



Aspen Ranch Crop Demonstration Site

2024 Project Report

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Project Background

The Aspen Ranch Crop Demonstration Site is a collaborative effort between Aspen Ranch Canada (James River Bridge, AB) and the Central Alberta Forage and Livestock Association. This site is designed as a location that can be used to educate producers, youth, and the public on various agricultural practices surrounding the planting, growth, and harvest of forage and cereal crops. This site serves to showcase these species in their various growth stages, at the same time, highlighting the impact these species can have on soil and microorganism health.

Objectives

For 2024, the focus of this project was to showcase the differences between traditional cereal greenfeed and a cover crop mix.

Objectives:

- Compare the dry biomass production levels between the crop types.
- Compare the nutritional characteristics of the vegetation as a feed for beef cattle.
- Compare the impacts (if any) that the different crops have on the soil profile.
- Compare the cost of production between the crop types.

Methodology:

The project site covers approximately 4.21 acres, which was split into two sections in order to facilitate easy management. The first section hosted 3 varieties of cereals (1 malt barley, 1 feed barley, and 1 oat) planted in individual plots, as well as a Covers & Co. Full Season Cover Crop Mix (Henderson Ag.) (Figure 1). This allowed for an effective, side by side comparison of total dry biomass production and vegetation nutrient content. Soil samples were also taken to compare the impact that the different crops had on the soil. To investigate the economics behind these crops, a cost of production analysis was run comparing the three varieties of cereals to the cover crop. As the north half of the site was not utilized for the 2024 season, it was left in summer fallow.

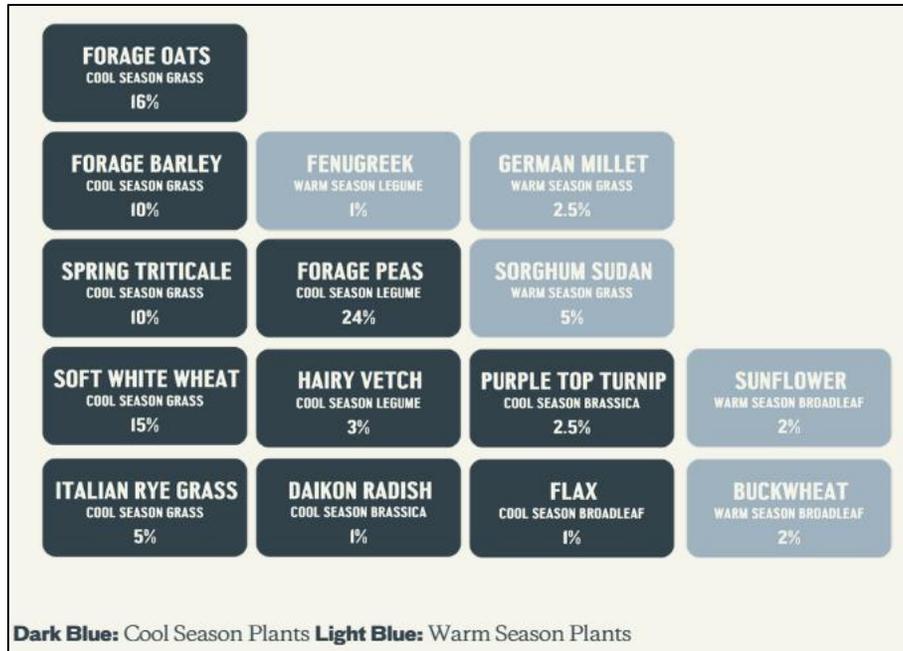


Figure 1. Covers & Co. Full Season Cover Crop Mix (Henderson Ag.) (Covers & Co. n.d.).

Plot Set-up:

Pre-seeding, the site was sprayed with a glyphosate herbicide to control excessive growth of weeds. Weedy species identified onsite consisted mainly of quack grass, dandelion, and Canada thistle. Following this, the site was disked and harrowed to prepare the seedbed for seeding.

Plots were arranged starting at the south end of the demonstration site with Plot 1 and progressing north to Plot 4 (Figure 2). Malt barley was planted in Plot 1, feed barley in Plot 2, oats in Plot 3, and the full season cover crop in Plot 4. To facilitate access to the plots, a buffer of approximately 20' was left on all sides of each plot. This buffer was disked as needed (as little as possible) throughout the year to limit weedy encroachment.

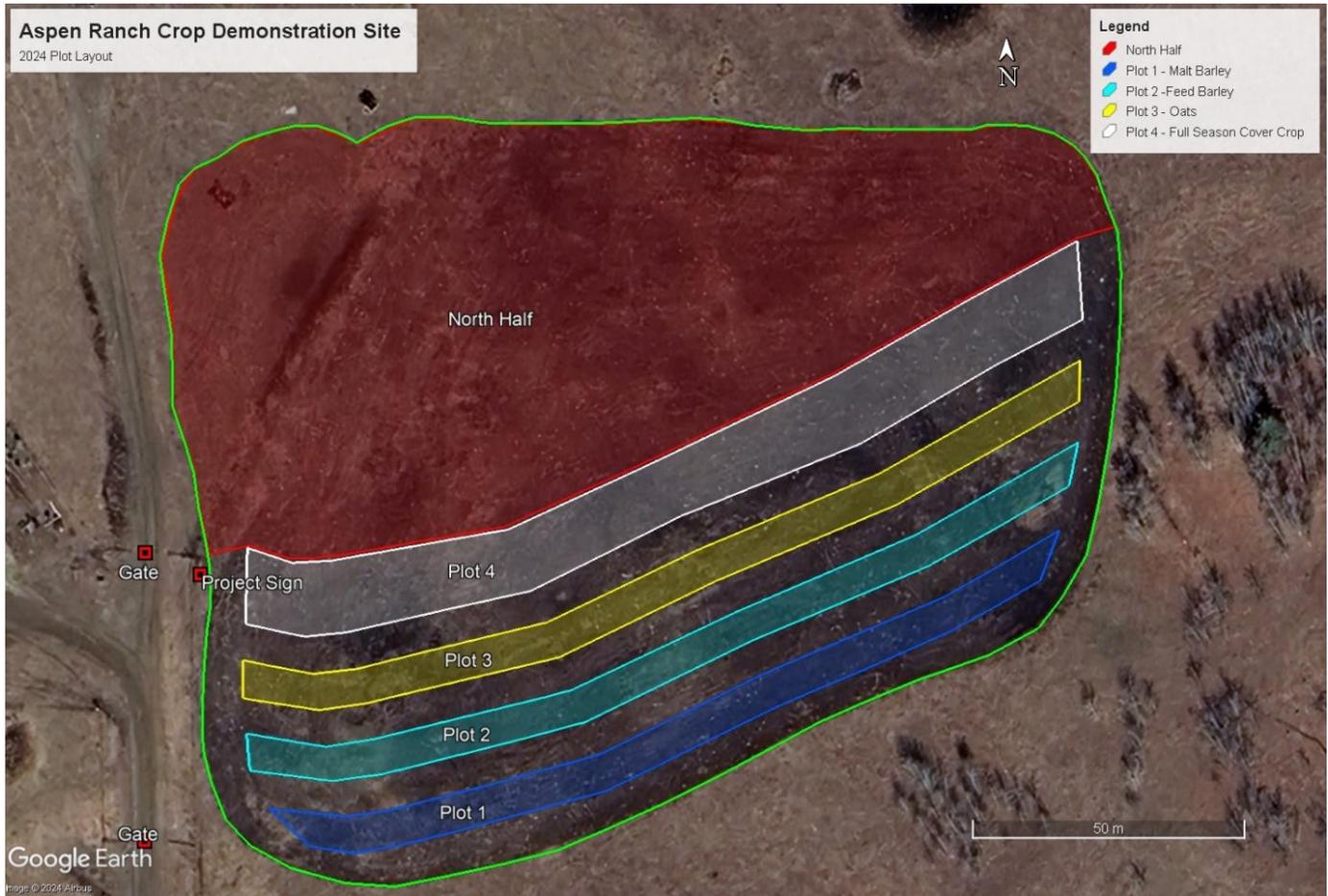


Figure 2. Aspen Ranch Crop Demonstration Plot – 2024 Plot Layout

For the 2024 season, plot size was determined by the availability of seed and the width of the available seeder. Due to constraints with the availability of seeding equipment, the plots were seeded on July 11, 2024 using a Brillion Sure-Stand 10' Grass Seeder with a cage agitator in the rear seed box. For plots 1-3 the limited volume of seed available, and the ten-foot seeder, resulted in plots that were approximately 20' wide and ran the full east-west width of the demonstration site (averaging 480' long). Plot 4 was slightly larger due to the higher volume of available seed, allowing for a plot size of 40' wide and the full east-west width of the demonstration site (averaging 480' long).

Vegetation Sampling:

For each plot, four vegetation samples were taken at peak production. To obtain each sample, hand shears were used to remove all above ground biomass within a randomly

placed 0.25m² quadrat. All clipped biomass was collected and placed in a brown paper bag labelled with the organization name/location, date, and sample ID (Plot # - Crop Type - Veg. Sample #). The wet weight of each sample was taken prior to the samples being dried; at which time the dry weight was recorded. Once dry, the samples were submitted to Blue Rock Animal Nutrition in Innisfail, AB for a BRAN nutrient analysis (package is only available through Blue Rock Animal Nutrition) (Figure 3).

BRAN Nutrient Analysis (\$55.00/sample)			
Includes	Unit	Includes	Unit
ESC (Simple Sugar)	%	Soluble Crude Protein	% of CP
pH	-	ADF-CP	%
Moisture	%	NDF-CP	%
Dry Matter	%	UIP (Bypass Protein)	Est. % of CP
Total Digestible Nutrients	%	Acid Detergent Fibre	%
Crude Protein	%	Lignin	%
Neutral Detergent Fibre	%	Starch	%
Calcium	%	Crude Fat	%
Phosphorus	%	Total Ash	%
Magnesium	%	NE Lactation	Mcal/kg
Potassium	%	NE Gain	Mcal/kg
Sulfur	%	NE Maintenance	Mcal/kg
Sodium	%	Total Digestible Nutrients (Weiss)	%
Copper	mg/kg	NE Lactation (Weiss)	Mcal/kg
Manganese	mg/kg	NE Gain (Weiss)	Mcal/kg
Zinc	mg/kg	NE Maintenance (Weiss)	Mcal/kg
Molybdenum	mg/kg	NFC	%
Iron	mg/kg		

Figure 3. Detailed overview of the BRAN Forage Nutrient Analysis from A&L Laboratories (A.A. Redman (P.Ag), personal communication, 2025).

Soil Sampling:

For baseline sampling purposes, a minimum of ten soil cores were collected pre-seeding from each half of the site. Each soil core was taken using a 0.75” diameter soil probe and divided into 0”-6” and 6”-12” depth samples. The soil cores specific to each half were combined and used to create a representative composite sample for each depth range for that half of the site. Each composite sample was placed in a separate Ziploc bag and labelled with the organization name/location, date, sample ID (N/S Half), and soil sample depth. All samples were then submitted to A&L labs through Benalto Agri Services for a Complete Analysis (Figure 4).

Complete Analysis (\$50.00/sample)	
Includes	Unit
Organic Matter	%
Bicarb P	ppm
Bray P	ppm
Potassium	ppm
Magnesium	ppm
Calcium	ppm
Sulfur	ppm
Zinc	ppm
Manganese	ppm
Iron	ppm
Copper	ppm
Boron	ppm
Sodium	ppm
Aluminium	ppm
Soil pH	-
Buffer pH	-
K/Mg Ratio	-
Nitrate	ppm
Cation Exchange Capacity	meq/100g
% Base Saturation of Cations	%
% Saturation of Phosphorus	%

Figure 4. Detailed overview of the Complete Soil Analysis from A&L Laboratories (A&L Canada Laboratories 2024).

To assess changes in the soil over the growing season, a minimum of ten soil cores were taken from each plot at the time of plot harvest. These cores were gathered using a 0.75” diameter soil probe and sampled to a depth of 6 inches. Using these cores, a representative composite sample was created for each plot. Each composite sample was placed in a separate Ziploc bag and labelled with the organization name/location, date, sample ID (Plot #), and soil sample depth. Once collected, the samples were submitted to A&L labs through Benalto Agri Services for a Complete Analysis. For the purposes of this

project, plot results were compared to the baseline report from the south half as all plots were located on the south half of the demonstration site.

Discussion of Results

Vegetation Analysis

Vegetation Biomass Comparison

As shown in Appendix A, analysis of the project results found that Plot 4 had the highest overall vegetative biomass production at 4.52 US tons DM/acre. In contrast, Plot 3 had the lowest biomass production at 3.12 US tons DM/acre. This highlights the fact that, overall, the cover crop plot trended towards a higher biomass production than did the annual cereal plots. In comparing the standard deviations, Plots 1 and 4 experienced a significant increase in biomass production compared to Plot 3. Although the results suggest that Plot 3 was the least productive plot, Plot 3 was seen to sustain extensive damage due to wildlife grazing. At the time of sampling, the oats within Plot 3 were significantly shorter than what was expected, with the plant canopy having a mown appearance. Due to this, the measured biomass value for Plot 3 is likely significantly less than the true amount of biomass grown on-site. Wildlife damage was also seen to a lesser extent in Plot 4, while Plots 1 and 2 had very little to no evidence of wildlife grazing. Overall, this means that the loss of biomass from Plots 3 and 4 must be considered when comparing the overall production values between plots. However, even if there had been no wildlife damage, Plot 4 would still be expected to have the highest production as research has shown that cover crop mixtures tend to have higher production than monocrops (Beef Cattle Research Council 2019). This is largely due to the increased diversity of species within cover crop mixes and the relationship that this has with increasing production (Martinez et al. 2024).

Vegetation Nutrient Comparison

When evaluating the nutrient content of the different crops, the levels of total digestible nutrients, crude protein, neutral detergent fibre, calcium, phosphorus, and sulfur were identified as critical to evaluate the quality of forage produced (A.A. Redman (P.Ag), personal communication, 2025). To compare the recorded levels of each nutrient between plots, a Kruskal-Wallis Test with Pairwise Comparison was run.

The level of total digestible nutrients, or %TDN, was used to evaluate the energy content of the feed. This was based on the digestible fibre, fat, protein, and carbohydrate content of the forage samples (Montana State University n.d.; Van Emon et al. 2016). In comparison, samples with a higher %TDN are considered to be a higher quality forage and thus a higher %TDN is more desirable (A.A. Redman (P.Ag), personal communication, 2025). For beef cows the requirement for %TDN ranges from 50% to 86%, while the range for growing calves stretches from 54% to 83% (Lalman and Holder n.d.). These levels differ based on the age, gender, weight, and life stage of the animal (Lalman and Holder n.d.). For this study, Plot 3 was found to have the highest %TDN at 63.84%, while Plot 1 had the lowest at 60.73% (Table 1). This suggests that the oat greenfeed crop had a higher energy content and was a higher quality feed compared to the other plots, however, statistical analysis showed that the difference between the plots was not significant. This means that, although there were variances between the plots, the differences were likely caused by random chance and not because of differences in the quality of the crops (Gallo 2016).

Table 1. Percent content of total digestible nutrients (%TDN) within vegetation samples per plot.

	Plot 1	Plot 2	Plot 3	Plot 4
Median (%)	60.73	61.43	63.84	63.62
Rank Sum	21.00	25.00	47.00	43.00
Count	4	4	4	4
Average Rank	5.25	6.25	11.75	10.75

Concerning the crude protein content, requirements for beef cows vary from 7% to 12% depending on their gestation stage or if they are post-calving (Government of Manitoba (1) n.d.). For calves, 10% to 14% crude protein is considered sufficient in relation to their body weight (Government of Manitoba (1) n.d.). As a result, with crude protein levels ranging from 15.69% (Plot 3) to 12.20% (Plot 1), all four plots were seen to meet or exceed the crude protein requirements for beef cattle (Table 2). Similar to the %TDN, although Plot 3 had the highest crude protein content, no significant difference between the plots was identified. Therefore, it is assumed that the crude protein content across the plots is relatively similar, with no crop type having a discernible advantage.

Table 2. Percent content of crude protein within vegetation samples per plot.

	Plot 1	Plot 2	Plot 3	Plot 4
Median (%)	12.20	15.48	15.69	14.79
Rank Sum	14.00	44.00	47.00	31.00
Count	4	4	4	4
Average Rank	3.50	11.00	11.75	7.75

Neutral detergent fibre, or NDF, is the proportion of cellulose, hemicellulose, and lignin that makes up part of the fibre content of forages (Montana State University 2012). This helps to determine the bulk and quality of the forage, thus a forage low in %NDF has a lower percentage of these fibre types and is higher in quality and less bulky than one which is high in %NDF (Montana State University 2012). Ideally, the %NDF of a forage will be below 60% (A.A. Redman (P.Ag), personal communication, 2025). Although Table 3 shows that all plots fall below 60% NDF, Plot 3 was seen to have the lowest %NDF at 49.27%. However, in the case of this project, all the plots were seen to be alike in their %NDF values as no significant difference was noted. This result suggests that the studied crops all have a similar fibre content but does not guarantee the same level of NDF digestibility between plots (Government of Manitoba 2003).

Table 3. Percent content of neutral detergent fibre (%NDF) within vegetation samples per plot.

	Plot 1	Plot 2	Plot 3	Plot 4
Median (%)	53.75	54.50	49.27	50.26
Rank Sum	42.00	47.00	18.00	29.00
Count	4	4	4	4
Average Rank	10.50	11.75	4.50	7.25

Regarding the mineral content of the vegetation, the requirements for calcium in beef cattle range from 0.16% to 0.89%, while phosphorus ranges from 0.12% to 0.40% (Gadberry 2018). Within these ranges, the individual requirements of an animal are influenced by the age, gender, weight, and life stage of the animal (Gadberry 2018). As shown in Tables 4 and 5, all plots fall within the acceptable range of percent mineral content. Upon statistical analysis, a significant difference was identified between the calcium content of Plots 3 and 4. This suggests that the full season cover crop contained a noticeably higher amount of calcium than did the oats in Plot 3. This is likely as a result of the root structure of the cover crop being better able to scavenge for nutrients found deeper in the soil, bringing them up

and incorporating them into the plant tissue (Delta Farmland & Wildlife Trust 2023). No other significant differences were found between the plots.

Table 4. Percent content of calcium within vegetation samples per plot.

	Plot 1	Plot 2	Plot 3	Plot 4
Median (%)	0.50	0.55	0.45	0.86
Rank Sum	28.50	41.00	13.50	53.00
Count	4	4	4	4
Average Rank	7.13	10.25	3.38	13.25

Table 5. Percent content of phosphorus within vegetation samples per plot.

	Plot 1	Plot 2	Plot 3	Plot 4
Median (%)	0.28	0.27	0.32	0.29
Rank Sum	27.00	27.00	45.50	36.50
Count	4	4	4	4
Average Rank	6.75	6.75	11.38	9.13

For beef ration formulation, calcium and phosphorus must not only meet the mineral requirements but must also be in a ratio of between 1.5 to 7 Ca:P, with the ideal value being around 2 (A.A. Redman (P.Ag), personal communication, 2025). As shown in Table 6, all the plots meet this threshold with the exception of Plot 3. As a result, feed from Plot 3 would require additional calcium supplementation to meet the nutritional requirements of beef cattle (A.A. Redman (P.Ag), personal communication, 2025).

Table 6. Calcium to phosphorus ratio within vegetation samples per plot.

	Plot 1	Plot 2	Plot 3	Plot 4
Ca:P Ratio	1.79	2.04	1.41	3.00

In comparing sulfur, no notable differences were found, although levels ranged from 0.11% in Plot 1 to 0.16% in Plot 2. Certain crops, especially certain cover crop mixes, can be prone to accumulating sulfur and thus pose a danger for polio in beef cattle (A.A. Redman (P.Ag), personal communication, 2025). The results of this project suggest that this is not a high

risk for the forages which were studied as the sulfur content of all the plots fell well below the threshold risk value of 0.40% sulfur (Gadberry 2018).

Table 7. Percent content of sulfur within vegetation samples per plot.

	Plot 1	Plot 2	Plot 3	Plot 4
Median (%)	0.11	0.16	0.14	0.15
Rank Sum	18.00	44.50	36.50	37.00
Count	4	4	4	4
Average Rank	4.50	11.13	9.13	9.25

Soil Analysis

As detailed in Table 8, the baseline soil organic matter content of the site was found to be 5.7%. When comparing the plot results to this value, Plots 2, 3, and 4 were seen to increase in soil organic matter, while Plot 1 experienced a slight reduction. Of the plots that increased in organic matter, Plot 4 had the highest percentage at 6.5%. This suggests that growing the full season cover crop (Plot 4) is the best strategy to maximize the organic matter content of the soil. However, all four plots have sufficient organic matter and are within the ideal 4% to 12% range that allows for the efficient and steady release of nutrients (D. Knopp (P.Ag), personal communication, 2025).

Table 8. Percent soil organic matter per plot.

	Plot 1	Plot 2	Plot 3	Plot 4
Baseline: Soil Organic Matter (%)	5.7	5.7	5.7	5.7
Year-end Sampling: Soil Organic Matter (%)	4.9	5.8	6.3	6.5

In comparing the pH across the site, Plots 1, 2, and 3 experienced a decrease in pH from the baseline of 7.1 (Table 9). Plot 4, however, increased to a pH value of 7.3. For most crops in Western Canada, a pH of between 6.3 to 6.8 is ideal (D. Knopp (P.Ag), personal communication, 2025). Using this range, Table 9 shows that Plots 1 and 2 have an ideal pH, while Plots 3 and 4 exceed the upper limit. Although Plots 3 and 4 are more basic than is ideal, soil with a pH of 7 to 7.5 will have little observable effect on the overall performance

of the crop (D. Knopp (P.Ag), personal communication, 2025). Overall, this suggests that the pH of the plots provided a good base to promote the success of the various crops.

Table 9. Soil pH per plot.

	Plot 1	Plot 2	Plot 3	Plot 4
Baseline: pH	7.1	7.1	7.1	7.1
Year-end Sampling: pH	6.4	6.8	7.0	7.3

Although the nitrate nitrogen content of the plots was seen to be moderate to low throughout the trial, the estimated nitrogen release, or ENR values, were higher relative to the concentration in the soil. This is detailed in Table 10. The ENR values, being closely linked to the organic matter content, represent the amount of nitrogen that is estimated to be released from the soil organic matter within a year (A&L Canada Laboratories n.d.; D. Knopp (P.Ag), personal communication, 2025). As a result, although the nitrogen concentration was low, the soil across the plots has a high potential to release nitrogen throughout the growing season (D. Knopp (P.Ag), personal communication, 2025). However, given the location of this trial (west of HWY 2), the adjusted ENR values are likely a better approximation of the potential nitrogen release as they take into account the influence of the local climate and growing season length (D. Knopp (P.Ag), personal communication, 2025). When considering the differences in nitrogen concentration between the baseline and later season values, the lower values at the end of the growing season are likely as a result of the uptake of the available nitrogen by plants as they grow (D. Knopp (P.Ag), personal communication, 2025). Overall, Plot 4 had the highest adjusted ENR value at 65 lbs/acre. This suggests that the full season cover crop (Plot 4) was the best method to maximize the nitrogen cycling and thus nitrogen release in the soil.

Table 10. Soil nitrogen content (ppm) and estimated nitrogen release (ENR)(lbs/acre) per plot.

	Plot 1	Plot 2	Plot 3	Plot 4
Baseline: Nitrate Nitrogen (ppm)	15	15	15	15
Baseline: ENR (lbs/acre)	70	70	70	70
Baseline: Adjusted ENR (% OM*10) (lbs/acre)	57	57	57	57
Year-end Sampling: Nitrate Nitrogen (ppm)	4	10	8	9
Year-end Sampling: ENR (lbs/acre)	62	71	76	78
Year-end Sampling: Adjusted ENR (% OM*10) (lbs/acre)	49	58	63	65

Regarding the concentration of phosphorus in the soil, the baseline sample indicated that at the beginning of the year the phosphorus concentration was at an acceptable level (Table 11) (D. Knopp (P.Ag), personal communication, 2025). Post growing season, however, the phosphorus concentrations varied from moderate (Plot 1) to good (Plot 2) to very high (Plots 3 and 4) (D. Knopp (P.Ag), personal communication, 2025). Given the soil conditions, the ideal percent saturation of phosphorus ranges from 7% to 9% (CEC: 14-17) (A&L Canada Laboratories 2024). As a result, Plot 3 was seen to have a low %P, Plot 2 maintained an acceptable %P, and Plots 3 and 4 had a very high %P. This suggests that the feed barley (Plot 2) was the best crop to maintain the ideal concentration of phosphorus in the soil.

Table 11. Soil phosphorus content (ppm) and percent saturation of phosphorus (%P) per plot.

	Plot 1	Plot 2	Plot 3	Plot 4
Baseline: Phosphorus (ppm)	39	39	39	39
Baseline: %P	8	8	8	8
Year-end Sampling: Phosphorus (ppm)	20	35	63	72
Year-end Sampling: %P	3	7	14	16

Tables 12 and 13 show the levels of potassium and sulfur across the plots. While the potassium concentration was seen to remain high to very high throughout the trial, the sulfur content remained very low (D. Knopp (P.Ag), personal communication, 2025). Although the concentration of potassium was high across the plots, the base saturation of

potassium for both Plots 1 and 2 was found to be within the ideal 3% to 7% range that ensures enough potassium is available for plant uptake (A&L Canada Laboratories 2024; D. Knopp (P.Ag), personal communication, 2025). Plots 3 and 4, however, were just outside the upper limit, with recorded values of 7.1% and 7.6% respectively. This suggests that Plots 1 and 2 are better for maintaining an appropriate base saturation of potassium. The sulfur content across the plots, although the results show that it is very low, is likely sufficient and the artificially low test values are because of the shallow sampling depth (6”) not accurately representing the true availability of sulfur (Government of Manitoba (2) n.d.). As sulfur is very mobile in the soil, samples would have to be taken to 24” to cover a larger area of the soil profile and gather more data on the concentration of sulfur within a larger area of the rooting zone (D. Knopp (P.Ag), personal communication, 2025; Government of Manitoba (2) n.d.).

Table 12. Soil potassium content (ppm) and base saturation of potassium (%K) per plot.

	Plot 1	Plot 2	Plot 3	Plot 4
Baseline: Potassium (ppm)	364	364	364	364
Baseline: %K	4.9	4.9	4.9	4.9
Year-end Sampling: Potassium (ppm)	207	270	520	512
Year-end Sampling: %K	3.3	3.9	7.1	7.6

Table 13. Soil sulfur content (ppm) per plot.

	Plot 1	Plot 2	Plot 3	Plot 4
Baseline: Sulfur (ppm)	9	9	9	9
Year-end Sampling: Sulfur (ppm)	6	8	8	8

Cost of Production Analysis

Using 2024 prices, Table 14 highlights the approximate cost of production for each crop type covered in this project. For the purposes of this comparison, the fertilizer cost was estimated using standard blends targeted for forage production. As Table 14 details, an advantage of the full season cover crop is the ability to seed without the need for fertilizer (Covers & Co. n.d.). This helps to lower the cost per acre, resulting in the full season cover

crop with no fertilizer being the cheapest option of the crops studied. In addition, the full season cover crop has a greater ability to regrow after being harvested, thus allowing for late season grazing and further increasing the return on investment (Covers & Co. n.d.).

Table 14. Estimated cost of production per crop type (Covers & Co. n.d.; D. Knopp (P.Ag), personal communication, 2025; Olds Seed Processing Co-op Ltd., personal communication, 2025).

	Malt Barley	Feed Barley	Oats	Full Season Cover Crop (w/ fert.)	Full Season Cover Crop (no fert.)
Seed Cost (\$/acre)	\$29.30	\$29.30	\$24.00	\$88.00	\$88.00
Fertilizer Cost (\$/acre)	\$75.00	\$75.00	\$65.00	\$34.00	\$0.00
Total Cost of Production (\$/acre)	\$104.30	\$104.30	\$89.00	\$122.00	\$88.00

Conclusion

Overall, although all of the studied crops work well for forage production, the full season cover crop (Plot 4) was seen to outperform the other crop types. Not only did Plot 4 produce the most vegetation, but the full season cover crop was also the equal of the other plots in terms of forage quality, while being the cheapest to produce. As per this study, for producers looking to minimize input costs and maximize production of a quality cattle forage, it is recommended that the full season cover crop mix be utilized. Ultimately, as all of the plots were successful, the decision on which species to select belongs to the producer.

Appendices

Appendix A – Aboveground Biomass Analysis

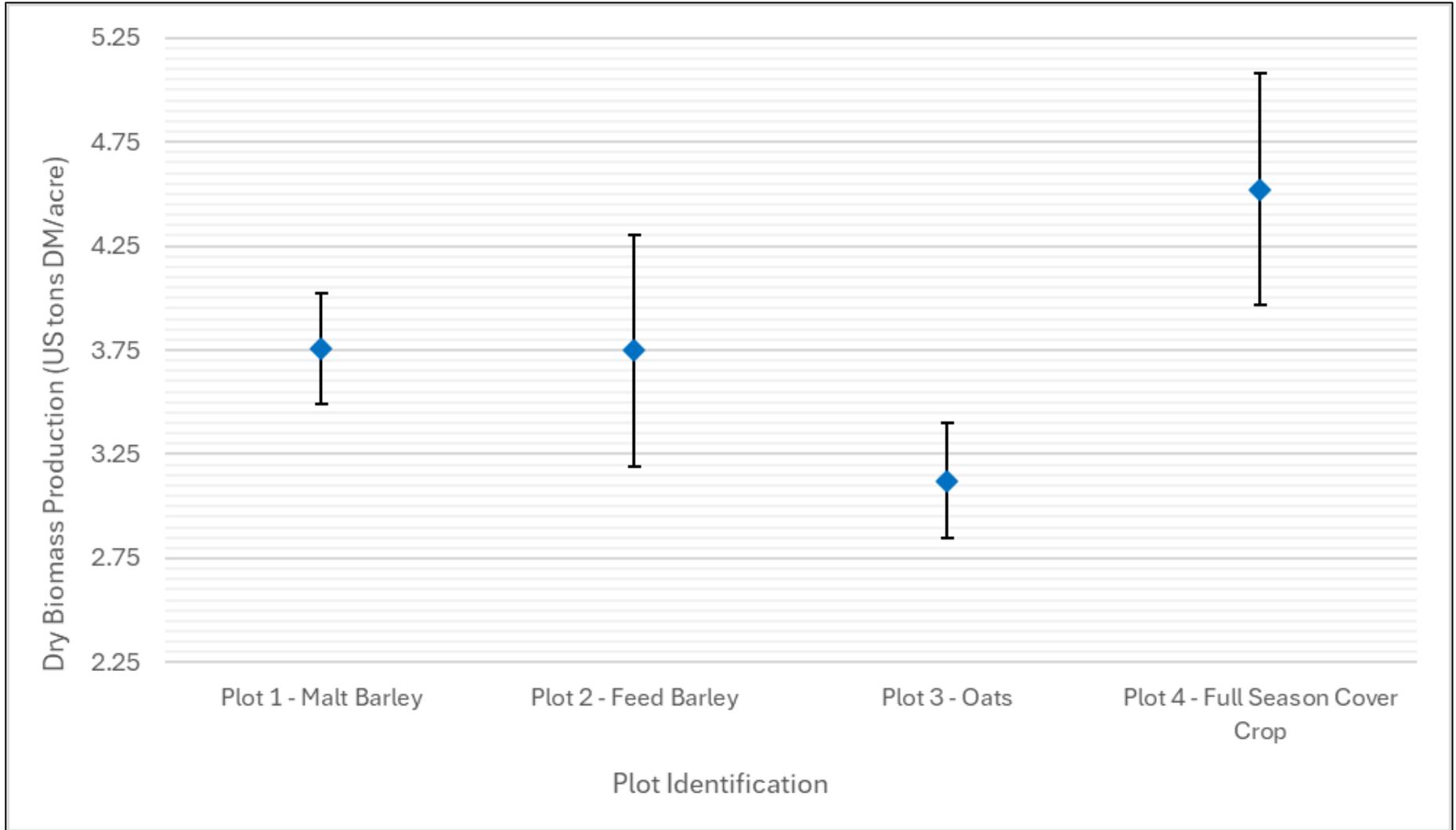


Figure A1. Annual dry biomass production of various forages (aboveground biomass).

References

- A&L Canada Laboratories. (n.d.) Soil analysis reference guide. Available from A&L Canada Laboratories: chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.alcanada.com/pdf/technical/fertilizer/Soil_Analysis_Guide.pdf [accessed 7 March 2025].
- A&L Canada Laboratories. 2024. Understanding your A&L soil test report. Available from A&L Canada Laboratories: https://www.alonline.alcanada.com/understanding-soil-test-report [accessed 7 March 2025].
- Beef Cattle Research Council. 2019. Cover crops are a balance between reward and risk. Available from the Beef Cattle Research Council: https://www.beefresearch.ca/blog/cover-crops-are-a-balance-between-reward-and-risk/ [accessed 2 April 2025].
- Covers & Co. (n.d.) Full season cover. Available from Covers & Co.: https://www.coversandco.ca/full-season-cover [accessed 2 April 2025].
- Delta Farmland & Wildlife Trust. 2023. Practical benefits of cover crops. Available from the Delta Farmland & Wildlife Trust: https://deltafarmland.ca/practical-benefits-of-cover-crops/#:~:text=By%20planting%20a%20cover%20crop,the%20upper%20layers%20of%20soil. [accessed 2 April 2025].
- Gadberry, S. 2018. Beef cattle nutrition series part 3: nutrient requirement tables. Available from the University of Arkansas Division of Agriculture - Research and Extension: chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.uaex.uada.edu/publications/pdf/MP391.pdf [accessed 25 March 2025].

Gallo, A. 2016. A refresher on statistical significance. Available from Harvard Business Review: <https://hbr.org/2016/02/a-refresher-on-statistical-significance> [accessed 2 April 2025].

Government of Manitoba. 2003. NDF digestibilities: a new analysis to evaluate forage quality. Available from the Government of Manitoba: <https://www.gov.mb.ca/agriculture/livestock/dairy/ndf-digestibilities-a-new-analysis.html> [accessed 2 April 2025].

Government of Manitoba (1). (n.d.) Ration balancing checklist for cattle. Available from the Government of Manitoba: <https://www.gov.mb.ca/agriculture/livestock/beef/ration-balancing-checklist-for-cattle.html> [accessed 2 April 2025].

Government of Manitoba (2). (n.d.) Soil fertility guide. Available from the Government of Manitoba: <https://www.gov.mb.ca/agriculture/crops/soil-fertility/soil-fertility-guide/sulphur.html> [accessed 7 March 2025].

Lalman, D., and A, Holder. (n.d.) Nutrient requirements of beef cattle. Available from Oklahoma State University: <chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://extension.okstate.edu/fact-sheets/print-publications/e/nutrient-requirements-of-beef-cattle-e-974.pdf> [accessed 2 April 2025].

Martinez, D.A., A. Gathorne-Hardy, and B.M. Smith. 2024. Impacts of polycultural cropping on crop yields and biodiversity: a systematic map protocol. *Ecological Solutions and Evidence* 5(3). doi: <https://doi.org/10.1002/2688-8319.12349>

Montana State University. (n.d.) Feed sampling and analysis. Available from the Montana State University: <chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/http://animalrange.montana.edu/documents/courses/ANSC320/Feedsamplinganalysisishandout.pdf> [accessed 7 March 2025].

Montana State University. 2012. Nutritional definitions. Available from the Montana State University: chrome-extension://efaidnbnmnnibpcajpcglclefindmkaj/https://agr.mt.gov/_docs/analytical/ab-docs/ForageNutritionalDefinitions.pdf [accessed 7 March 2025].

Van Emon, M. 2016. Forage analysis interpretation. Available from the Montana State University Extension: [https://apps.msueextension.org/montguide/guide.html?sku=MT201609AG#:~:text=Nutral%20Detergent%20Fiber%20\(NDF\),forage%2C%20dry%20matter%20intake%20decreases](https://apps.msueextension.org/montguide/guide.html?sku=MT201609AG#:~:text=Nutral%20Detergent%20Fiber%20(NDF),forage%2C%20dry%20matter%20intake%20decreases) [accessed 7 March 2025].