-98% (mean 56, n=3) for bare urea and 25-136% (mean 71, n=6) with enhanced efficiency products.

Finances

15. Expenditure Statement

- Expenditure Statement included in Excel Spreadsheet.