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Date: April 9, 2019
Humboldt, Saskatchewan

Final Report

Defining Agronomic Practices for Forage Corn Production in Saskatchewan

For:
Agriculture Development Fund
Saskatchewan Cattleman's Association

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Defining Agronomic Practices for Forage Corn Production in Saskatchewan

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1. Executive Summary

Forage corn may be an economical and high-quality alternative for winter feeding in Saskatchewan, but the cost of corn production is high compared to other forage crops. To maximize the economic potential of forage corn for feeding, input costs, such as seed and fertilizer, need to be minimized. The existing recommendations for nitrogen application rate and seeding rate for forage corn are based on grain corn production; therefore, the objectives of this project were to develop and refine seeding and fertility recommendations for corn silage production and to evaluate the cost of production and feed quality of corn silage grown in Saskatchewan.

The study took place at six sites over three growing seasons (2016, 2017, and 2018); Lanigan, Melfort, and Scott were considered short-season sites, while Yorkton, Redvers, and Outlook were considered long-season sites. Two brands were compared and hybrids were selected for each site based on the regional corn heat unit (CHU) rating; treatments included three target seeding rates and three nitrogen application rates. Biomass yield was measured for each plot and subsamples were collected for forage quality analysis. Cost of production was calculated to determine which combination of seeding rate and nitrogen rate was most economical.

All but five site-years experienced sufficient CHU for corn silage production, indicating that hybrid selection based on existing CHU maps is appropriate. Low precipitation amounts in 2017 and 2018 may have impacted biomass yield at several sites. The emergence counts for the low seeding rate treatment resulted in the lowest deviation from the target rate, indicating that less competition may result in a higher germination rate. Plant populations were comparable between both seed brands.

The site-year and ‘site-year x brand’ interactions were significant for dry matter (DM) yield; however, brand alone did not cause a significant effect on DM yield. There was a significant effect of N-fertilizer rate at only two of the site-years, and seeding rate only had a significant effect when averaged over all site-years.

Nitrogen fertilizer rate had a significant effect on forage quality, particularly crude protein (CP); however, current N-fertilizer rate recommendations for corn silage production in Saskatchewan are adequate. Increasing the seeding rate resulted in lower CP concentration. Total Digestible Nutrients (TDN) was not affected by N-rate or seeding rate; mineral concentrations for all treatments were suitable for beef-cow wintering diets.

The cost of production for the short-season sights was lowest (\$107/t DM) for the low seeding rate and low nitrogen rate treatments; however, at the long-season sites, it was

economically viable to increase the N-rates as the low seeding rate and the high nitrogen rate resulted in the lowest cost per tonne ($120/t DM).

2. Introduction

Corn production in Saskatchewan is gaining popularity due to its high feed quality for cattle production. The agronomic recommendations for corn production in Saskatchewan are based on field trials conducted before hybrids were developed for the corn heat units (CHUs) typically experienced in Saskatchewan. Since the input costs for corn production are more than double those for barley or oats (2015 Crop Production Guide), more refined recommendations for seeding and fertility rates are required to maximize profitability. In addition, a detailed economic analysis of the cost of production and an analysis of the feed value of the product are required to facilitate management decisions regarding feedstocks and feeding practices.

Grain corn production research is on-going in Manitoba with the goal of capitalizing on opportunities for expanded and more efficient corn production in the province. The Manitoba Corn Growers' Association (MCGA) is funding a variety of projects involving crop rotations, residue management, corn row spacing, and an evaluation of the CHU model for Western Canada. The MCGA previously assessed row spacing, plant populations (ranging from 70,000 to 99,000 plants per hectare or 28,340 to 40,000 plants per acre), variable-rate seeding and fertilization, fungicides, and nutrient uptake and removal for grain corn production.

There is also some preliminary work on the value of corn for winter grazing of cattle. With funding from the Alberta Livestock and Meat Agency (ALMA) and Agriculture Development Fund (ADF), the Western Beef Development Centre (WBDC) is evaluating the potential of corn grazing to reduce winter feeding costs. The study is comparing grazing of whole corn plants to grazing swathed barley and feeding barley hay in pens. These trials (the third and final year's trial was completed this past winter) included an assessment of the biomass quality for three low-heat unit hybrids of corn in Alberta and Saskatchewan. However, this on-going study is not systematically evaluating the effect of seeding or fertility rate on forage yield and quality.

Most of the studies that evaluated agronomics of corn production in Canada were conducted in the late 1970s and early 1980s, and recommendations for plant density seem to vary based on location and study. For example, Fairey (1982) recommended a planting density of 100,000 plants per ha (40,500 plants per acre) using 75 cm (30 in) row spacing in British Columbia, while Daynard and Muldoon (1981) concluded that a density of 63,000 plants per ha (25,500 plants per acre) using 75 cm (30 in) row spacing resulted in the highest dry matter (DM) yield in Ontario. Fairey's (1982) study varied the plant densities from 75,000 to 100,000 plants per ha (30,300 to 40,500 plants per acre), while Daynard and Muldoon's (1981) study varied the densities from 50,000 to 92,000 plants per ha (20,250 to 37,250 plants per acre).

Fairey's (1982) study also evaluated the effect of hybrid selection (early, medium, and late) on forage and grain yield as well as forage quality. The CHU rating of the sites used for this study was approximately 2,500 CHU (based on 2014 data), and the hybrids used included early (up to 2,500 CHU), medium (2,500 to 2,750 CHU), and late (2,500 to 3,000 CHU). They concluded that it may be beneficial to use later-maturing hybrids compared to those normally adopted for grain production. In contrast, data from Yu (2014) showed that cultivars that reached target CHU were found to be optimal in nutrient and energy for cattle feeding.

More recently, Baron et al. (2006) evaluated the influence of population density, row spacing, and hybrid selection on forage yield at two sites in Alberta. They concluded that population density had a greater impact on whole-plant yield than row spacing and hybrid choice. They evaluated three different densities (75,000, 100,000, and 125,000 plants per ha or 30,350, 40,500 and 50,500 plants per acre) with two row spacings (76 cm and 38 cm or 30 and 15 in). Both hybrids were selected based on the corn heat unit rating for the area (2,000 CHU). Generally, yield leveled off with 100,000 plants per ha (40,500 plants per acre) yielding 12 tonnes per ha (5.4 tons per acre). The treatment effects on forage quality were minimal. The authors concluded that narrow rows did not adversely affect forage yield and may be used to accommodate traditional planting equipment, and producers should target a plant density of approximately 100,000 plants per ha (40,500 plants per acre).

While these studies form a baseline of knowledge for corn forage production in cooler climates, critical information for cost-effective production is lacking. For example, none of these studies evaluated the effect of nutrient application, nor did they address economic trade-offs or the cost of production versus the feeding value of the forage produced.

Cox and Cherney (2001) did evaluate nitrogen effects on forage yield and quality in addition to row spacing, hybrid, and plant density. The authors also included an economic analysis of the return on switching from 76 cm (30 in) row spacing to 38 cm (15 in) row spacing for corn production. Cox and Cherney (2001) concluded maximum economic yields occurred at about 97,600 plants per ha (39,500 plants per acre) and reported that maximum yields were achieved at a nitrogen (N) rate of 150 kg per ha (133 lb per acre). However, this study was conducted in the United States with hybrids adapted to longer growing seasons.

In fact, much of the agronomic information provided to Canadian producers from seed companies, such as Dupont/Pioneer and Dekalb/Monsanto, is based on studies conducted in areas with longer growing seasons or is not specific to forage production (Dupont, no date; Dekalb, no date). For example, Monsanto/Dekalb's Canadian website offers information on planting considerations in Western Canada (but discusses grain corn production only), how to deal with a wet spring (data from Ohio), planting delays and hybrid selection (data from Indiana), planting date (data from Iowa, Pennsylvania, and Ontario), impact of frost (data from Indiana and Iowa), and effect of growing season on corn silage quality (data from Wisconsin). DuPont/Pioneer's factsheet on corn production for Western Canada contains some basic agronomy information including seeding depth, spacing based on row width and target population, soil temperature at seeding, weed control, etc. However, neither the factsheet nor their website has information on the effect of plant population or nitrogen rate on silage yield. On the topic of seeding rate for silage corn versus grain corn, Monsanto/Dekalb's website states that "when planting for silage or grazing corn, you should use a seeding rate with higher populations to maximize forage yield while maintaining forage quality." This recommendation agrees with research conducted in Western Canada (Baron et al., 2006; Baron et al., 2008), but it is not nearly specific enough to help producers wishing to grow corn for forage.

The previous and on-going research has either focused on grain corn production or has lacked an assessment of the impact of input parameters on feed quality. There is a need for a science-based evaluation of the effect of varying seeding and fertility rates on corn biomass yield and feed quality for both silage production and winter grazing standing corn in Western Canada. Optimizing these inputs will help minimize the cost of production and improve the economic viability of corn production for feeding cattle. Corn production offers an alternative to both crop and livestock producers, which in turn reduces overall production risks.

2.1 Research Objectives

The research objectives of this project are to

1. develop and refine seeding and fertility recommendations for corn silage production; and
2. evaluate the cost of production and feed quality of corn silage grown in Western Canada.

3. Materials and Methods

Information on the experimental design, site selection and preparation, planting, and harvesting methods are outlined in the following section.

3.1 Experimental Design

To properly evaluate the effect of seeding rate and nitrogen application rate on forage corn production in Saskatchewan, the project involves six sites and three growing seasons (2016, 2017, and 2018). The six sites were selected to represent the range of CHU zones in Saskatchewan where forage corn production may be viable. Five of the six sites were located at and managed by existing agricultural research farms (Agri-ARM), and one site was located near Lanigan and managed by Prairie Agricultural Machinery Institute (PAMI).

At each site, two corn brands were planted (Brand A and Brand B). The hybrids within each brand were selected by representatives from the seed companies and were based on the CHU rating at each location. The hybrids used for the 2018 trial were the same for each site as in 2017. In 2017, the specific hybrids for each site were adjusted to include new varieties that more suitably matched the site CHU rating where appropriate; refer to the 2016 interim report for the hybrids used in Year 1. A summary of the CHU rating of the sites, soil zones, and selected hybrids is included in **Table 1**.

Table 1. Summary of corn heat unit (CHU) rating of each site, soil zone, and hybrid selected for Year 3 of the study.

Site	Site CHU Rating	CHU Rating (2017/2018/2019)		Soil Zone
		Brand A	Brand B	
Scott	2,100	2,200 / 2,075 / 2,075	2,050 / 2,050 / 2,050	Dark Brown
Lanigan	2,150	2,200 / 2,075 / 2,075	2,050 / 2,050 / 2,050	Thin Black
Melfort	2,175	2,200 / 2,200 / 2,200	2,225 / 2,150 / 2,150	Black
Yorkton	2,250	2,325 / 2,200 / 2,200	2,225 / 2,150 / 2,150	Black
Outlook	2,300	3,325 / 2,350 / 2,350	2,300 / 2,300 / 2,300	Dark Brown
Redvers	2,450	3,325 / 2,350 / 2,350	2,300 / 2,300 / 2,300	Black

Three seeding rates and three nitrogen application rates were evaluated at each site, as shown in **Table 2**. The same seeding and nitrogen fertilizer rates were used in all three growing years.

Table 2. Summary of seeding rates and nitrogen application rates used in each trial year of the study.

	Seeding Rate		Nitrogen Application Rate	
	(plants/ha)	(plants/acre)	(kg N/ha)	(lb N/acre)
Low	75,000	30,350	112	100
Medium	100,000	40,470	168	150
High	125,000	50,600	225	200

The treatment combinations (two brands, three seeding rates, and three nitrogen application rates) were arranged in a completely randomized block design with three repetitions. Therefore, there were 54 plots per site and 324 plots in total each year.

At each site, the following data was collected:

- Planting, emergence, and maturity dates
- Plant counts within two weeks of emergence
- Weather (rainfall, corn heat units)

At harvest, the following data was collected from each plot:

- Wet yield (wet tonne/ha)
- Moisture content (to calculate yield in dry tonne/ha)
- Forage quality

3.2 Site Preparation and Planting

Soil samples were collected from the top 30 cm (12 in) of soil at each site and analyzed for nutrient content (NO_3-N, P, K, and SO_4-S). If the soil was deficient in P, K, or S (less than 56, 140 and 17 kg/ha, respectively or 50, 125 and 15 lb/acre, respectively), the amount of P, K, and S required to at least meet those levels was added. The amount of urea (N) added to the plots was determined based on the residual NO_3-N in the soil and the rate required for each of the N application rate treatments (refer to **Table 2**).

Depending on the site, the seedbed was tilled prior to fertilizer application and incorporation (**Figure 1**). Tillage and fertilizer application occurred no more than two days prior to planting. Refer to **Appendix A** for details on soil conditions at seeding, specific seeding dates, and for actual fertilizer rates (based on soil analysis results).

Figure 1. A rototiller was used to till the soil at the Lanigan site prior to urea broadcast and incorporation.

The plots were sized to accommodate four rows per plot with a 76 cm (30 in) spacing between rows. Therefore, each plot was 3 m (10 ft) wide. Plots were 6 m (20 ft) long at all sites except Outlook where they were 9 m (30 ft) long. There was no space between adjacent plots, but only the middle two rows in each plot were harvested and analyzed to allow a buffer zone between treatments.

All plots were seeded when the soil temperature in the top 5 cm (2 in) reached a minimum 10°C (50°F); see **Table 3** for exact seeding dates. All plots were seeded using a modified, four-row Vaderstad planter (**Figure 2**) that had been calibrated for each brand of seed to deliver the required seeding rate. Based on this calibration data (information not shown), the actual seeding rate was within 2% of the target seeding rate.

Table 3. Seeding and harvest dates for each trial site.

Trial Site	Seeding Date / Harvest Date		
	2016	2017	2018
Scott	May 26 / September 21	May 30 / September 26	May 22 / September 19
Lanigan	May 30 / September 20	June 1 / September 21	May 29 / September 27
Melfort	May 25 / November 3	May 31 / October 10	May 30 / September 28
Yorkton	May 17 / September 22	May 16 / September 21	May 15 / September 12
Outlook	May 18 / September 19	May 23 / September 6	May 16 / September 18
Redvers	May 16 / September 28	May 17 / September 11	May 14 / September 12

Figure 2. Vaderstad planter used for seeding at all project sites.

3.3 Harvesting

The corn was considered ready for silage harvest when the kernels reached the half milk line (**Figure 3**). Since nitrogen application rate may affect maturity rate, the maturity of the cobs was assessed in the mid-N rate, mid-seeding rate treatments. Once those treatments reached maturity, all plots were harvested, but the maturity (milk line progression) was recorded for each plot.

Figure 3. Example of a cob that has reached the half milk line stage of maturity.

The plots were all harvested in September of each year, with the exception of Melfort in 2016 and 2017, which was harvested in November and October, respectively (refer to **Table 3** for specific harvest dates).

The wet biomass yield was recorded separately for each plot. A minimum of 3 m (10 ft) of the center two rows was cut from each plot (**Figure 4**), leaving a 5 to 7.5 cm (2 to 3 in) stubble height. The material from each plot was weighed individually (**Figure 5**), and the harvest length recorded to allow for the calculation of a wet yield. Plant height of each plot was also measured and recorded, as well as any observable fusarium or bird damage. At the Melfort site (2017 and 2018 site years) the entire plot (full length of all four rows) was harvested; therefore; possible edge effects could not be ignored, and so the Melfort yield data was removed from some of the analyses.

Figure 4. The center two rows of each plot were cut by hand using a machete at the Lanigan site.

Figure 5. The total mass of the biomass from each plot was weighed.

Subsamples were also collected from each plot for DM and forage quality analysis. Two full stalks were collected from each plot and chopped (a wood chipper was used for the Lanigan samples, **Figure 6**). The first stalk was run through to flush out the material remaining in the chipper, while the material from the second stalk was collected and bagged. The DM content of each of the subsamples was determined by drying the samples in a forage oven at 65°C for 24 to 48 hours. The samples from Redvers, Yorkton, Scott, Melfort, and Lanigan were dried at PAMI, while the samples from Outlook were dried at Outlook.

Figure 6. Stalks were chopped using a wood chipper for DM and forage quality analysis.

The dried subsamples were sent to Strathroy Central Lab for near infrared reflectance spectroscopy (NIR) analysis of crude protein, soluble protein, fat, ash, cADF, cNDF, lignin, calcium, phosphorous, magnesium, potassium, sodium, chloride, sulfur, total sugar, and starch. Total Digestible Nutrients (TDN) were calculated from ADF concentration by the equation of Weiss et al. (1992).

3.4 Economic Analysis

An economic analysis was performed to determine which combination of seeding rate and nitrogen rate resulted in the lowest cost per tonne of corn biomass yield. The results depend on two main factors, the cost of the crop inputs and the resulting biomass produced. An increase in crop inputs, such as seed and fertilizer, will increase total costs; however, it is expected this will also increase the total biomass produced, which could result in higher overall revenues.

The total input costs of each plot were estimated by summing all of the associated costs to produce the corn forage crop, which included the cost of seed, cost of fertilizer (Urea), "variable costs" as well as "other expenses". These costs were referenced from the Crop Planning Guide (2018). To see the full breakdown of the "variable costs" and "other expenses", see Appendix **Table D-1**. The variable and other expenses did not include the cost of seed or nitrogen fertilizer, as per the Crop Planning Guide, as these values were based on standard rates and did not allow for varying costs due to changes in seeding/fertilizer rates. Therefore, the seeding and nitrogen costs were calculated on a per unit basis and added to the total costs so the three seeding/nitrogen rates could be accounted for.

A summary of the total expenses (sum of variable and other expenses with seed and nitrogen costs omitted) across the three soil zones in Saskatchewan can be seen in **Table 4** below.

Table 4. Summary of total expenses includes "variable" and "other" expenses but omits seed and nitrogen costs.

Variables Expenses/Acre	Black	Dark Brown	Brown	Average
Total Variable Expenses	$ 313.52	277.46	285.41	292.13
Seed	87.00	87.00	87.00	87.00
Fertilizer - Nitrogen	50.91	38.53	43.57	44.34
Total Variable Expenses (Seed & Nitrogen Costs Omitted)	175.61	151.93	154.84	160.79
Total Other Expenses	148.19	130.29	114.02	130.83
Total Expenses (Seed/Nitrogen Omitted)	**$ 323.80**	**$ 282.22**	**$ 268.86**	**$ 291.63/ac**
	$ 800.13	**$ 697.38**	**$ 664.37**	**$ 720.62/ha**

To calculate the cost of seed and nitrogen fertilizer used per hectare on each of the plots, standard rates were again referenced from the Crop Planning Guide (2017) on a per unit basis. **Table 5** shows the associated seed costs for the three rates (high, medium and low) when using a standard rate of $0.003 per unit.

Table 5. Cost of Seed per hectare across low, medium, and high rates.

	Low	Medium	High
Seeding Rate (plants/ha)	75,000	100,000	125,000
Seed Costs ($/plant)	0.003	0.003	0.003
Seed Costs ($/ha)	225	300	375

Finally, the nitrogen costs associated with each plot was calculated using a standard rate of $0.413 per kg of urea (Crop Planning Guide, 2017). Using this standard rate, along with the applied urea rate for each individual plot, the cost of nitrogen was calculated for each plot in dollars per hectare.

The total cost associated with each plot could then be calculated in dollars per hectare as shown by the following equation:

$$Total\ Cost = Variable\ Cost + Other\ Costs + Seed\ Cost + Nitrogen\ Cost$$

Total Cost: Total cost of all expenses associated with each plot ($/ha)

Variable Cost: Costs directly associated with crop production (chemical, fertilizers other than nitrogen, machinery operational costs, etc. [$/ha])

Other Costs: Costs indirectly associated with crop production (Property tax, business overhead, machinery depreciation, etc. [$/ha])

Seed Costs: Cost of seed, dependent on seeding rate ($/ha)

Nitrogen Costs: Cost of nitrogen, dependent on applied rate ($/ha)

Once a total cost in dollars per hectare was determined for each plot, it was divided by the corresponding dry biomass yield of the plot to achieve the total cost per metric ton of biomass yield.

4. Results and Discussion

A summary of the results and analysis is presented here with discussion about key findings. Supplementary data is included in the **Appendix** and referenced as needed.

4.1 Plant Counts

The actual plant populations were recorded at four sites shortly after emergence, and the averaged results are presented in **Table 6**.

Table 6. Actual plant populations for each seeding rate (averaged across 11 site-years*) and percent difference from target.

	High Seed Rate	Mid Seed Rate	Low Seed Rate
Target plants/ha (plants/acre)	125,000 (50,600)	100,000 (40,500)	75,000 (30,350)
Average actual plants/ha (plants/acre)	111,042 (44,938)	90,503 (36,626)	69,977 (28,319)
Difference (%)	11.2	9.5	6.7

*Lanigan (2016, 2017, 2018), Outlook (2016, 2017, 2018), Scott (2017, 2018), Yorkton (2016, 2017, 2018)

Actual plant populations were 7% to 11% lower than the target for all seeding rate treatments. This difference is likely due to the germination rate being less than 100% and a margin of error in the actual number of seeds planted by the planter. These results indicate that less competition may result in a higher germination rate, and thus, higher emergence rates at a lower seeding rate on average.

The relative difference between the actual and target plant populations by brand for the Lanigan, Outlook, Scott, and Yorkton plots are shown in **Table 7**. Full plant population data from the other sites was not available. In Year 1 (2016) of this project, there was a large discrepancy regarding plant emergence between brands, however, in Year 2 (2017), the difference between plant counts and target seeding rate for both brands was similar. In Year 3, (2018) Brand B displayed a larger deviation from the target seeding rate than Brand A, particularly at the high seeding rate. Overall, both brands performed similarly across all site-years.

Table 7. Average relative difference between actual and target plant populations by brand for Lanigan, Outlook, Yorkton, and Scott plots.

	Difference (%)		
	High seed rate	**Mid seed rate**	**Low seed rate**
Brand A	10.2	9.9	6.8
Brand B	11.4	8.7	6.1

These results indicate that the actual plant populations are closer to target at lower seeding rates for both Brands.

4.2 Corn Heat Units (CHU)

CHU is a means to calculate the potential growing conditions for corn at any field site. It is determined from a formula that includes the maximum and minimum daily temperatures at the site and accumulates from planting until a -2°C frost in the fall. In the case of silage corn, the CHU calculation accumulates until harvest if the harvest occurs prior to a killing frost. Corn silage harvest occurred prior to killing frost at all site-years except for those indicated in **Table 8**.

Table 8. Site-years that experienced a killing frost prior to harvest.

Site – Year	Harvest Date	CHU End Date (-2°C frost)
Melfort – 2016	November 3	October 5
Scott – 2017	September 26	September 20
Lanigan – 2018	September 27	September 5
Melfort – 2018	September 28	September 21

Environment Canada (EC) daily temperature data was used to calculate CHU. At Lanigan and Redvers, the closest available EC weather station data was used, namely Watrous and Oxbow. Any missing data points from a particular weather station were supplemented by data from the next closest weather station to the respective location. If not accounted for, missing data points, particularly during the hot summer months, would significantly alter the cumulative CHU.

The highest cumulative CHU across all site-years was experienced at Yorkton in 2016, while Lanigan in 2018 had the lowest CHU (**Table 9**). For all years, the CHU at Yorkton was slightly higher than the rating for that site. Site CHU ratings are based on grain corn production; silage corn production generally requires 200 CHU values less than grain corn. All sites met this requirement for corn production except those marked with an asterisk in **Table 9**.

Table 9. CHU calculated for all 18 site-year locations using the nearest available EC weather stations.

Trial Site	Weather Station Site	CHU Rating	2016 CHU	2017 CHU	2018 CHU
Redvers	Oxbow	2450	2209*	2149*	2332
Yorkton	Yorkton	2250	2372	2291	2287
Outlook	Outlook	2300	2271	2091*	2288
Melfort	Melfort	2175	2263	2181	1876*
Scott	Scott	2100	2002	1983	1976
Lanigan	Watrous	2150	2104	2025	1826*

* Did not experience sufficient CHU for silage production

(Source: http://climate.weather.gc.ca/historical_data/search_historic_data_e.html)

4.3 Precipitation

It was observed that there was substantial variation in rainfall between all three growing seasons; weather data from the EC weather stations was used to quantify the cumulative rainfall for each trial year. All sites in 2018 saw a cumulative rainfall between the 2016 and 2017 values for the corresponding site, except for Outlook and Melfort, which experienced much lower precipitation amounts compared to the first two growing seasons as shown in **Table 10**. The plots at Outlook were irrigated. The difference in precipitation correlates to some of the differences in biomass yield between years (discussion to follow in subsequent sections).

Table 10. Cumulative precipitation (mm) calculated for all 18 site-years using the nearest available EC weather station.

Trial Site	Weather Site	2016 Precipitation		2017 Precipitation		2018 Precipitation	
		(mm)	(in)	(mm)	(in)	(mm)	(in)
Redvers	Oxbow	381	15.0	141	5.56	283	11.1
Yorkton	Yorkton	296	11.7	167	6.57	230	9.06
Outlook	Outlook	346	13.6	112	4.41	99	3.90
Melfort	Melfort	338	13.3	122	4.80	99	3.90
Scott	Scott	239	9.41	128	5.04	197	7.76
Lanigan	Watrous	316	12.4	82	3.23	147	5.79

(Source: http://climate.weather.gc.ca/historical_data/search_historic_data_e.html)

4.4 Dry Matter Forage Yield

4.4.1 Summary of DM Yield Data

A summary of the average dry yield from each site is presented in **Table 11**.

Table 11. Summary of average dry yield, dry tonne/ha (dry ton/ac), for all site-years.

Site	2016	2017	2018	Average	Standard Deviation
Redvers	17.4 (7.76)	15.1 (6.7)	15.7 (4.8)	15.4 (6.4)	0.4 (1.5)
Yorkton	18.3 (8.16)	14.4 (6.4)	16.3 (5.6)	16.3 (6.7)	2.0 (1.3)
Outlook	16.0 (7.14)	18.2 (8.1)	18.8 (7.3)	17.7 (7.5)	1.5 (0.5)
Melfort	10.9 (4.86)	16.1 (7.2)	15.2 (6.8)	11.7 (5.2)	3.2 (1.4)
Scott	12.3 (5.49)	12.7 (5.7)	10.8 (7.)	11.9 (6.1)	1.0 (0.8)
Lanigan	19.1 (8.52)	13.8 (6.2)	12.5 (8.4)	15.1 (7.7)	3.5 (1.3)

Moisture content (MC) was used to determine the dry yield for each biomass subsample; the average MC for each site is presented in **Figure 7**. This information will be referenced later in this report to discuss the effect of MC on forage quality.

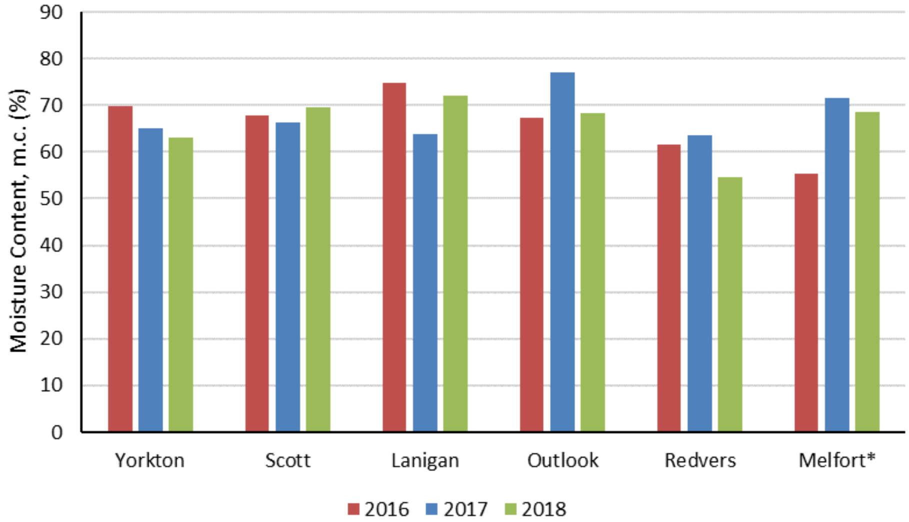

Figure 7. Average MC data for each site. (*Melfort 2017 yield data is subject to edge effects and was not included in statistical analysis).

The yield summary for each site and treatment is summarized in **Table 12** and **Figure 8** to **Figure 11**. As shown in **Table 12**, yields with a different letter within each treatment group for each site are considered statistically different at a 95% confidence level. A statistically significant result indicates that the difference is likely due to the treatment effect rather than natural variability. Melfort yield data was not included in the 2017 or 2018 yield analysis due to the inability to account for edge effects caused by error in harvest methodology.

Table 12. Average DM yield, tonne/ha (ton/acre) for each treatment group.

	Treatment	2016	2017	2018
Site	Outlook	16.0 (8.5) a	18.2 (8.1) a	18.8 (8.4) a
	Redvers	18.3 (8.2) ab	15.1 (6.7) b	15.7 (7.0) b
	Yorkton	17.4 (7.8) b	14.4 (6.4) bc	11.6 (5.2) c
	Lanigan	19.1 (7.1) c	13.8 (6.2) cd	12.5 (5.6) c
	Scott	12.3 (5.5) d	12.7 (5.7) d	10.8 (4.8) c
	Melfort	10.9 (4.9) e	-	-
Brand	Brand A	16.0 (7.1) a	14.8 (6.6) a	13.6 (6.1) a
	Brand B	15.4 (6.9) b	14.9 (6.6) a	14.7 (6.6) b
N Rate	High rate	16.1 (7.2) a	14.8 (6.6) a	14.8 (6.6) a
	Mid rate	15.7 (7.0) ab	15.2 (6.8) a	14.2 (6.3) ab
	Low rate	15.2 (6.8) b	14.5 (6.5) a	13.3 (5.9) a
Seeding Rate	High rate	16.4 (7.3) a	15.3 (6.8) a	14.3 (6.4) a
	Mid rate	15.4 (6.9) b	14.9 (6.6) ab	14.1 (6.3) a
	Low rate	15.2 (6.8) b	14.3 (6.4) b	14.0 (6.2) a

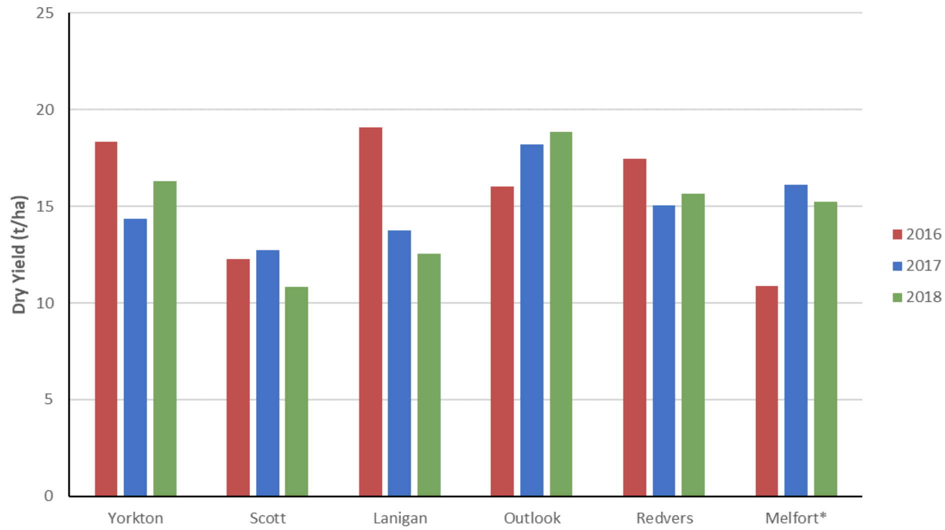

Figure 8. Average dry yield data for each site. (*Melfort 2017 and 2018 yield data is subject to edge effects and was not included in statistical analysis).

It is reasonable to note that the long season sites have the highest average yield as there are more available CHU.

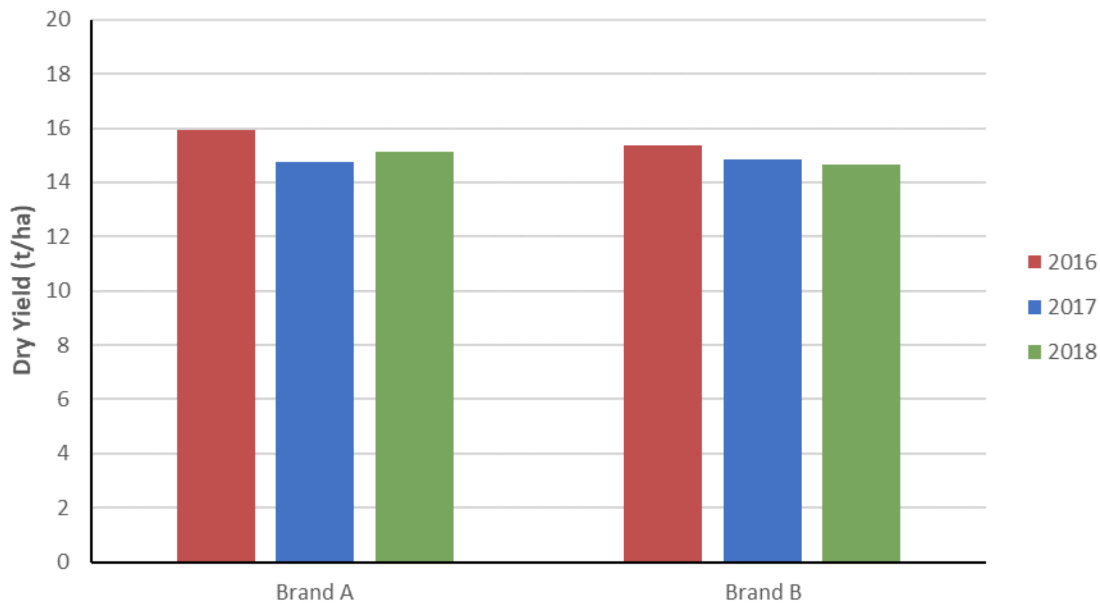

Figure 9. Average dry yield data for each seed brand. (*Melfort 2017 yield data is subject to edge effects and was not included in statistical analysis). Different letters denote significant differences between sites in Year 3 (2018).

While there was a significant difference in dry yield between brands in Years 1 and 3, there was no difference between the brands in Year 2. There was also a significant interaction between brand and site as seen in **Figure 10**; however, the effect was inconsistent across all years.

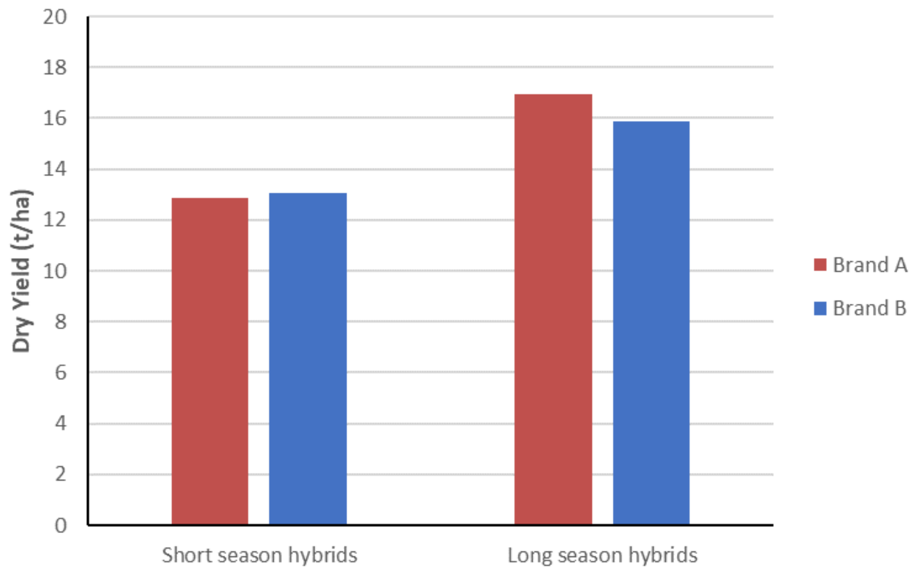

Figure 10. Average dry yield for long season (Redvers, Outlook, Yorkton) and short season (Lanigan, Melfort, Scott) hybrids in Year 3 (2018).

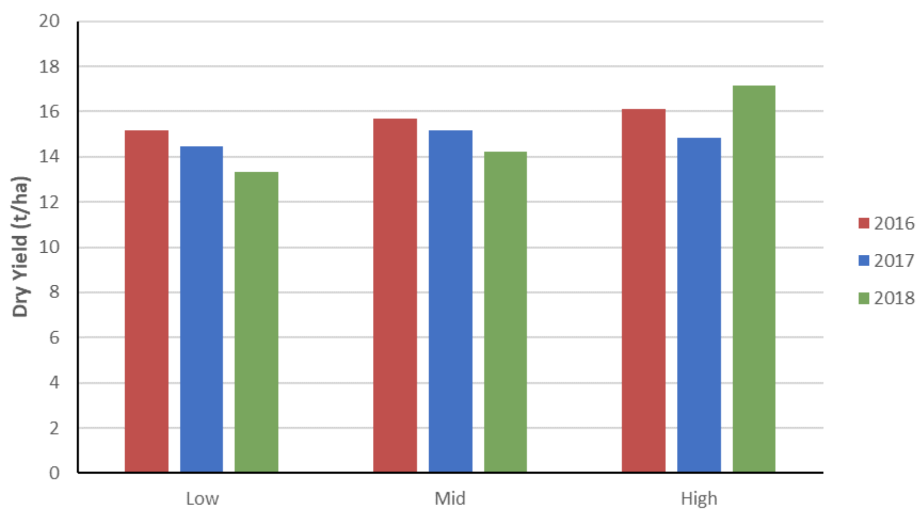

Figure 11. Average dry yield data for each nitrogen application rate. (*Melfort 2017 yield data is subject to edge effects and was not included in statistical analysis).

The high nitrogen application rate generated significantly higher yields than the low nitrogen application rates in Years 1 and 3; however, there was no difference as a result of N-rate in 2017. Soil samples were not collected from the plots after harvest to assess the Nitrogen efficiency of the corn.

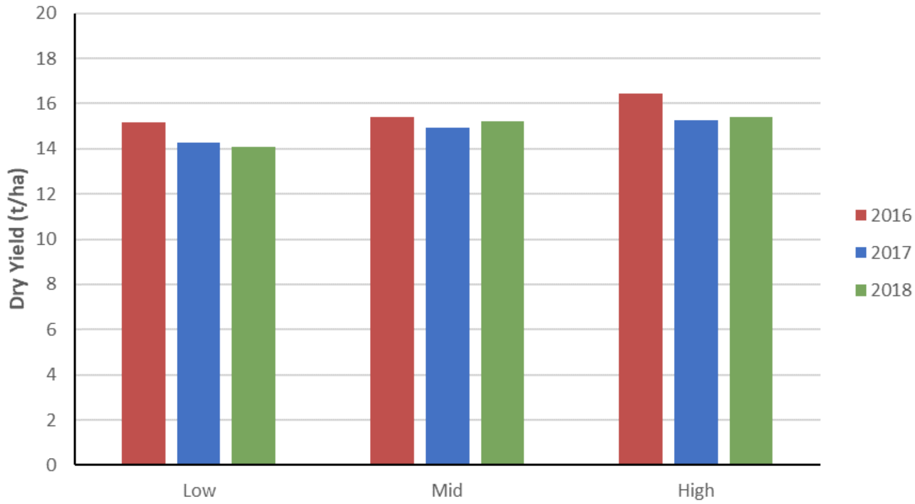

Figure 12. Average dry yield data for each seeding rate. (*Melfort 2017 yield data is subject to edge effects and was not included in statistical analysis).

The high seeding rate generated a significantly higher yield than the low seeding rate in 2016 and 2017, but there was no difference in 2018.

A basic analysis of variance (ANOVA) for MC and DM yield for each site-year is summarized in **Appendix B**.

4.4.2 Combined Site-Year DM Yield Analysis

A detailed statistical analysis of DM forage yield (**Table 13**) was conducted based on site-year (i.e., each site alone was not treated as a variable) due to the following reasons:

- In 2016, sub-samples from Yorkton spoiled before they could be analyzed for forage quality.
- In 2017 and 2018, entire plots were harvested at Melfort, so there was a possibility of edge effect on results.
- There was a lot of variability in precipitation and CHU experienced at each site over the three years.

Table 13. ANOVA probabilities for MC and DM yield silage corn trial across 18 site-years. Probabilities less than 0.05 are highlighted in red text, indicating a statistically significant effect at a 95% level of confidence.

Source	df	Prob >F Moisture (%)	Prob >F DM Yield (Mg/ha)
Site-Year (SY)	16	<0.001	<0.001
Brand (B)	1	0.013	0.139
N rate (NR)	2	0.046	0.016
Seed Rate (SR)	2	0.366	<0.001
SY*B	16	<0.001	<0.001
SY*NR	32	0.093	0.002
SY*SR	32	0.005	0.281
B*NR	2	0.171	0.828
B*SR	2	0.445	0.876
NR*SR	4	0.967	0.246
SY*B*NR	32	0.548	0.212
SY*B*SR	32	0.850	0.996
SY*NR*SR	64	0.940	0.974
B*NR*SR	4	0.923	0.595
SY*B*NR*SR	64	0.986	0.953
C.V. (%)		5.1	14.7

The MC of forage corn varied by site-year, hybrid, the site-year x Brand interaction, and by N fertilizer rate (**Table 13**). The interaction can be attributed to the Brand A hybrid containing more water than Brand B at Scott 2017, Lanigan 2018, and Redvers 2018, while the reverse was true at Redvers 2016 (**Figure 13**). There was no difference between Brands for moisture concentration at the other 13 site-years. Outlook 2017 had the highest MC (**Figure 13**), while Melfort 2016 and Redvers 2018 had the lowest. Brands differed in MC with Brand A at 67.1 and Brand B at 66.5% (±0.2%). N fertilizer affected the MC of the corn (**Table 13**). The concentrations were 66.4%, 66.8%, and 67.2% (±0.2%) for low, medium, and high N fertilizer rate, respectively. The significant site-year x seeding rate interaction can be attributed to a seeding rate response at Redvers 2018. The MC was 52.0%, 53.9%, and 57.4% (±0.8%) for low, medium, and high seeding rate at that location. At the other site-years, there was no difference in MC due to seeding rate (data not shown).

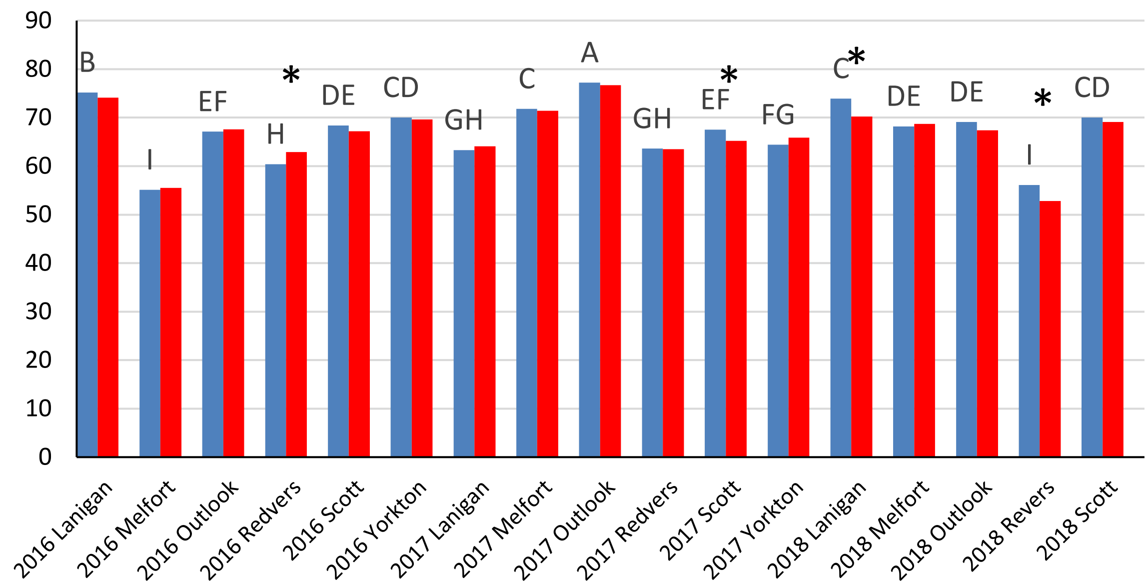

Figure 13. MC (%) by site-year x Brand (P<0.001). Asterisks indicate site-years where brands differed in starch concentration. Site-years (P<0.0001) topped by the same letters are not different by Tukey's honestly significant difference (HSD).

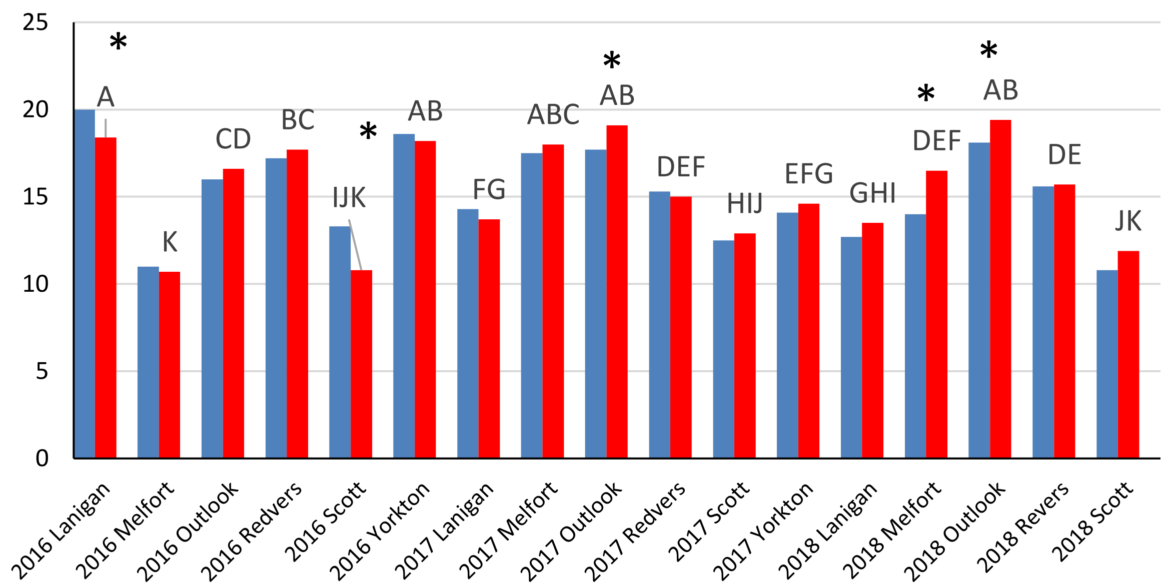

Figure 14. DM forage corn yield (Mg/ha) by site-year x Brand (P<0.001). Asterisks indicate site-years where brands differed in starch concentration. Site-years (P<0.0001) topped by the same letters are not different by Tukey's HSD.

The site-year and site-year x Brand interaction were significant for forage yield (**Table 13**). The interaction was complex with Brand B yielding more forage at Lanigan 2016 and Scott 2016, Brand A yielding more at Outlook 2017, Melfort 2018, and Outlook 2018, and then no difference between Brands at 12 site-years (**Figure 14**). As a result, the Brands were not significantly different (P=0.139) when averaged over all 16 site-years (15.2 vs. 15.4 (±0.1) Mg/ha for Brand A and B, respectively).

There was some forage yield data that could be considered as outliers based on box-and-whisker displays of the data within site-years. In other words, the data points were less than or greater than the 99% distribution limits. Treating these data points as outliers reduced the coefficient of variation within site-years at 9 of 16 site-years. However, the improvement (reduction) in variability was deemed insufficient to continue to exclude the data points without additional justification.

Melfort 2016 forage harvest was delayed over a month due to insufficient resources. Melfort 2017 forage yield represented a full plot harvest without borders, which may have increased edge effects on the data. However, neither site-year was identified as exhibiting more unexplained variability than the other site-years. Therefore, the original data for both site-years was included in the combined analysis for DM corn forage yield. The advantage of irrigation was evident in the site-year differences in forage yield (**Figure 14**). Outlook results ranked 2,4, and 7 out of 16 site-years' data. Scott results ranked 13, 14, and 15 out of the 16 site-years' data. However, forage corn yield ranged from 11.4 to 12.7 Mg/ha at Scott (**Appendix B Table B-5**), which is good forage productivity compared to traditional annual forage crops, such as barley and oats. The late harvest at Melfort 2016, and likely weathering losses of DM yield, result in the lowest DM yield. If the Melfort 2016 yield data are excluded, there is a significant linear relationship between accumulated CHU and DM forage yield (r=0.582, P<0.05). This relationship would be expected for a C4 photosynthetic pathway plant growing at the northern limit of adaptation.

N fertilizer rate, site-year x N rate interaction and seeding rate were also significant for DM forage yield (**Table 13**). The site-year x N rate interaction can be attributed to a significant N rate effect at Yorkton 2016 and Scott 2018 (**Figure 15**) while there were no significant differences at the other 14 site-years. At some site-years, such as Melfort 2018, there were numerical differences in forage yield due to N fertilizer rate, but these differences were not statistically significant (**Appendix B Table B-3**). These results indicate that in most site-years, N fertility was not limiting forage corn yield.
Averaged over all site-years, the N fertilizer effect was significant (P=0.016, **Table 13**). The mean yields were 15.0, 15.4, and 15.6 Mg/ha for low, medium, and high N rates, respectively. Only the low N rate mean was lower than the high N rate mean by Tukey's HSD mean separation test.

The seeding rate had a significant (P<0.001) effect on forage yield when averaged over all site-years. The mean forage yields were 14.8, 15.4, and 15.8 Mg/ha for low, medium, and high seeding rates, respectively. The yield of the medium and high seeding rates are similar and higher than the low seeding rate based on Tukey's HSD mean separation test.

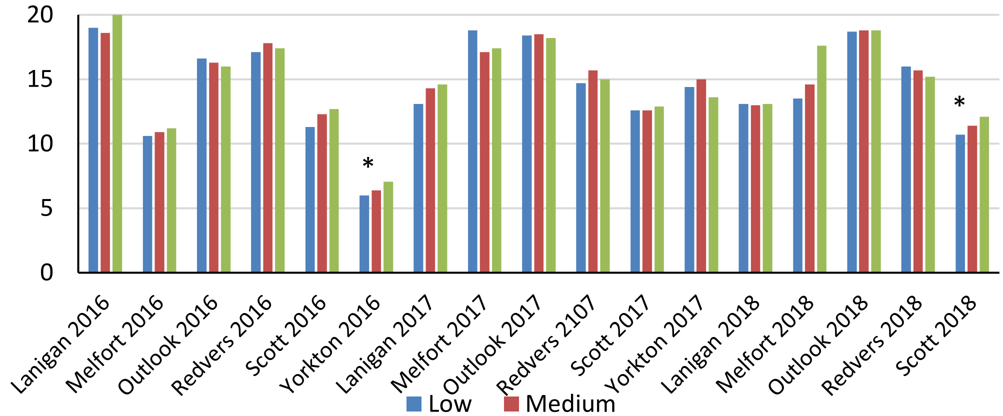

Figure 15. Mean DM forage yield (Mg/ha) as affected by site-year x N fertilizer rate interaction. Asterisks indicate site-years where brands differed in starch concentration.

4.5 Forage Quality Data

The effect of treatments on forage quality was analysed according to site-year in order to reflect data from all three trial years. Significant influences on nutritional parameters are summarized in **Table 14** and **Table 15**.

Table 14. ANOVA probabilities (P>F value*) by source of variation for CP, soluble protein, TDN, starch, and sugar concentration of forage corn across 16 site-years in Saskatchewan.

Source	df	CP	Soluble Protein	TDN	Starch	Sugar
Replicate	2	0.7796	0.0302	0.9446	0.8368	0.9702
Site-Year (SY)	15	<.0001	<.0001	<.0001	<.0001	<.0001
Brand (B)	1	<.0001	<.0001	<.0001	0.1579	<.0001
N rate (NR)	2	<.0001	<.0001	0.1256	0.8658	0.0305
Seeding rate (SR)	2	0.0001	0.0018	0.2064	0.5380	0.9333
SY x B	15	<.0001	<.0001	<.0001	<.0001	<.0001
SY x NR	30	0.0007	0.6035	0.9996	1.0000	0.9982
SY x SR	30	0.2829	0.61	0.6989	0.4388	0.1544
B x NR	2	0.287	0.9721	0.7605	0.6900	0.3573
B x SR	2	0.1927	0.6745	0.1445	0.0666	0.7098
NR x SR	4	0.7134	0.4466	0.8892	0.8772	0.1102
SY x B x NR	30	0.6238	0.7418	0.9756	0.9528	0.7426
SY x B x SR	30	0.4591	0.7924	0.8711	0.9813	0.6928
SY x NR x SR	60	0.9241	0.839	0.9994	0.9956	0.6731
B x NR x SR	4	0.6682	0.8628	0.6203	0.6444	0.5755
SY x B x NR x SR	60	0.9843	0.6462	0.6258	0.5900	0.8357

*Probabilities less than 0.05 are highlighted in red text, indicating a statistically significant effect at a 95% level of confidence. This means that there is a 95% or higher probability that the differences are due to treatment rather than natural variability.

4.5.1 Crude Protein (CP)

Site-year, Brand, Site-year x Brand interaction, N rate, Site-Year x N rate, and seeding rate all had significant effects on CP concentration (**Table 14**).

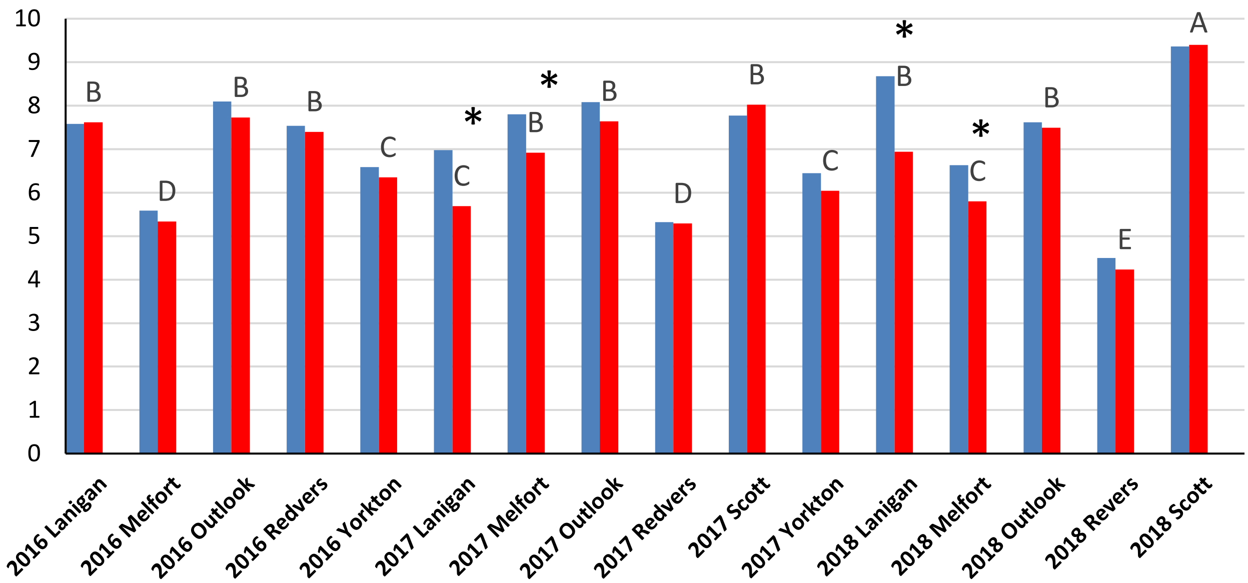

Figure 16. CP concentration (%) as affected by site-year x Brand interaction at 16 site-years in Saskatchewan. Significant difference between Brands within site-year are denoted by asterisk.

The site-year x Brand interaction results from significantly higher CP concentration for Brand A compared to Brand B at Lanigan 2017, Melfort 2017, Lanigan 2018, and Melfort 2018, whereas there was no difference between Brands at the other 12 site-years (**Figure 16**). Averaged over all 16 site-years, the Brand A exhibited 7.16% CP compared to 6.74% for Brand B (±0.04%).

Across site-years, CP concentration ranged from 4.36% at Redvers 2018 to 9.38% at Scott 2018 (**Figure 16**). Outlook ranked 2, 4, and 7 for CP concentration, so irrigation and history of growing corn may have attributed to higher N concentration at that site. Redvers ranked 8, 15, and 16 for CP concentration. Melfort ranked 9, 13, and 14 for CP concentration. These sites may have lower potential for N uptake by corn.

As would be expected, N fertilizer increased CP concentration ($P<0.0001$). CP concentrations averaged 6.45%, 6.96%, and 7.44% for low, medium, and high N fertilizer rate, respectively. These are significantly different as tested by Tukey's HSD mean separation test.

The site-year x N rate interaction for CP concentration can be attributed to significant N fertilizer rate effects at 11 site-years, but not significant N rate effect at 5 site-years (**Figure 17**).

The effect of seeding rate on CP concentration was evident. The CP concentration was 7.11%, 6.92%, and 6.81% for low, medium, and high seeding rates, respectively. The low N rate CP concentration was significantly higher than the medium and high seeding rate.

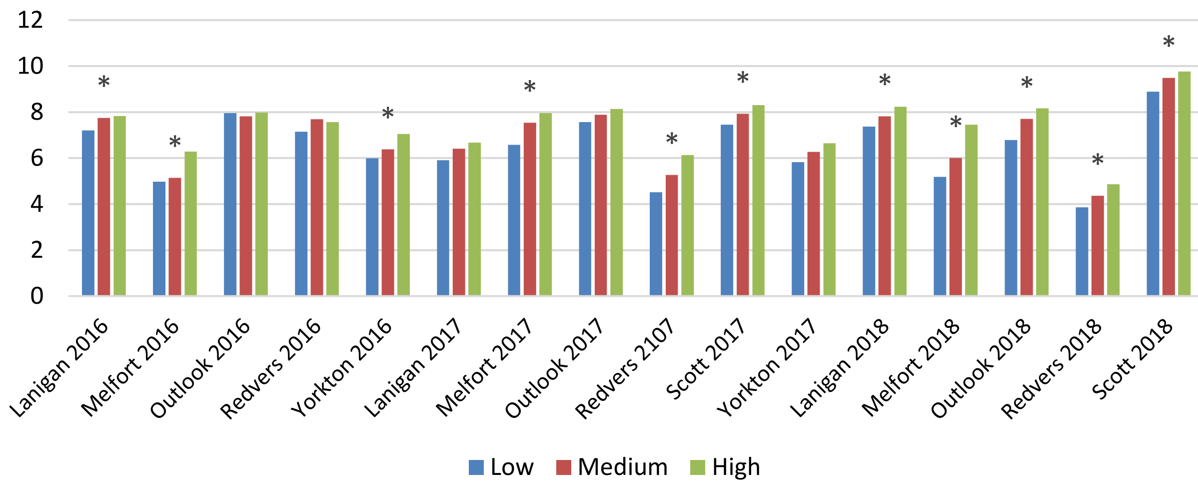

Figure 17. CP concentration (%) as affected by site-year x N rate interaction (P<0.001) at 16 site-years in Saskatchewan. Significant difference between Brands within site-year are denoted by an asterisk.

4.5.2 Soluble Protein

Soluble protein is the fraction of crude protein that is immediately available for digestion in the rumen and contributes to rapid microbial activity and digestion of more slowly metabolized dietary components. The main effects of site-year, Brand, site-year x Brand interaction, N fertilizer rate, and seeding rate are significant for soluble protein concentration (**Table 14**), similar to the CP results.

The site-year x Brand interaction for soluble protein results from Brand A expressing higher soluble protein than Brand B at 8 site-years (**Figure 18**) while there is no difference between Brands at the other 8 site-years. Averaged over all 16 site-years, the Brand A expressed higher soluble protein than the Brand B (3.48 vs 3.03%, P<0.0001).

When averaged over Brands, the site-differed in soluble protein concentration (**Table 14**). There was no consistent pattern among the site-years (**Figure 18**). For example, the results from Redvers over three years ranked 5, 14, and 16 for soluble protein. Results from Outlook ranked 2, 10, and 13 for soluble protein. The results for soluble protein appear similar to crude protein across site-years, and the correlation coefficient between them is r=0.69, P<0.01, df=15). The relationship is not perfect, and the value of soluble protein data in addition to crude protein should not be discounted.

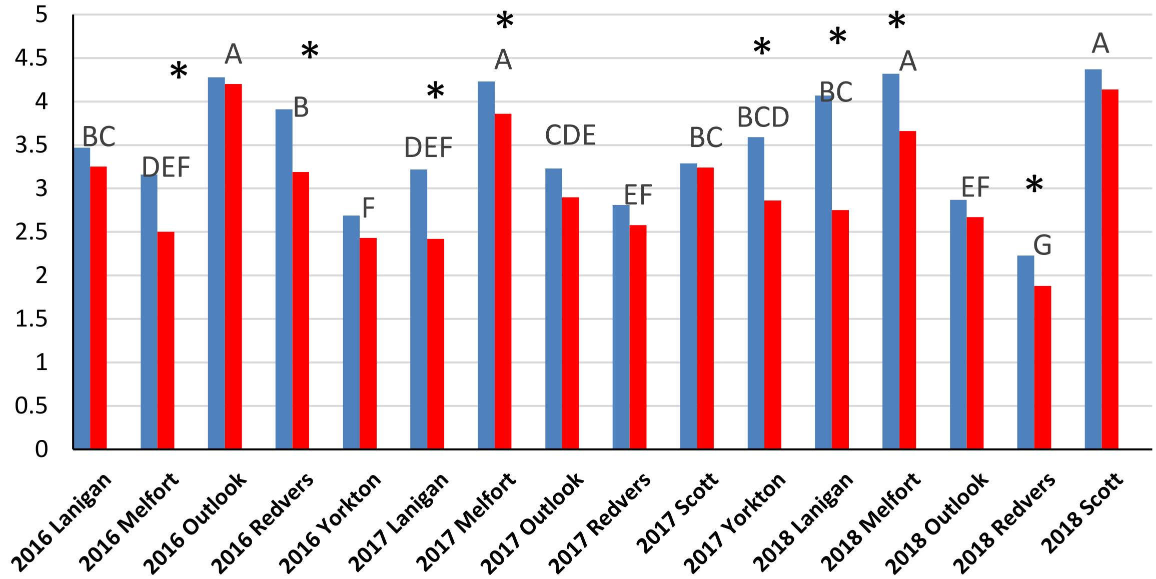

Figure 18. Soluble protein concentration (%) as affected by site-year x Brand interaction (P<0.001) at 16 site-years in Saskatchewan. Significant difference between Brands within site-year are denoted by an asterisk.

Nitrogen fertilizer rate improved soluble protein (**Table 14**). The concentrations were 3.07%, 3.28%, and 3.43% for low, medium, and high fertilizer rates, respectively. All three levels differed from each other based on Tukey's HSD mean separation test.

4.5.3 Total Digestible Nutrients (TDN)

TDN concentration was affected by site-year, Brand, and the site-year x Brand interaction (**Table 14**). Recall that TDN concentration is based on Acid Detergent Fiber concentration and reflects the digestible energy of the corn plants. After CP, it is the most important forage quality parameter for overwintering beef cow diets.

The significant site-year x Brand interaction was the result of Brand A containing more TDN than Brand B at 5 site-years, while the opposite result occurred at three other site-years. No difference between Brands was observed at 8 other site-years (**Figure 19**). Brand A expressed greater TDN than Brand B at Melfort for all three site-years there. The Brand B expressed greater TDN concentration than Brand A at Lanigan in two of the three years there. Otherwise, TDN differences between Brands were inconsistent across the other sites and years.

Averaged over all site-years, the Brand A had greater TDN concentration than the Brand B (63.4 vs. 62.5%, P<0.0001).

The site-year differences in TDN concentration are shown in **Figure 19**. The highest TDN concentrations occurred at Outlook 2018 and Outlook 2016. The lowest concentrations occurred at Redvers 2018 and Redvers 2017. Locations tended to group together for two out of three years results for TDN. For example, Outlook 2018 and Outlook 2016 rank 1 and 2, while Redvers 2017 and Redvers 2018 rank 15 and 16 for TDN concentration. There was no correlation (r = -0.08, P>0.95) between CHU rating at each site-year and TDN concentration.

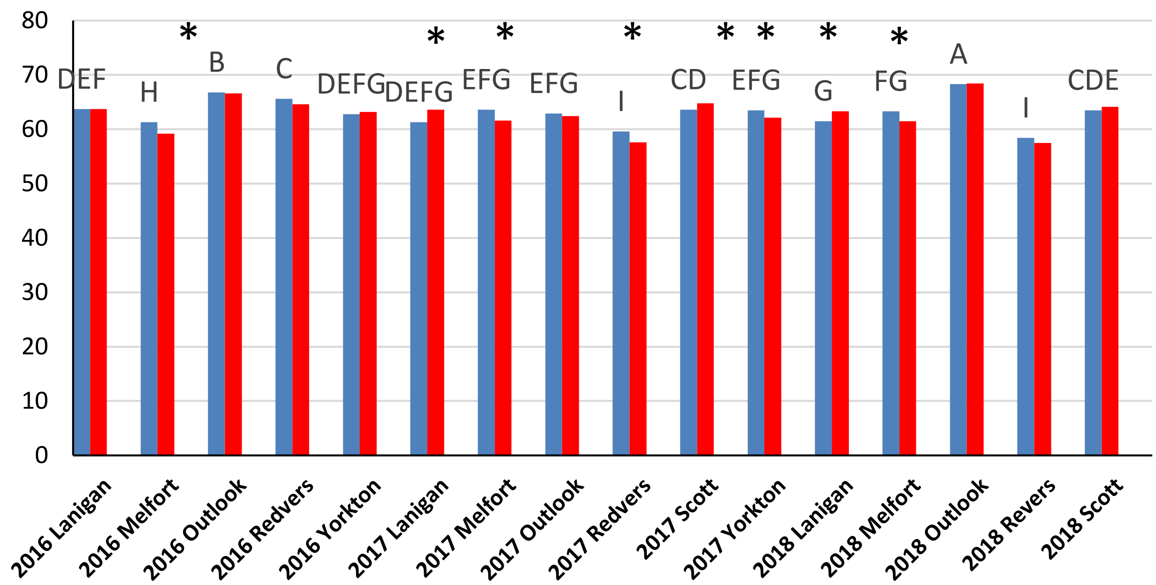

Figure 19. TDN concentration (%) as affected by site-year x Brand interaction (P<0.001) at 16 site-years in Saskatchewan. Significant difference between Brands within site-year are denoted by an asterisk. Site-years (P<0.0001) topped by the same letters are not different by Tukey's HSD.

4.5.4 Non-fiber carbohydrates (starch and sugar)

Site-year and site-year x Brand interaction were significant for starch concentration (**Table 14**).

Brands differed at three site-years (**Figure 20**). At Scott 2017 and Scott 2018, the Brand B corn had greater starch concentration than Brand A, but the reverse result was observed at Melfort 2016.

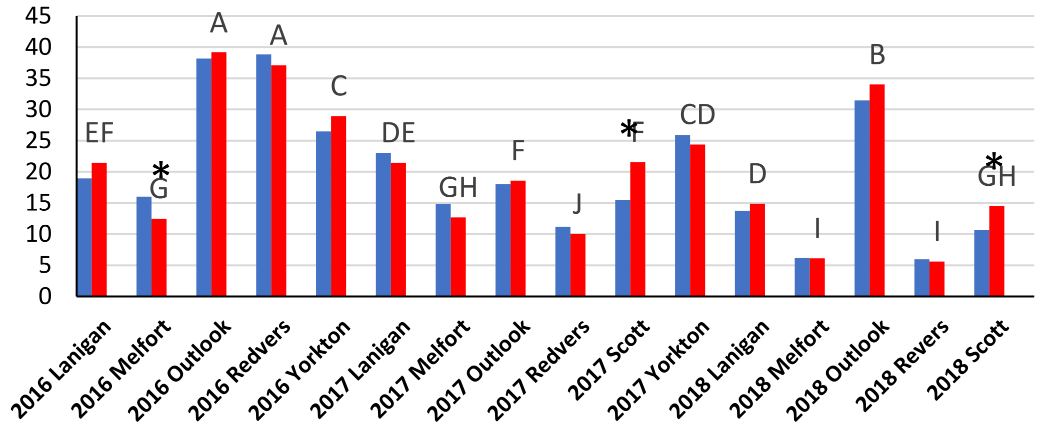

Figure 20. Starch concentration (%) as affect by site-year x brand interaction (P<0.0001) at 16 site-years in Saskatchewan. Asterisks indicate site-years where brands differed in starch concentration. Site-years (P<0.0001) topped by the same letters are not different by Tukey's HSD.

Site-year differences in starch concentration ranged from 5.78% at Redvers 2018, to 38.7% at Outlook 2016 (**Figure 20**). Starch accumulates in the corn kernel as the grain matures. We used a visual guide (1/2 milk line) for harvest timing that is typical of silage corn maturity. The milk line moves acropetally as starch deposition occurs in the corn kernel, assuming that milk region of the kernel is immature and the floury region represents deposited starch. It appears that this visual indicator of silage corn maturity can still represent a wide range of starch concentrations.

There was no difference between brands for starch concentration (**Table 14**).

There was a significant site-year x brand interaction for sugar concentration (**Table 14**). The interaction resulted from Brand A corn exhibiting greater sugar concentration than Brand B corn at 8 of the 16 site-years while there was no difference between brands at the other site-years (**Figure 21**). The brands differed in all three years at the Lanigan site, in two years at the Melfort site, and in two years at the Redvers site. Over all 16 site-years, Brand A averaged 11.6% sugar, while Brand B averaged 9.5%, which was significantly different (**Table 14**).

Sugar concentration ranged from 23.09% at Melfort 2018, to 1.78% at Redvers 2016 (**Figure 21**). All three years at Melfort had among the highest sugar concentrations while all three years at Outlook were consistently among the lowest. Other sites varied from year to year in sugar concentration. For example, Lanigan 2016 was among the highest mean sugar concentrations, while Lanigan 2017 and 2018 were amongst the lowest.

As N fertilizer increased, sugar concentration was less when averaged over all site-years. The concentrations were 10.9%, 10.6%, and 10.2% for low, medium, and high N rates, respectively. The low and high rates were significantly different by Tukey's HSD mean separation test.

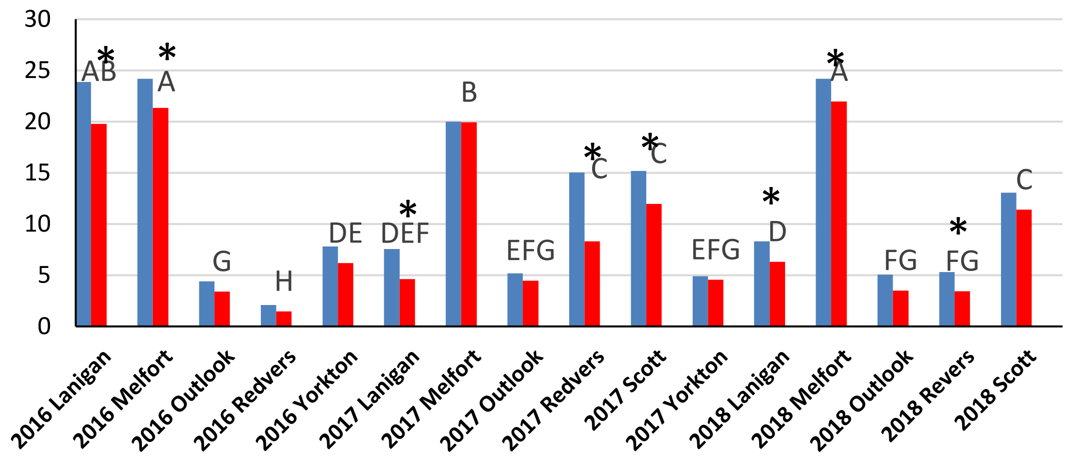

Figure 21. Sugar concentration (%) as affected by site-year x brand interaction (P<0.0001) at 16 site-years in Saskatchewan. Asterisks indicate site-years where brands differed in sugar concentration. Site-years (P<0.0001) topped by the same letters are not different by Tukey's HSD.

4.5.5 Fiber and Fat

Significant influences on fiber and fat are summarized in **Table 15**.

Table 15. ANOVA probabilities (P>F value) by source of variation for Neutral Detergent Fibre (NDF), NDF digestibility, Lignin, and fat concentration of forage corn across 16 site-years in Saskatchewan.

Source	df	NDF	NDF_dig	Lignin	Fat
Replicate	2	0.612	0.9779	0.1322	0.1021
Site-Year (SY)	15	<.0001	<.0001	<.0001	<.0001
Brand (B)	1	<.0001	<.0001	0.0338	0.0098
N rate (NR)	2	0.4484	<.0001	0.1069	0.9388
Seeding rate (SR)	2	0.3789	0.4373	0.433	0.6092
SY x B	15	<.0001	<.0001	<.0001	<.0001
SY x NR	30	0.9999	0.9765	0.594	0.8373
SY x SR	30	0.3805	0.8621	0.4255	0.9917
B x NR	2	0.6666	0.9094	0.1958	0.9308
B x SR	2	0.1878	0.1935	0.8467	0.6795
NR x SR	4	0.9965	0.5233	0.3395	0.9943
SY x B x NR	30	0.9333	0.8618	0.9583	0.9904
SY x B x SR	30	0.8824	0.8673	0.3123	0.9149
SY x NR x SR	60	0.9951	0.9985	0.9507	0.9526
B x NR x SR	4	0.7928	0.4424	0.871	0.6748
SY x B x NR x SR	60	0.8354	0.676	0.6501	0.8878

*Probabilities less than 0.05 are highlighted in red text, indicating a statistically significant effect at a 95% level of confidence. This means that there is a 95% or higher probability that the differences are due to treatment rather than natural variability.

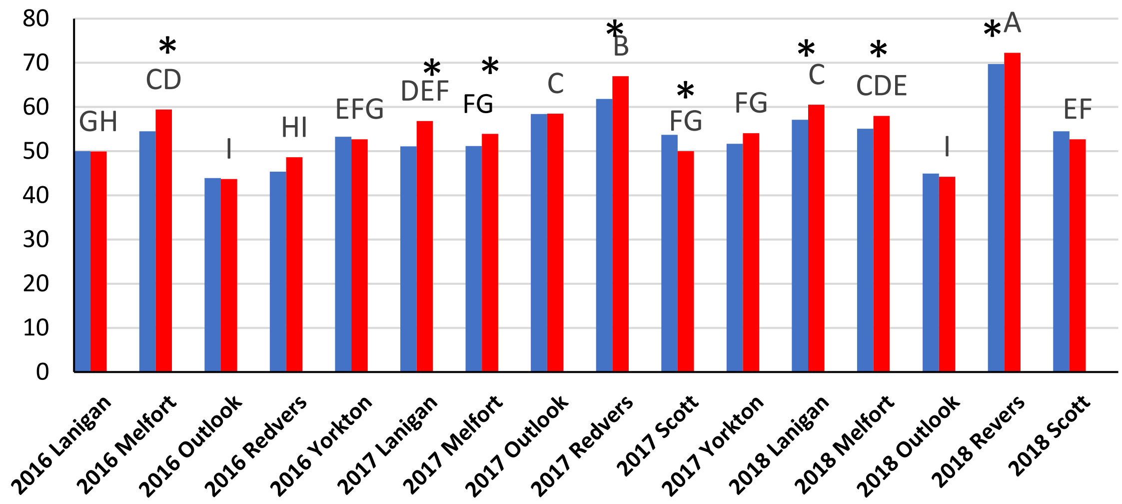

Figure 22. NDF concentration (%) as affected by site-year x brand interaction (P<0.0001) at 16 site-years in Saskatchewan. Asterisks indicate site-years where brands differed in NDF concentration. Site-years (P<0.0001) topped by the same letters are not different by Tukey's HSD.

There was a significant site-year x brand interaction for NDF concentration (**Table 15**). The interaction resulted from Brand B corn exhibiting greater NDF concentration than Brand A corn at seven site-years (**Figure 22**), while Brand A NDF concentration was greater than Brand B at one site-year (Scott 2017). There was no difference between brands at the other eight site-years. When averaged over all 16 site-years, NDF concentration was greater for Brand B than Brand A (55.1% vs. 53.5%, respectively, P<0.0001).

NDF concentration ranged from 71.0% at Redvers 2018, to 43.8% at Outlook 2016 (**Figure 22**). There was year to year variation within sites for NDF. For example, Redvers 2018 and 2017 were the highest and second highest site-years for NDF concentration, while Redvers 2016 was among the lowest.

NDF digestibility concentration also exhibited a significant site-year x brand interaction (**Table 15**). Brand B exhibited greater NDF digestibility concentration than Brand A corn at six site-years (**Figure 22**), while the reverse was observed at Scott 2017, and no difference between brands was observed at nine site-years. When averaged over all 16 site-years, Brand B corn exhibited greater NDF digestibility than Brand A (42.3% vs. 41.2%, respectively, P<0.0001).

NDF digestibility concentration also varied among site-years (**Table 15**). Redvers 2016, at 50.8%, was the highest NDF digestibility concentration, while Outlook 2018, at 32.9%, was the lowest site-year (**Figure 23**). Some sites were not consistent across years for this variable, while other sites were. For example, Redvers exhibited high NDF digestibility in 2017 and 2018, but was amongst the lowest concentration in 2016. However, Lanigan at 38.8%, 40.9%, and 42.5% NDF digestibility in 2016, 2017, and 2018 respectively, was consistent.

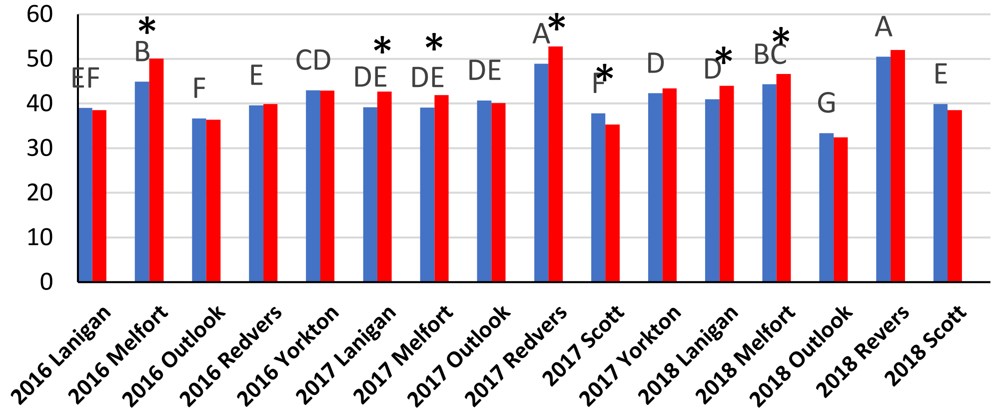

Figure 23. NDF digestibility concentration (%) as affected by site-year x brand interaction (P<0.0001) at 16 site-years in Saskatchewan. Asterisks indicate site-years where brands differed in NDF digestibility concentration. Site-years (P<0.0001) topped by the same letters are not different by Tukey's HSD.

Increasing N fertilizer rate resulted in lower NDF digestibility when averaged across all sites (**Table 15**). The mean NDF digestibility was 42.5%, 41.9%, and 41.0% for low, medium, and high N rates, respectively. The NDF digestibility for the high N rate is lower than the low and medium N rate means when tested by Tukey's HSD.

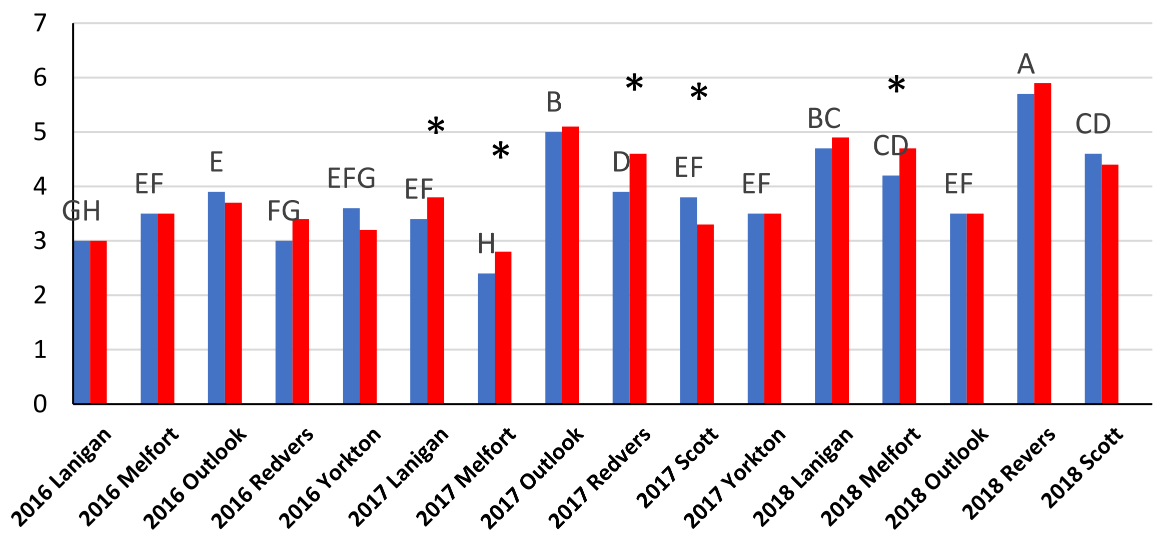

Figure 24. Lignin concentration (%) as affected by site-year x brand interaction (P<0.0001) at 16 site-years in Saskatchewan. Asterisks indicate site-years where brands differed in lignin concentration. Site-years (P<0.0001) topped by the same letters are not different by Tukey's HSD.

There was a significant site-year x brand interaction for lignin concentration (**Table 15**). This resulted from Brand B expressing greater lignin concentration than Brand A corn at four site-years (**Figure 24**), the reverse at Scott 2017, and no difference between seed brands at 11 other site-years. Averaged over all site-years, the Brand B lignin concentration (3.95%) was significantly higher than the Brand A lignin concentration (3.86%, P<0.0338).

Lignin concentration varied significantly among site-years (**Table 15**) from 2.7% at Melfort 2017, to 5.8% at Redvers 2018 (**Figure 24**). Lignin concentration was not consistent across years within sites.

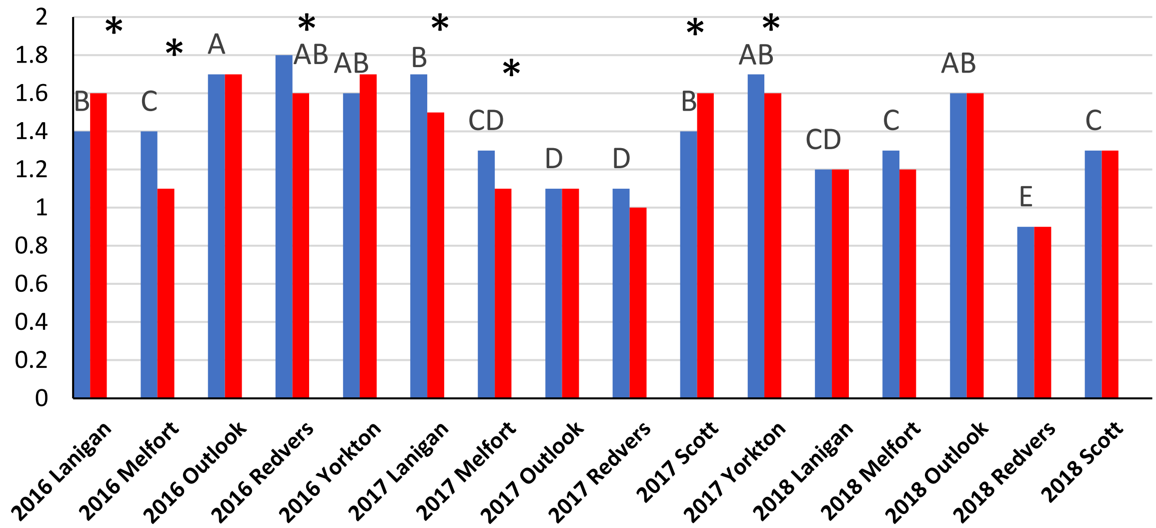

Figure 25. Fat concentration (%) as affected by site-year x brand interaction (P<0.0001) at 16 site-years in Saskatchewan. Asterisks indicate site-years where brands differed in fat concentration. Site-years (P<0.0001) topped by the same letters are not different by Tukey's HSD.

There was a significant site-year x brand interaction for fat concentration (**Table 15**) that resulted from Brand A corn exhibiting higher fat concentration at five site-years (**Figure 25**), Brand B exhibiting higher concentration than Brand A at two site-years, and no difference due to brand at ten site-years. Averaged over all 16 site-years, Brand A corn had higher fat concentration than Brand B (1.42% vs. 1.37%, P=0.0098).

Fat concentration was inconsistent across years within sites. For example, Redvers site reported among the highest fat concentration in 2016, but among the lowest in 2017 and 2018. Outlook had among the highest fat concentrations in 2016 and 2018, but among the lowest in 2017.

4.5.6 Minerals

Significant influences on mineral parameters are summarized in **Table 16**.

Table 16. ANOVA probabilities (P>F value) by source of variation for P, Ca, Mg, K, Cl, S, and ash concentrations of forage corn across 16 site-years in Saskatchewan.

Source	df	P	Ca	Mg	K	Cl	S	Ash
Replicate	2	0.1666	0.4811	0.9243	0.4555	0.2474	0.7961	0.6078
Site-Year (SY)	15	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
Brand (B)	1	0.9836	<.0001	<.0001	<.0001	<.0001	<.0001	0.0163
N rate (NR)	2	0.0002	<.0001	<.0001	<.0001	0.0329	<.0001	0.0203
Seeding rate (SR)	2	0.0204	0.9051	0.2545	0.0292	0.5019	0.0663	0.6919
SY x B	15	<.0001	<.0001	<.0001	0.0003	<.0001	<.0001	<.0001
SY x NR	30	0.8961	0.2213	0.4348	0.4403	0.8086	0.0086	0.1921
SY x SR	30	0.2243	0.4026	0.7189	0.2873	0.0016	0.3507	0.3873
B x NR	2	0.7275	0.0161	0.2854	0.1018	0.1189	0.3543	0.648
B x SR	2	0.6131	0.3611	0.3808	0.2263	0.4396	0.6716	0.9769
NR x SR	4	0.7721	0.2019	0.5431	0.9773	0.1853	0.5115	0.2422
SY x B x NR	30	0.899	0.6409	0.0719	0.7003	0.6359	0.2221	0.6978
SY x B x SR	30	0.4629	0.996	0.2999	0.9168	0.9432	0.7791	0.9067
SY x NR x SR	60	0.7987	0.9953	0.0853	0.3519	0.6164	0.641	0.9976
B x NR x SR	4	0.259	0.4727	0.6	0.2082	0.6362	0.6412	0.5541
SY x B x NR x SR	60	0.0315	0.8978	0.945	0.6056	0.6691	0.6185	0.9369

*Probabilities less than 0.05 are highlighted in red text, indicating a statistically significant effect at a 95% level of confidence. This means that there is a 95% or higher probability that the differences are due to treatment rather than natural variability.

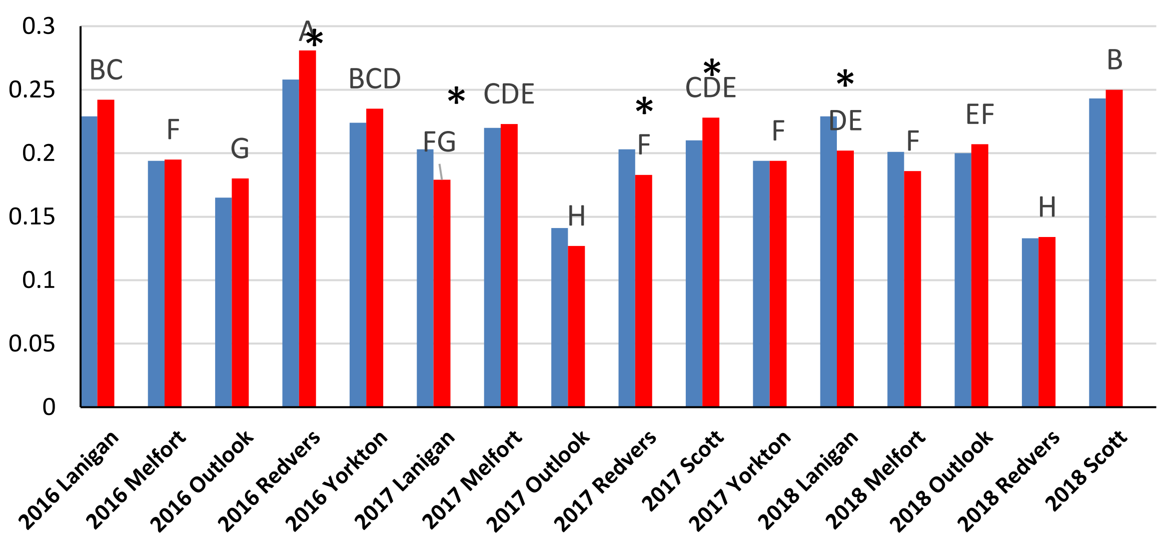

Figure 26. P concentration (%) as affected by site-year x brand interaction (P<0.0001) at 16 site-years in Saskatchewan. Asterisks indicate site-years where brands differed in P concentration. Site-years (P<0.0001) topped by the same letters are not different by Tukey's HSD.

There was a significant site-year x brand interaction (P<0.0001) for P concentration (**Table 16**). This resulted from higher P concentration in the Brand A corn at three site-years (**Figure 26**), higher P concentration in the Brand B corn at two site-years, and no difference due to brand at 11 site-years. There was no difference between brands for P concentration when averaged over all 16 site-years (**Table 16** and **Table 17**).

Site-years differed in P concentration ranging from 0.134% at Outlook 2017 and Redvers 2018, to 0.269% at Redvers in 2016 (**Figure 26**). P concentration was not consistent across years within sites. For example, Redvers 2016 was the highest P concentration observed at 0.269%, while Redvers 2018 was the lowest at 0.134%. In comparison, P concentration at Melfort ranged from 0.194% in 2016, to 0.221% in 2017, and to 0.193% in 2018.

N fertilizer increased P concentration at the highest fertilizer rate (**Table 18**).

Table 17. Mean P, Ca, Mg, K, Cl, S, and ash concentration (%) by seed brand.

Brand	P	Ca	Mg	K	Cl	S	Ash
A	0.203 a	0.246 a	0.154 a	0.84 b	0.182 b	0.095 a	4.55 a
B	0.203 a	0.220 b	0.141 b	0.91 a	0.203 a	0.091 b	4.44 b

* Means followed by the same letter are not significantly different as test by Tukey's HSD.

Table 18. Mean P, Ca, Mg, K, Cl, S, and ash concentration (%) by N fertilizer rate.

N-Rate	P	Ca	Mg	K	Cl	S	Ash
Low	0.199 b	0.219 c	0.142 b	0.84 c	0.184 a	0.088 c	4.42 a
Medium	0.201 b	0.234 b	0.149 a	0.88 b	0.196 ab	0.093 b	4.49 ab
High	0.209 a	0.245 a	0.153 a	0.92 a	0.198 a	0.098 a	4.58 a

* Means followed by the same letter are not significantly different as test by Tukey's HSD.

There was a significant site-year x brand interaction for Ca concentration (**Table 16**). The interaction resulted from Brand A corn exhibiting higher Ca concentration at seven site-years (**Figure 27**), Brand B exhibiting higher Ca concentration at Redvers 2017, and no difference between brands at the other eight site-years. Averaged over all site-years, the Brand A exhibited greater Ca concentration than Brand B (**Table 17**).

Site-years varied in Ca concentration (**Table 16**). Outlook 2017 exhibited the highest Ca concentration at 0.383%, while Melfort 2016 exhibited the lowest at 0.146% (**Figure 27**). The Melfort site exhibited among the lowest Ca concentration in all three years while other sites, such as Outlook, were not consistent in Ca concentration from year to year.

N fertilizer increased Ca concentration with each increment of fertilizer rate (**Table 18**).

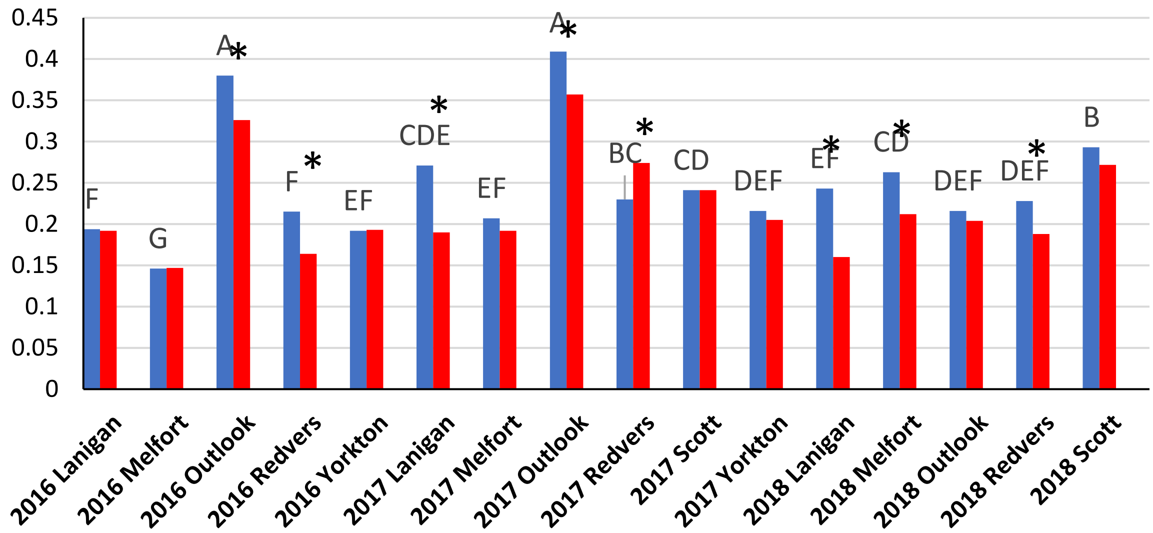

Figure 27. Calcium concentration (%) as affected by site-year x brand interaction (P<0.0001) at 16 site-years in Saskatchewan. Asterisks indicate site-years where brands differed in Ca concentration. Site-years (P<0.0001) topped by the same letters are not different by Tukey's HSD.

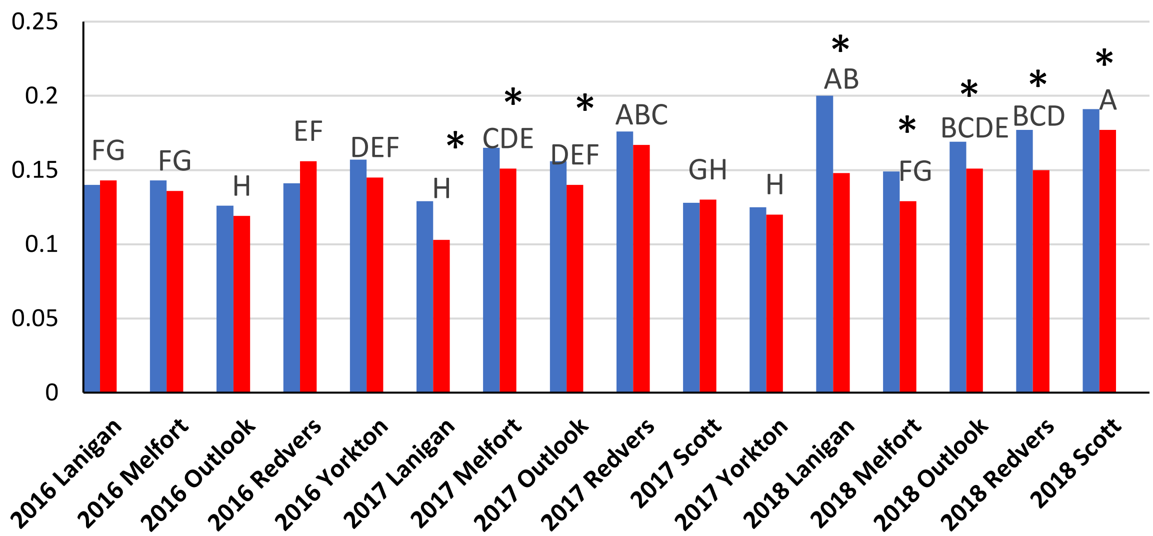

Figure 28. Magnesium concentration (%) as affected by site-year x brand interaction (P<0.0001) at 16 site-years in Saskatchewan. Asterisks indicate site-years where brands differed in Mg concentration. Site-years (P<0.0001) topped by the same letters are not different by Tukey's HSD.

There was a significant site-year x brand interaction for Mg concentration (**Table 16**), due to Brand A exhibiting higher levels at eight site-years than Brand B, while there was no difference at the other eight site-years (**Figure 28**). The site-years where the brands differed were clustered in 2017 (three site-years) and in 2018 (five site-years), which suggests that environmental conditions are involved in the expression of Mg concentration differences. When averaged over all 16 site-years, Brand A corn exhibited greater Mg concentration than Brand B corn (**Table 17**).

Site-years varied in mean Mg concentration (**Table 16**). Scott 2018 exhibited the greatest Mg concentration at 0.184%, while Lanigan 2017 exhibited the lowest at 0.116% (**Figure 28**).

Reducing the N rate resulted in less Mg in the corn (**Table 18**).

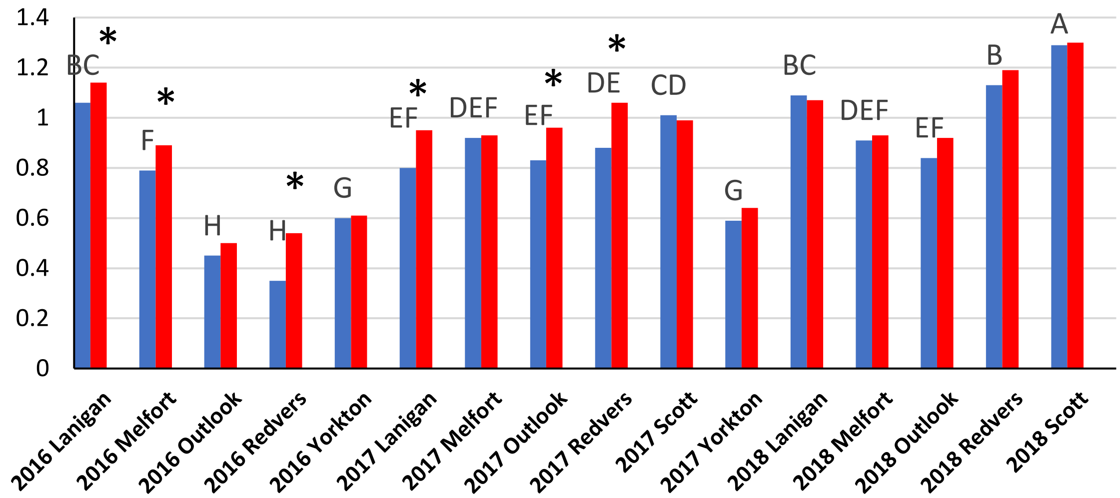

Figure 29. Potassium concentration (%) as affected by site-year x brand interaction (P<0.0001) at 16 site-years in Saskatchewan. Asterisks indicate site-years where brands differed in K concentration. Site-years (P<0.0001) topped by the same letters are not different by Tukey's HSD.

There was a significant site-year x brand interaction for K concentration (**Table 16**). This was the result of Brand B corn exhibiting greater K concentration than Brand A at six site-years, while there was no brand difference at the other ten site-years (**Figure 29**). When averaged over all 16 site-years, the Brand B exhibited greater K concentration than Brand A (**Table 17**).

Potassium concentration varied among site-years (**Table 16**, **Figure 29**). Scott 2018 had the greatest K concentration at 1.30%, while Redvers 2016 had the lowest at 0.45%. Year to year variation within sites for K concentration was evident at some sites, but not at others. For example, K concentration at Redvers ranged from 1.16% in 2018, to 0.45% in 2016. In contrast, at Lanigan K, concentration ranged from 1.08% in 2018, to 0.88% in 2017.

N fertility increased K concentration of the corn forage at each increment of fertilizer (**Table 18**).

Increasing seeding rate also affected K concentration (**Table 14**). High seeding rate exhibited higher K concentration (0.90%) than medium (0.87%) or low (0.87%) seeding rate.

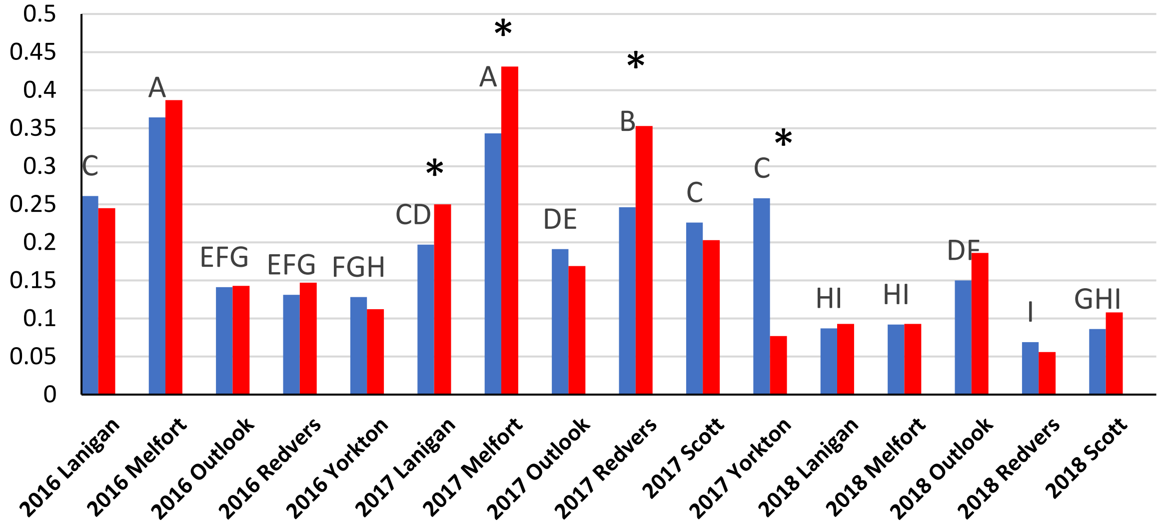

Figure 30. Chloride concentration (%) as affected by site-year x brand interaction (P<0.0001) at 16 site-years in Saskatchewan. Asterisks indicate site-years where brands differed in Cl concentration. Site-years (P<0.0001) topped by the same letters are not different by Tukey's HSD.

There was a significant site-year x brand interaction for Cl concentration (**Table 16**). Brand B exhibited greater Cl concentration at three site-years, while Brand A was greater at Yorkton 2017, and there was no difference at the other 12 site-years (**Figure 30**). When averaged over all site-years, Brand B had higher Cl concentration than Brand A (**Table 17**).

Site-years varied in Cl concentration (**Table 16**), with Melfort 2016 at 0.376% exhibiting the highest level, and Redvers at 0.062% exhibiting the lowest (**Figure 30**). The lowest levels were exhibited in 2018. Melfort Cl concentration varied from 0.376% in 2016, to 0.092% in 2018, so year to year variation within sites was common for Cl concentration.

N fertilization increased Cl concentration (**Table 18**).

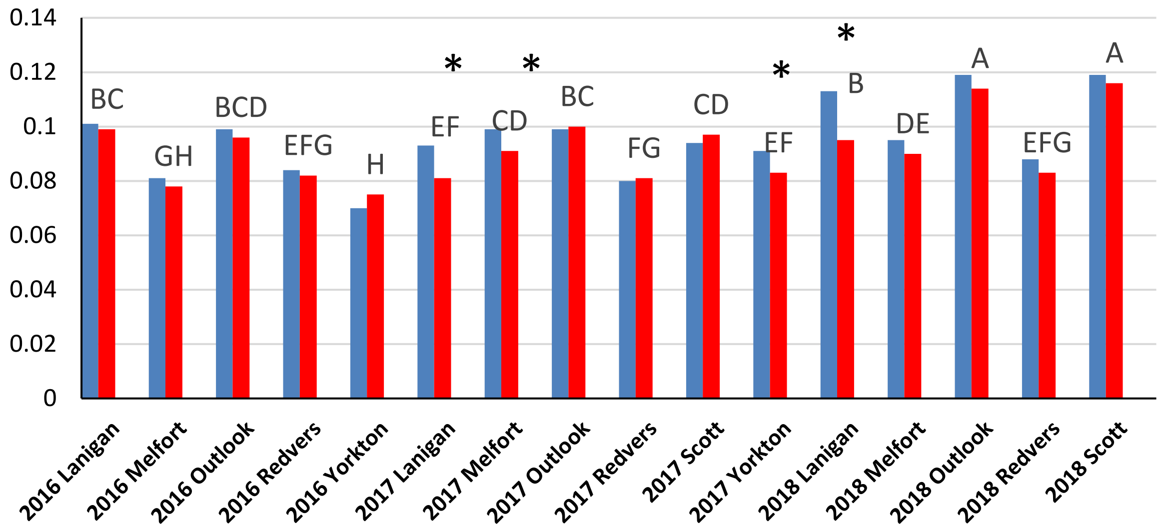

Figure 31. Sulfur concentration (%) as affected by site-year x brand interaction ($P<0.0001$) at 16 site-years in Saskatchewan. Asterisks indicate site-years where brands differed in S concentration. Site-years ($P<0.0001$) topped by the same letters are not different by Tukey's HSD.

There was a significant site-year x brand interaction for S concentration (**Table 16**). The interaction resulted from Brand A corn exhibiting greater S concentration at four site-years, while there was no difference due to brand at the other 12 site-years (**Figure 31**). Averaged over all site-years, the Brand A had greater S concentration than Brand B (**Table 17**).

Site-years varied for S concentration (**Table 16**) with Scott 2018 at 0.117%, the highest concentration, and Yorkton 2016 at 0.073%, the lowest concentration (**Figure 31**). Redvers was consistently among the lowest site-years, while Outlook was among the highest concentration sites.

Increasing N fertilizer increased S concentration (**Table 18**). The N fertilizer effect was significant at some site-years, but not others (data not shown), and this resulted in a significant site-year x N rate interaction that was observed for S concentration (**Table 16**).

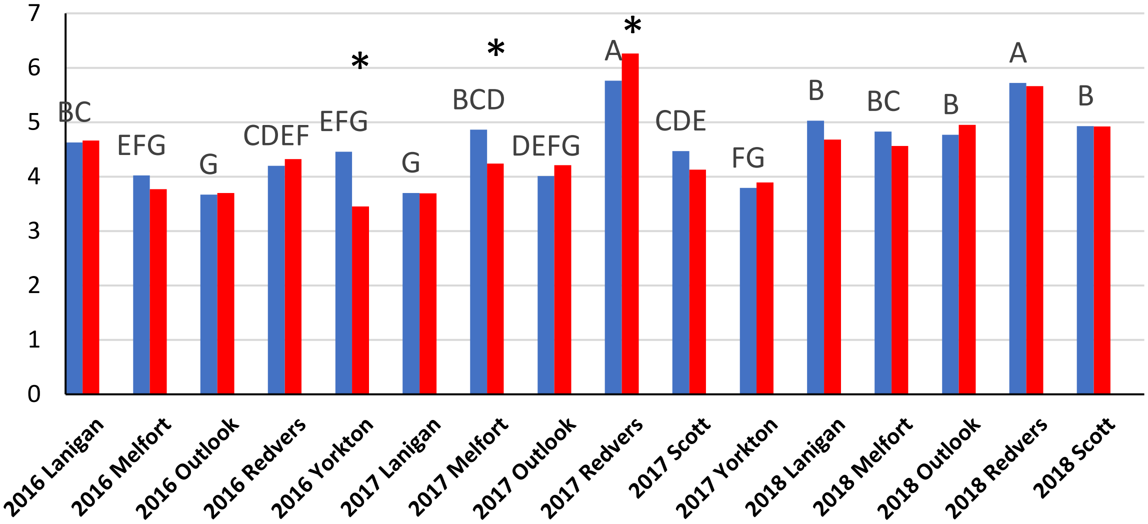

Figure 32. Ash concentration (%) as affected by site-year x brand interaction (P<0.0001) at 16 site-years in Saskatchewan. Asterisks indicate site-years where brands differed in Ash concentration. Site-years (P<0.0001) topped by the same letters are not different by Tukey's HSD.

There was a significant site-year x brand interaction for ash concentration (**Table 16**), due to Brand A exhibiting greater ash concentration as two site-years, while Brand B was greater at Redvers 2017 (**Figure 32**). When averaged over all site-years, Brand A corn had greater ash concentration than Brand B (**Table 17**).

Site-years varied for ash concentration (**Table 16**). Redvers 2017 exhibited the highest ash concentration at 6.01%, while Lanigan was the lowest at 2.70% (**Figure 20**). There was variation among years within sites for ash concentration. For example, Redvers had the highest ash concentration in 2017 and 2018, and among the lowest in 2016.
N fertilizer increased ash concentration (**Table 18**).

4.6 Cost of Production

The following section discusses the results of the economic analysis for growing corn forage in Saskatchewan. More specifically, the overall trends on how the seeding rate and nitrogen fertilizer rates effect the cost per metric ton of biomass yield.

As discussed in the methodology (**Section 3.4**), total cost per hectare was determined for each treatment at each site. This cost was then compared to the biomass yield to obtain a cost per yield or cost per metric ton. The average cost per metric ton of biomass yield was analyzed over the short season sites (Scott, Lanigan, and Melfort) as well as the long season sites (Yorkton, Outlook, and Redvers). The average total cost per metric ton of biomass yield of the short and long season sites can be found in **Table 19** and **Table 20**, respectively.

Table 19. Short season - average cost per metric ton of biomass yield.

Seed Rate	Low N-Rate	Mid N-Rate	High N-Rate
Low Seed Rate	107	110	112
Mid Seed Rate	114	115	119
High Seed Rate	126	130	123

Table 20. Long season - average cost per metric ton of biomass yield.

Seed Rate	Low N-Rate	Mid N-Rate	High N-Rate
Low Seed Rate	123	122	120
Mid Seed Rate	123	127	135
High Seed Rate	144	142	141

The corresponding graphs of the average total cost per metric ton for both the short and long season sites can be seen in **Figure 33** and **Figure 34**, respectively.

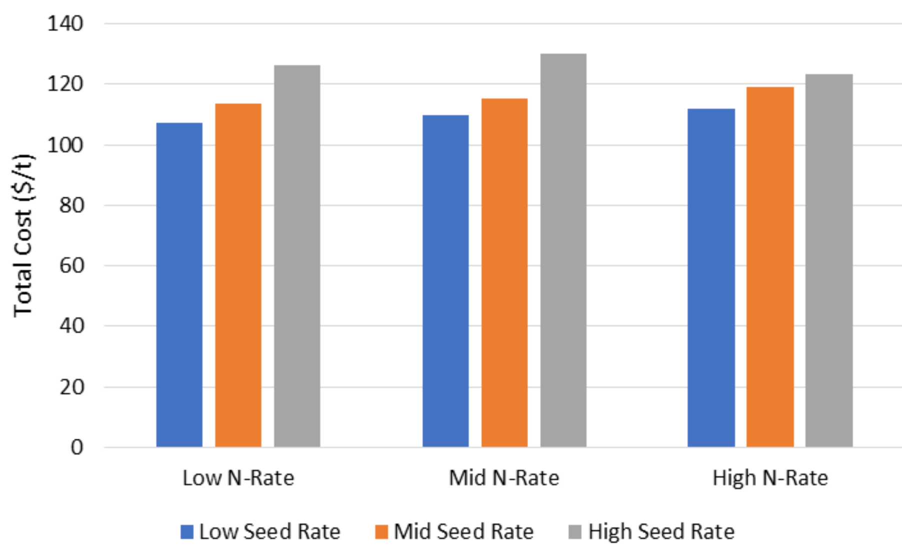

Figure 33. Short season - average cost per metric ton of biomass yield.

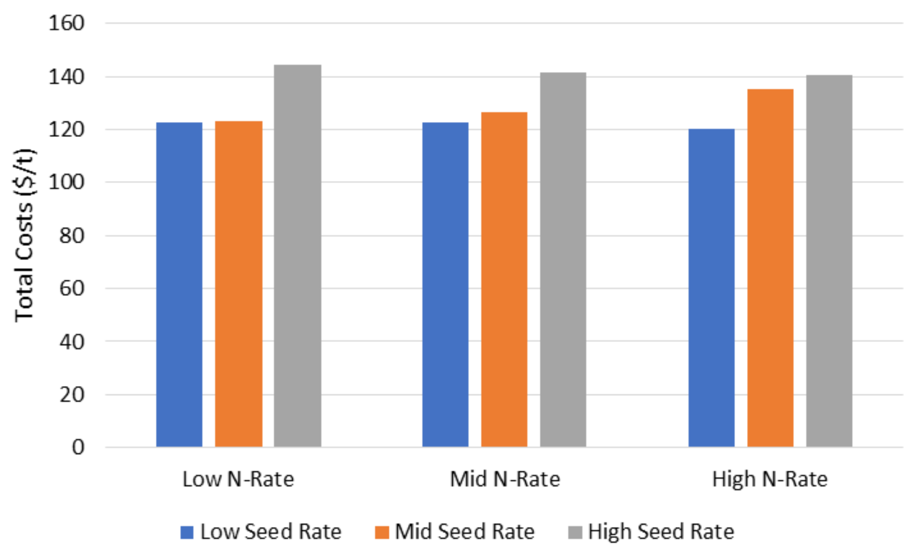

Figure 34. Long season - average cost per metric ton of biomass yield.

As seen from **Table 19** and **Figure 33,** the low seeding rate and low nitrogen rate resulted in the lowest cost per metric ton of biomass yield at $107/t for the short season sites. The costs increase relatively linearly with an increase in seeding rate and nitrogen rate with the highest cost per ton of biomass yield at 130 $/t (high seed rate and mid nitrogen rate). It is important to note, that the total costs are dominated by the seeding rate when compared to the nitrogen rate.

From **Table 20** and **Figure 34,** the low seeding rate and the high nitrogen rate resulted in the lowest cost per metric ton of biomass yield at $120/t for the long season sites. The highest cost per metric ton of biomass yield occurred at the high seed rate and low nitrogen rate at $144/t. The average costs again generally increased with an increase in seeding rate and nitrogen rate, as well the seeding rate showed to be the dominant factor in total cost when compared to nitrogen rate.

4.7 Results Summary

Forage DM corn yield in this report is higher than yields reported by Lardner et al. (2017) at Scott and Melfort. They found that corn averaged 10.0 Mg/ha at Scott, and 12.6 Mg/ha at Melfort averaged over three hybrids and three years (2012-2014). When averaged over two Brands, three seeding rates, three N rates and three years (2016-2018) in this study, Scott produced 12.0±1.8 Mg/ha, and Melfort produced 14.5±4.5 Mg/ha. These sites were the lowest yielding sites in our research, suggesting that forage corn has potential for greater DM forage yield than has been reported to date.

Hybrids differed in forage yield, protein, and digestibility in Alberta (Baron et al. 2006) similar to the results that we found. However, we found that brand x site-year interaction for yield and forage quality parameters were consistently significant while they reported significant interaction for digestibility, NDF, and ADF, but not forage yield and protein. In Northeastern USA, Cox and Cherney (2001) reported increased DM forage yield, NDF concentration, but decreased digestibility and CP concentration at higher seeding rate. They also found no interactions between seeding rate and N fertilizer rate for DM forage yield and forage quality.

The recommended seeding rate for corn production in Saskatchewan is 29,000 plants per acre, or 63,800 plants per hectare for Brown, Dark Brown, and Black soils zones (Saskatchewan Agriculture 2018), which is similar to the low seeding rate used in this study. Increasing the seeding rate in this study reduced CP and soluble protein, but increased DM forage yield. Based on seed prices from Saskatchewan Agriculture (2018) Crop Planner, an increase of 25,000 seeds /ha represents $75.00/ha greater seed expense, for an increased yield of 0.6 Mg/ha from low to medium, and 0.4 Mg /ha from medium to high. Baron et al. (2006) reported that DM forage yield of corn in Alberta reached a maximum level of 12.0 Mg/ha at the 100,000 (medium) plants/ha seeding. In this study, the medium seeding rate produced 15.4 Mg/ha of forage corn, and while the high seeding rate (125,000) produced 15.8 Mg/ha, the difference was statistically significant. Greater increases (1.0 Mg/ha) in forage corn yield with increased plant density was observed in Michigan USA (Widdicombe and Thelen, 2002).

Subedi et al. (2006) reported that hybrid, N fertilizer rate, and seeding rate were factors that affected forage yield in Ottawa. N and seeding rate increased corn forage yield, but there was no interaction of these factors. An optimum N rate was 150 lb N/ha across all seeding rates and hybrids.

Variation in response to the seeding rate across the corn zone of adaptation may be related to genetic potential to tolerate high interplant competition in high plant densities. Mansfield and Mumm (2013) reported genetic variability among corn hybrids for plant density up to 116,000 plants/ha. In their study of 32 hybrids for 48 phenotypic traits, testing resulted in identification of 5 hybrids with grain yield stability at increasing plant density (seeding rate). Further research on the genetic control of stability for forage yield at increasing seeding rates is needed.

Nitrogen fertilizer is one of the most important requirements for productive forage corn stands (Scheaffer et al. 2006; Budakli Carpici et al. 2010). The recommended N fertilizer rate for corn production in Saskatchewan is 112 kg/ha (Saskatchewan Agriculture 2018). Increasing the N fertilizer application resulted in greater DM forage yield at 225 kg/ha, but the increase was only 0.6 Mg/ha, and the increased CP and soluble protein concentration was only 0.99% and 0.36%, respectively. Scheaffer et al. (2006) similarly reported positive effects of N fertilization on CP concentration of silage corn.

Research results from other climatic regions have also reported increased corn DM yield with increased seeding rate (Cox and Cherney 2001; Coulter et al. 2010; Baghdadi et al. 2012; Mohammadi et al. 2012; Van Roekel and Coulter 2012; Karasahin 2014a). The highest seeding rate and highest silage yield in Ottawa Canada was 90,000 plants/ha (Subedi et al. 2006) which is similar to our optimum seeding rate of 100,000 plants/ha (medium). Increasing corn seeding rate reduced forage yield in drought prone environments in Montana (Allen 2012). Adequate summer precipitation for continued biomass growth, pollination and grain fill is needed for corn production in short-season regions.

Seeding rate resulted in lower CP and soluble protein in this research, which is similar to results of plant density in Michigan (Widdicombe and Thelen 2002) and Malaysia (Baghdadi et al. 2012), while Baron et al. (2006) reported no effect of seeding rate on CP. In Turkey, increasing seeding rate resulted in greater CP concentration of forage corn (Karashin 2014b). The requirement of mid-gestation beef cows for CP (NRC 2001) is 7% to 8%, so forage corn at some site-years in this study, such as Redvers 2018, would be too low to meet this requirement. Only 50% of the site-years in this study would not requirement CP supplementation for overwintering beef cow diets in the mid- to late-gestation physiological state. While increasing CP concentration was observed with N fertilization, it may be more economical to provide CP supplementation in a concentrate or pelleted form as suggested by Lardner et al. (2017).

The TDN requirements of mid-gestation, late-gestation, and early-lactation beef cows increases from 55% to 50% to 65%, respectively (NRC 2001). Thus, the forage corn in this study would be adequate for the energy requirements up to late-gestation stage of overwintering beef cows. In some site-years, such as Redvers 2018, the energy would be inadequate for beef cows at late gestation. At Outlook in 2016; however, the forage corn would be adequate for beef cows at early lactation stage. The TDN values in this study are consistent with the values reported by Lardner et al. (2017) at four sites across Alberta and Saskatchewan. The significant site-year x brand interaction and variation among site-years for TDN in this study reinforce the essential practice of feed testing forage corn prior to winter grazing to ensure that the nutrient requirements of the grazing animals are met.

Baron et al. (2006) reported a significant effect of seeding rate on NDF concentration, while we did not observe this. They also observed no interactions between seeding rate and hybrid as we report in this study. While plant density reduced digestibility and increased NDF in Michigan and Cornell, New York, there was no seeding rate x hybrid interaction for forage quality, which is consistent with our results (Widdicombe and Thelen 2002; Cox and Cherney 2011). Silage-specific corn hybrids grown in Cornell, USA, did not differ from dual-purpose hybrids in response to seeding rate (Cox and Cherney, 2011). The NDF concentrations in our study are consistent with those reported by Lardner et al. (2017). This study reports a variation in NDF digestibility, which has not been reported previously. Exploitation of variation in NDF digestibility in beef cow overwintering diets will require additional research.

This study no effect of seeding rate on corn sugar concentration. Ma et al. (2017) reported that increasing seeding rate of corn hybrids developed to express high stalk sugar concentration showed increased sugar concentration at increasing plant density (seeding rate). Response to seeding rate may depend on the trait of interest and its genetic potential for expression in forage corn.

Previous reports on grazing corn did not include comprehensive mineral analysis (Baron et al. 2006; Lardner et al 2017). The results show that P concentration (0.203%) was generally adequate for all stages of overwintering beef cow diets (NRC 2001), while Ca concentration (0.23%) would only be adequate for cows in mid-gestation stage of reproduction. Potassium concentration (0.88%) would be adequate for all stages, while Mg concentration (0.15%) would be adequate only for mid-gestation stage, and S concentration (0.09%) would be inadequate for all stages. Sodium concentration was ten times lower than required (0.007% vs. 0.07% [Rasby et al. 2011]). Salt and mineral supplementation can address the deficient minerals in a grazing corn situation. It should be noted; however, that many beef cow/calf producers have stopped mineral supplementation in periods of low economic returns as a cost-saving measure.

Some research results have suggested that increasing seeding rate results in decreased ability to take up soil N after silking and decreased yield (Yan et al. 2017). If these results were applicable to Saskatchewan conditions, then results would expect a significant seeding rate x N fertilizer rate interaction, but the study did not observe this interaction. Perhaps the environmental limitations (low CHU) of this region for corn production result in different responses to agronomic management factors here compared to the traditional corn production region of the Midwestern USA.

N fertilizer rate x site-year interaction was significant for forage DM yield and CP concentration, but not for other forage quality and mineral parameters. It can be concluded that the recommended N rate for corn production in Saskatchewan is generally adequate but, in some sites where growing conditions or edaphic factors either limit N availability or increase N demand by the corn crop, there was a response to applied N fertilizer. This represented about 12% of site-years for DM forage yield and 25% of the site-years for CP concentration.

The economic analysis showed that the lowest cost per biomass yield generally occurred with lower seeding rates and lower nitrogen fertilizer rates. This suggests that the higher costs of additional inputs from seed and fertilizer were not fully offset by higher yields and; therefore, resulted in a higher cost per biomass yield. From the data collected, it was shown that out of the three seeding rates applied (75,000, 100,000 and 125,000 plants/ha), the lowest seeding rate (75,000 plants/ha) resulted in the lowest costs per biomass yield across both the short season and long season sites. In addition, the costs per biomass yield was also generally reduced with lower nitrogen rates. The short season sites showed a strong correlation to lower costs per biomass yield with reduced nitrogen rates, with the lowest nitrogen rate 112.1 kg/ha (100 lb/ac), resulting in the lowest cost per biomass yield ($107 per tonne). The long season sites, however, did not show a strong correlation when relating cost per biomass yield to nitrogen rates and was generally dominated by seeding costs.

5. Conclusions

The research objectives of this project were to develop and refine seeding and fertility recommendations for corn silage production and to evaluate the cost of production and feed quality of corn silage grown in Western Canada. Upon completion of this research project, the following conclusions can be made in regards to the original objectives:

- Significant ‘site-year x brand’ interactions for forage yield and quality indicates that regional trial results will be useful for producer hybrid selection.
- Nitrogen fertilizer rate had a small and variable effect on forage yield and a significant effect on forage quality; current N-fertilizer rate recommendations for corn silage production in Saskatchewan are adequate.
- Increasing the seeding rate resulted in a higher forage yield, but a lower CP concentration.
- TDN was not affected by N-rate or seeding rates; mineral concentrations for all treatments were suitable for beef-cow wintering diets.
- The cost of production per tonne of biomass yield increased with seeding rate; increasing the nitrogen rate was only economically viable at the long-season sites.

5.1 Recommendations

Since there are significant site-year effects for forage quality, producers should always test the nutritional quality of the corn forage to confirm whether supplemental minerals are required based on nutritional requirements of their cattle.

6. Technology Transfer (Dissemination) Activities

A goal of this project was to provide cattle producers with agronomic recommendations for growing forage corn in Saskatchewan; results were (will be) disseminated in the form of presentations and technical reports.

6.1 Technical Reports

This final report will be made publicly available by ADF upon completion of the funding agreement. PAMI will issue a press release summarizing the major findings of the project and indicating that the full research results are available for producers.

6.2 Presentations

Preliminary three-year results were presented at the following two events:

- Corn Summit 2018, Regina, SK
- Soils and Crops Conference 2019, Saskatoon, SK

PAMI staff also participated at the following Agri-Arm Field Days over the course of the project:

- Outlook, 2017
- Scott (WARC), 2017
- Outlook, 2018

PAMI will continue to engage in producer presentations and workshops (as requested) as part of ongoing dissemination of knowledge by the organization.

7. References

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Appendix A – Detailed Seeding Information

Table A-1. Detailed information on seeding dates and conditions in 2016.

Site	Date Seeded	Seeding Depth [(1)], cm (in)	Soil Conditions at Seeding	Cropping History
Redvers	May 16, 2016	3.2 to 3.8 (1.3 to 1.5)	• Lighter soil • Flowed good had very good closure of furrow • Previously worked using plot drill that incorporated fertilizer • Seed placed in good moisture at furrow bottom • Some cereal stubble present from previous year • This site did not have the outer openers set at a higher pressure to compensate for the tractor tire compaction; therefore, rows 1 and 4 were seeding approx. 0.6 cm shallower	n/a
Yorkton	May 17, 2016	4.4 to 5 (1.7 to 2)	• Heavy soil (black clay) • Approximately 2.5 cm of crumbly dry soil on top • Previously worked using a cultivator, rough surface susceptible to moisture loss • Good moisture at seed placement • Some cereal stubble present from previous year	Wheat in 2014 Canola in 2015
Outlook	May 18, 2016	3.8 to 5 (1.5 to 2)	• High quality soil • Flowed good and had good closure at furrow • Moisture at furrow bottom, but soil was quite dry on top • Soil was tilled and therefore was consistent and smooth • Cereal stubble was again present	n/a
Melfort	May 25, 2016	1.8 to 6.4 (0.7 to 2.5)	• Heavy soil (black clay) • Soil surface was rough/crumbly and susceptible to moisture loss • Some cereal stubble present from previous year • Moisture at seed placement but not saturated	Canola in 2014 Peas in 2015
Scott	May 26, 2016	3.8 to 5 (1.5 to 2)	• High quality soil • Very good moisture (5 cm of rain 2 days before seeding) • Soil was tilled one day before seeding • Soil flowed good and had good closure on furrows • Overall the best conditions for seeding out of all the sites	Spring wheat in 2015
Lanigan	May 30, 2016	3.8 to 5.7 (1.5 to 2.2)	• Lots of stubble and trash from previous year (Corn and cereal stubble) • Soil was tilled to a depth of 3.8 to 5.7 cm • Good moisture at furrow bottom and furrow closed well • Trash guards on middle two rows did remove trash in front of openers and maintained the desired seeding depth (all other sites they did not engage due to the lack of trash)	Corn in 2014 (grazed) Barley in 2015

Table A-2. Detailed information on seeding dates and conditions in 2017.

Site	Date Seeded	Seeding Depth[1]	Soil Conditions at Seeding
Yorkton	May 16, 2017	3.8 to 5.1 cm 1.5 to 2.0 in	• Heavy soil (black clay) • Previously worked using a cultivator, at shallow depth smooth surface • Good moisture all the way to top of soil profile (rained 6.35 mm [0.25 in]) the night before) • Fair amount of cereal stubble present from previous year
Redvers	May 17, 2017	4.4 to 5.1 cm 1.75 to 2.0 in	• Lighter soil • Soil did not flow as nice due to high moisture content • Previously worked using plot drill that incorporated fertilizer • Soil was saturated throughout (12.7 mm [0.5 in] of rain the day before) • Some canola stubble present from previous year
Outlook	May 23, 2017	5.1 to 5.72 cm 2.0 to 2.25 in	• Dark brown, high quality soil • Good moisture at furrow bottom (2.54 cm [1 in] of moisture over seed) • Top inch of soil was dry due to pre-work, fertilizer application, and dry weather • Soil was clumpy in areas, susceptible to moisture loss, furrow still closed adequately • Pre-worked depth of 5.1 to 7.6 cm (2 to 3 in) • Small amounts of cereal stubble was present
Scott	May 30, 2017	4.4 to 5.1 cm 1.75 to 2.0 in	• Dark brown, high quality soil • Very good moisture (38.1 mm [1.5 in] of rain previous week) • Soil was tilled three days before seeding, pre-worked depth was roughly 3.81 cm (1.5 in) • Soil flowed good and had good closure on furrows • Overall the best conditions for seeding out of all the sites
Melfort	May 31, 2017	3.2 to 5.1 cm 1.25 to 2.0 in (most common was 4.45 cm or 1.75 in)	• Heavy soil (black clay) • Canola stubble present from previous year • Worked to 2.5 to 7.6 cm (1 to 3 in) depth (mostly 6.4 cm [2.5 in] as was shallower on tractor tire tracks) • Seeding depth varied more at this site due to working depth variance • Fairly clumpy soil, susceptible to moisture loss • Top 2.5 cm (1 in) of soil fairly dry but good moisture at furrow bottom
Lanigan	June 1, 2017	4.4 to 5.1 cm 1.75 to 2.0 in	• Good quality soil • Pre-worked (4.4 to 5.7 cm or 1.75 to 2.25 in) with tiller and fertilizer incorporation same day as seeding • Good moisture almost to the top of soil profile • Cereal stubble from previous year • Good closure of furrow

[1] Indicates that seeding depth is from seed to the top of the soil surface at packer wheel

Table A-3. Detailed information on seeding dates and conditions in 2018.

Site	Date Seeded	Seeding Depth*	Soil Conditions
Redvers	May 14, 2018	3.2 to 5.1 cm 1.25 to 2.0 in	• Heavy soil (black clay) • Plots are located on canola stubble • Fertilizer was applied with seeder so there are furrows running lengthways with plots at 10 in. row spacing • Dry soil due to not receiving rain this spring • Moisture found at 1 in.
Yorkton	May 15, 2018	4.4 to 5.1 cm 1.75 to 2.0 in	• Lighter soil • Moisture found at 1.75 in. (Very dry above) • Wheat stubble scattered amongst plots
Outlook	May 16, 2018	3.8 to 5.1 cm 1.5 to 2.0 in	• Good mellow black soil • Field had potatoes on it previously • Worked with a tillage implement containing a rolling basket (approx. 1.5 in. to 2 in. tillage depth) • Tillage resulted smooth surface, excellent for seed bed.
Scott	May 22, 2018	3.8 to 5.1 cm 1.5 to 2.0 in	• Dark brown, high quality soil • Relatively dry for top 1.5 in. • Seeded on top of canola stubble • Smooth surface resulted from tilling
Lanigan	May 29-30, 2018	5.1 to 6.4 cm 2.0 to 2.5 in	• Dark brown soil • Slight downhill slope from west to east • Summer fallowed last year • Moisture found at 2 in.
Melfort	May 30, 2018	4.4 to 5.1 cm 1.75 to 2.0 in	• Heavy soil (black clay) • Fairly hard packed soil • Top 1 in. had been worked • Good moisture at 1.75 in. • Cereal stubble from previous year

Table A-4. Actual fertilizer rates applied at each site in 2016. P, K, and S, respectively.

Site	N Rate	Nitrogen, N		Phosphorus, P		Potassium, K		Sulphur, S	
		kg/ha	lb/acre	kg/ha	lb/acre	kg/ha	lb/acre	kg/ha	lb/acre
Lanigan	low	56	50	0	0	0	0	0	0
	mid	112	100	0	0	0	0	0	0
	high	168	150	0	0	0	0	0	0
Scott	low	80	71	0	0	0	0	0	0
	mid	136	121	0	0	0	0	0	0
	high	192	171	0	0	0	0	0	0
Melfort	low	86	77	5.6	5	0	0	3.4	3
	mid	142	127	5.6	5	0	0	3.4	3
	high	198	177	5.6	5	0	0	3.4	3
Yorkton	low	191	170	34	30	0	0	0	0
	mid	312	278	34	30	0	0	0	0
	high	434	387	34	30	0	0	0	0
Outlook	low	92	82	0	0	0	0	0	0
	mid	148	132	0	0	0	0	0	0
	high	204	182	0	0	0	0	0	0

* Target nitrogen rate was 112, 168, and 225 kg N/ha (100, 150, and 200 lb N/acre) for the low, mid, and high N rates, respectively.

** The minimum concentrations for P, K, and S were 56, 140 and 16.8 kg/ha (50, 125 and 15 lb/acre) respectively.

*** Redvers fertility information was not available.

Table A-5. Actual fertilizer rates applied at each site in 2017.

Site	N Rate	Nitrogen, N		Phosphorus, P		Potassium, K		Sulphur, S	
		kg/ha	lb/acre	kg/ha	lb/acre	kg/ha	lb/acre	kg/ha	lb/acre
Lanigan	low	0	0	0	0	0	0	0	0
	mid	44.9	40	0	0	0	0	0	0
	high	101	90	0	0	0	0	0	0
Scott	low	80.9	72	0	0	0	0	0	0
	mid	137	122	0	0	0	0	0	0
	high	193	172	0	0	0	0	0	0
Melfort	low	86.5	77	5.6	5	0	0	3.4	3
	mid	143	127	5.6	5	0	0	3.4	3
	high	199	177	5.6	5	0	0	3.4	3
Yorkton	low	87.6	78	34	30	0	0	0	0
	mid	144	128	34	30	0	0	0	0
	high	200	178	34	30	0	0	0	0
Outlook	low	90	80	0	0	0	0	0	0
	mid	146	130	0	0	0	0	0	0
	high	202	180	0	0	0	0	0	0

* Target nitrogen rate was 112, 168, and 225 kg N/ha (100, 150, and 200 lb N/acre) for the low, mid, and high N rates, respectively.

** The minimum concentrations for P, K, and S were 56, 140 and 16.8 kg/ha (50, 125 and 15 lb/acre) respectively.

*** Redvers fertility information was not available.

Table A-6. Actual fertilizer rates applied at each site in 2018.

Site	N Rate	Nitrogen, N		Phosphorus, P		Potassium, K		Sulphur, S	
		kg/ha	lb/acre	kg/ha	lb/acre	kg/ha	lb/acre	kg/ha	lb/acre
Lanigan	low	21	18	0	0	0	0	0	0
	mid	77	68	0	0	0	0	0	0
	high	133	118	0	0	0	0	0	0
Scott	low	89	79	27	24	0	0	0	0
	mid	145	129	27	24	0	0	0	0
	high	201	179	27	24	0	0	0	0
Melfort	low	87	77	25	22	0	0	0	0
	mid	143	127	25	22	0	0	0	0
	high	199	177	25	22	0	0	0	0
Outlook	low	21	79	45	40	0	0	0	0
	mid	77	69	45	40	0	0	0	0
	high	133	119	45	40	0	0	0	0

* Target nitrogen rate was 112, 168, and 225 kg N/ha (100, 150, and 200 lb N/acre) for the low, mid, and high N rates, respectively.

** The minimum concentrations for P, K, and S were 56, 140 and 16.8 kg/ha (50, 125 and 15 lb/acre) respectively.

*** Redvers and Yorkton fertility information was not available.

Appendix B – Supplementary Yield Data

Table B-1. ANOVA probabilities for sources of variation by site-year for MC from 2016 to 2018 silage corn trial. Probabilities less than 0.05 are highlighted in red text.

Source	df	Lanigan	Melfort	Outlook	Redvers	Scott	Yorkton
				2016			
Brand (B)	1	0.008	0.743	0.102	0.023	0.164	0.544
N Rate (NR)	2	0.339	0.660	0.645	0.339	0.494	0.602
Seed Rate (SR)	2	0.575	0.279	0.382	0.391	0.578	0.331
B*NR	2	0.252	0.927	0.042	0.409	0.4360	0.474
B*SR	2	0.699	0.408	0.649	0.680	0.332	0.485
NR*SR	4	0.571	0.483	0.009	0.765	0.926	0.762
B*NR*SR	4	0.516	0.496	0.538	0.646	0.474	0.958
CV (%)		1.9	8.9	1.6	6.2	4.5	3.2
Mean		74.6	55.3	67.4	61.6	67.8	69.8
				2017			
Brand (B)	1	0.487	0.386	0.161	0.875	0.001	0.039
N Rate (NR)	2	0.510	0.083	0.002	0.220	0.010	0.490
Seed Rate (SR)	2	0.104	0.747	0.553	0.663	0.164	0.206
B*NR	2	0.712	0.270	0.368	0.945	0.033	0.478
B*SR	2	0.021	0.946	0.134	0.866	0.439	0.264
NR*SR	4	0.424	0.318	0.382	0.732	0.977	0.610
B*NR*SR	4	0.698	0.759	0.033	0.879	0.032	0.840
CV (%)		6.2	2.5	2.0	5.6	4.3	4.0
Mean		63.7	71.6	77.0	63.6	66.4	65.2
				2018			
Brand (B)	1	0.003	0.773	<0.001	0.011	0.064	0.186
N Rate (NR)	2	0.428	0.062	0.003	0.392	0.090	0.014
Seed Rate (SR)	2	0.361	0.175	0.118	0.004	0.671	0.680
B*NR	2	0.390	0.269	0.467	0.081	0.347	0.680
B*SR	2	0.530	0.969	0.373	0.855	0.158	0.532
NR*SR	4	0.481	0.367	0.094	0.948	0.293	0.560
B*NR*SR	4	0.814	0.731	0.953	0.553	0.642	0.734
CV (%)		5.8	8.4	2.1	8.1	2.3	3.8
Mean		72.0	68.6	68.3	54.5	69.6	63.1

Table B-2. Coefficient of variation (cv %) of original and outliers removed DM yield (Mg/ha) data by site-year from 2016 to 2018 silage corn trial.

Year	Site	Original data cv	# of outliers removed	Edited data cv
2016	Lanigan	10.1	1	9.2
	Melfort	16.4	0	
	Outlook	13.0	0	
	Redvers	7.8	4	6.6
	Scott	19.3	1	13.1
	Yorkton	10.4	1	9.5
2017	Lanigan	17.1	2	14.8
	Melfort	12.2	0	
	Outlook	8.1	2	6.6
	Redvers	11.3	2	9.4
	Scott	12.7	0	
	Yorkton	11.7	0	
2018	Lanigan	25.6	3	18.5
	Melfort	34.3	0	
	Outlook	6.4	1	6.1
	Redvers	10.6	0	
	Scott	10.8	0	

Table B-3. ANOVA probabilities by site and year for DM yield (kg/ha) from 2016 to 2018 silage corn trial. Probabilities less than 0.05 are highlighted in red text.

Source	df	Lanigan	Melfort[1]	Outlook	Redvers	Scott	Yorkton
				2016			
Brand (B)	1	0.002	0.494	0.032	0.452	<0.001	0.435
N Rate (NR)	2	0.061	0.607	0.290	0.612	0.091	0.005
Seed Rate (SR)	2	0.003	0.106	**0.059**	0.901	0.043	0.012
B*NR	2	0.688	0.381	<0.001	0.2760	0.744	0.716
B*SR	2	0.617	0.973	0.128	0.405	0.816	0.873
NR*SR	4	0.042	0.299	0.001	0.671	0.844	0.711
B*NR*SR	4	0.100	0.351	0.809	0.236	0.097	0.727
CV (%)		9.2	16.4	6.6	13.1	13.1	9.5
Mean		19.2	10.8	16.4	17.4	12.1	18.4
				2017			
Brand (B)	1	0.339	0.338[z]	<0.001	0.359	0.525	0.339
N Rate (NR)	2	0.109	0.067	0.595	0.099	0.890	0.077
Seed Rate (SR)	2	0.870	0.242	<0.001	0.254	0.849	0.022
B*NR	2	0.981	0.406	0.356	0.044	0.472	0.403
B*SR	2	0.930	0.920	0.650	0.309	0.776	0.407
NR*SR	4	0.456	0.897	0.246	0.623	0.926	0.160
B*NR*SR	4	0.196	0.682	0.186	0.447	0.798	0.977
CV (%)		14.8	12.1	6.6	9.4	15.6	13.5
Mean		14.0	17.8	18.4	15.1	12.7	14.4
				2018			
Brand (B)	1	0.232	0.088	<0.001	0.960	0.002	0.044
N Rate (NR)	2	0.983	0.064	0.967	0.350	0.007	0.010
Seed Rate (SR)	2	0.420	0.333	<0.001	0.318	0.794	0.962
B*NR	2	0.455	0.239	0.696	0.036	0.612	0.323
B*SR	2	0.391	0.706	0.917	0.407	0.580	0.067
NR*SR	4	0.651	0.796	0.734	0.555	0.652	0.536
B*NR*SR	4	0.776	0.881	0.543	0.371	0.137	0.238
CV (%)		18.5	34.3	6.1	10.6	10.8	7.8
Mean		12.3	15.2	18.8	15.6	11.4	13.8

[1] Melfort yield data is subject to edge effect due to errors in harvest protocol.

Table B-4. Mean DM yield (kg/ha) and moisture (%) by site-year with Tukey HSD mean separation results and standard errors.

Site-Year	DM yield	Tukey HSD group	Std Error	Moisture	Tukey HSD group	Std Error
2016 Lanigan	19.2	A	0.31	74.7	B	0.46
2018 Outlook	18.8	AB	0.31	68.3	EFG	0.46
2016 Yorkton	18.4	AB	0.31	69.8	CDE	0.46
2017 Outlook	18.4	AB	0.31	77.0	A	0.46
2017 Melfort	17.7	ABC	0.31	71.6	CD	0.46
2016 Redvers	17.4	BC	0.31	61.7	J	0.46
2016 Outlook	16.3	CD	0.33	67.3	FGH	0.46
2018 Redvers	15.6	DE	0.31	54.5	K	0.46
2018 Melfort	15.2	DEF	0.31	68.4	EFG	0.46
2017 Redvers	15.1	DEF	0.31	63.6	IJ	0.46
2017 Yorkton	14.3	EFG	0.31	65.2	HI	0.46
2017 Lanigan	14.0	FGH	0.31	63.7	IJ	0.46
2018 Lanigan	13.1	GHI	0.32	72.1	C	0.46
2017 Scott	12.7	HIJ	0.31	66.4	GH	0.46
2016 Scott	12.1	IJK	0.31	67.8	EFG	0.46
2018 Scott	11.4	JK	0.31	69.6	DEF	0.46
2016 Melfort	10.9	K	0.31	55.3	K	0.46

Table B-5. Mean DM yield (kg/ha) by site-year and hybrid seed brand including contrast results between brands within site-year and standard errors.

Site-Year	Brand A	Brand B	P>F contrast	SE
2016 Lanigan	20.0	18.4	0.008	0.43
2016 Melfort	11.0	10.7	0.584	0.50
2016 Outlook	16.0	16.6	0.336	0.43
2016 Redvers	17.2	17.7	0.442	0.43
2016 Scott	13.3	10.8	<0.001	0.44
2016 Yorkton	18.6	18.2	0.505	0.44
2017 Lanigan	14.3	13.7	0.382	0.45
2017 Melfort	17.5	18.0	0.345	0.44
2017 Outlook	17.7	19.1	0.030	0.44
2017 Redvers	15.3	15.0	0.656	0.44
2017 Scott	12.5	12.9	0.525	0.43
2017 Yorkton	14.1	14.6	0.442	0.43
2018 Lanigan	12.7	13.5	0.204	0.45
2018 Melfort	14.0	16.5	<0.001	0.43
2018 Outlook	18.1	19.4	0.047	0.44
2018 Redvers	15.6	15.7	0.971	0.43
2018 Scott	10.8	11.9	0.071	0.43

Table B-6. Mean DM yield (kg/ha) and moisture by N fertilizer rate with Tukey mean separation results and standard errors.

N fertilizer rate	DM yield	Tukey HSD group	SE	Moisture	Tukey HSD group	SE
High	15.6	A	0.130	67.2	A	0.19
Medium	15.4	AB	0.131	66.9	AB	0.19
Low	15.0	B	0.131	66.5	B	0.19

Table B-7. Mean DM yield (kg/ha) by site-year and N fertilizer rate with contrast comparison probabilities for linear and residual effects and standard errors.

Site-Year	Low	Medium	High	P>F linear contrast	P>F residual contrast	Std Error
2016 Lanigan	19.0	18.6	20.0	0.210	0.150	0.55
2016 Melfort	10.6	10.9	11.2	0.250	0.986	0.53
2016 Outlook	16.6	16.3	16.0	0.435	0.991	0.57
2016 Redvers	17.1	17.8	17.4	0.619	0.380	0.53
2016 Scott	11.3	12.2	12.7	0.057	0.785	0.53
2016 Yorkton	17.2	19.2	18.9	0.024	0.085	0.55
2017 Lanigan	13.1	14.3	14.6	0.061	0.472	0.55
2017 Melfort	18.8	17.1	17.4	0.062	0.153	0.53
2017 Outlook	18.4	18.5	18.2	0.745	0.693	0.55
2017 Redvers	14.7	15.7	15.0	0.761	0.179	0.55
2017 Scott	12.6	12.6	12.9	0.731	0.735	0.53
2017 Yorkton	14.4	15.0	13.6	0.273	0.133	0.53
2018 Lanigan	13.1	13.0	13.1	0.917	0.973	0.57
2018 Melfort	13.5	14.6	17.6	<0.001	0.151	0.53
2018 Outlook	18.7	18.8	18.8	0.900	0.927	0.53
2018 Redvers	16.0	15.7	15.2	0.282	0.864	0.53
2018 Scott	10.7	11.4	12.1	0.063	0.952	0.53

Table B-8. Mean DM yield (kg/ha) for seeding rates with Tukey HSD mean comparison results and standard errors.

Seeding rate	Mean	Tukey HSD group	SE
High	15.8	A	0.130
Medium	15.4	A	0.132
Low	14.8	B	0.130

Table B-9. Mean moisture (%) by site-year and hybrid seed brand including contrast results between brands within site-year and standard errors.

Site-Year	Brand A	Brand B	P>F contrast	SE
2016 Lanigan	75.2	74.1	0.245	0.43
2016 Melfort	55.1	55.5	0.632	0.50
2016 Outlook	67.1	67.6	0.590	0.43
2016 Redvers	60.4	62.9	0.008	0.43
2016 Scott	68.4	67.2	0.200	0.44
2016 Yorkton	70.0	69.6	0.679	0.44
2017 Lanigan	63.3	64.1	0.435	0.45
2017 Melfort	71.8	71.4	0.639	0.44
2017 Outlook	77.2	76.7	0.560	0.44
2017 Redvers	63.6	63.5	0.855	0.44
2017 Scott	67.5	65.2	0.014	0.43
2017 Yorkton	64.4	65.9	0.106	0.43
2018 Lanigan	73.9	70.2	<0.001	0.45
2018 Melfort	68.2	68.7	0.564	0.43
2018 Outlook	69.1	67.4	0.067	0.44
2018 Redvers	56.1	52.8	0.001	0.43
2018 Scott	70.0	69.1	0.283	0.43

Table B-10. Mean moisture (%) by site-year and seeding rate including contrasts for seeding rates with site-year and standard errors.

Site-Year	Low	Medium	High	P>F linear contrast	P>F residual contrast	SE
2016 Lanigan	74.4	74.8	74.8	0.694	0.851	0.80
2016 Melfort	54.5	56.8	54.5	0.984	0.019	0.80
2016 Outlook	67.0	67.4	67.5	0.669	0.889	0.80
2016 Redvers	60.7	62.5	61.8	0.340	0.216	0.80
2016 Scott	67.3	67.8	68.4	0.342	0.957	0.80
2016 Yorkton	67.3	67.8	69.9	0.654	0.359	0.80
2017 Lanigan	62.2	64.8	64.1	0.091	0.078	0.80
2017 Melfort	71.8	71.6	71.3	0.688	0.935	0.80
2017 Outlook	76.7	77.2	77.1	0.757	0.794	0.80
2017 Redvers	64.2	67.2	63.2	0.355	0.604	0.80
2017 Scott	65.8	66.2	67.2	0.209	0.727	0.80
2017 Yorkton	65.6	65.5	64.3	0.224	0.525	0.80
2018 Lanigan	71.9	71.1	73.1	0.301	0.141	0.80
2018 Melfort	70.6	67.3	67.4	0.004	0.089	0.83
2018 Outlook	68.5	67.6	68.7	0.844	0.363	0.83
2018 Redvers	52.1	53.9	57.4	<0.001	0.400	0.80
2018 Scott	69.6	69.8	69.3	0.848	0.731	0.80

Appendix C – Supplementary Forage Quality Data

Table C-1. Mean ADF, NDF, NDF digestibility, lignin and fat concentrations across site-years for two hybrids. Bolded means are significantly different within site-year as tested by contrast.

Site-Year	Brand	ADF	NDF	NDF digestibility	lignin	Fat
2016 Lanigan	Brand A	31.9	50.0	39.0	3.0	**1.4**
	Brand B	31.9	49.9	38.5	3.0	**1.6**
2016 Melfort	Brand A	**36.1**	**54.5**	**44.9**	3.5	**1.4**
	Brand B	**39.7**	**59.4**	**50.1**	3.5	**1.1**
2016 Outlook	Brand A	26.6	43.9	36.7	3.9	1.7
	Brand B	26.9	43.7	36.4	3.7	1.7
2016 Redvers	Brand A	28.7	**45.4**	39.6	3.0	**1.8**
	Brand B	30.4	**48.6**	39.9	3.4	**1.6**
2016 Yorkton	Brand A	33.6	53.3	43.0	3.6	1.6
	Brand B	32.9	52.7	42.9	3.2	1.7
2017 Lanigan	Brand A	**30.2**	**51.1**	**39.2**	**3.4**	**1.7**
	Brand B	**36.0**	**56.8**	**42.7**	**3.8**	**1.5**
2017 Melfort	Brand A	**32.1**	**51.2**	**39.1**	**2.4**	**1.3**
	Brand B	**35.5**	**53.9**	**41.9**	**2.8**	**1.1**
2017 Outlook	Brand A	33.3	58.4	40.7	5.0	1.1
	Brand B	34.3	58.5	40.1	5.1	1.1
2017 Redvers	Brand A	39.0	**61.8**	**48.9**	**3.9**	1.1
	Brand B	**42.5**	**67.0**	**52.8**	**4.6**	1.0
2017 Scott	Brand A	**32.1**	**53.7**	**37.8**	**3.8**	**1.4**
	Brand B	**30.1**	**50.0**	**35.3**	**3.3**	**1.6**
2017 Yorkton	Brand A	**32.2**	51.7	42.3	3.5	**1.7**
	Brand B	**34.8**	54.1	43.4	3.5	**1.6**
2018 Lanigan	Brand A	**33.1**	**57.1**	**41.0**	4.7	1.2
	Brand B	**35.8**	**60.5**	**44.0**	4.9	1.2
2018 Melfort	Brand A	**32.7**	**55.1**	**44.3**	**4.2**	1.3
	Brand B	**35.6**	**58.0**	**46.6**	**4.7**	1.2
2018 Outlook	Brand A	23.9	44.9	33.4	3.5	1.6
	Brand B	23.7	44.2	32.4	3.5	1.6
2018 Redvers	Brand A	41.1	**69.7**	50.5	5.7	0.9
	Brand B	42.8	**72.3**	52.0	5.9	0.9
2018 Scott	Brand A	32.3	54.5	39.9	4.6	1.3
	Brand B	31.3	52.7	38.5	4.4	1.3

Table C-2. Mean ADF, NDF, NDF digestibilityestibility, lignin, and fat concentration by site-year. Means followed by the same letter are not significantly different as tested by Tukey's HSD.

Site-Year	ADF		NDF		NDF digestibility		Lignin		Fat	
2016 Lanigan	31.9	DEF	49.9	GH	38.8	EF	3.0	GH	1.5	B
2016 Melfort	37.9	B	56.9	CD	47.5	B	3.5	EF	1.3	C
2016 Outlook	26.7	H	43.8	I	36.5	F	3.8	E	1.7	A
2016 Redvers	29.6	G	47.0	HI	39.7	E	3.2	FG	1.7	AB
2016 Yorkton	33.2	CDEF	53.0	EFG	43.0	CD	3.4	EFG	1.7	AB
2017 Lanigan	33.1	CDEF	53.9	DEF	40.9	DE	3.6	EF	1.6	B
2017 Melfort	33.8	CDE	52.5	FG	40.5	DE	2.6	H	1.2	CD
2017 Outlook	33.8	CDE	58.5	C	40.4	DE	5.1	B	1.1	D
2017 Redvers	40.8	A	64.4	B	50.8	A	4.3	D	1.1	D
2017 Scott	31.1	FG	51.8	FG	36.6	F	3.5	EF	1.5	B
2017 Yorkton	33.5	CDE	52.9	FG	42.8	D	3.5	EF	1.7	AB
2018 Lanigan	34.5	C	58.8	C	42.5	D	4.8	BC	1.2	CD
2018 Melfort	34.1	CD	56.5	CDE	45.5	BC	4.4	CD	1.3	C
2018 Outlook	23.8	I	44.5	I	32.9	G	3.5	EF	1.6	AB
2018 Redvers	41.9	A	71.0	A	51.2	A	5.8	A	0.9	E
2018 Scott	31.8	EFG	53.6	EF	39.2	E	4.5	CD	1.3	C

Table C-3. Mean ADF, NDF, NDF dig, lignin, and fat concentration by hybrid.

Brand	ADF		NDF		NDF digestibility		Lignin		Fat	
A	32.4	B	53.5	B	41.2	B	3.86	B	1.42	A
B	34.0	A	55.1	A	42.3	A	3.95	A	1.37	B

Table C-4. Mean P, Ca, Mg, K, Cl, S, and ash concentration (%) by site-year and brand. Bolded means within site-year are significantly different brand means as tested by contrast.

Site Year	Brand	P	Ca	Mg	K	Cl	S	Ash
Lanigan 2016	A	0.229	0.194	0.140	**1.06**	0.261	0.101	4.63
	B	0.242	0.192	0.143	**1.14**	0.245	0.099	4.66
Melfort 2016	A	0.194	0.146	0.143	**0.79**	0.364	0.081	4.02
	B	0.195	0.147	0.136	**0.89**	0.387	0.078	3.77
Outlook 2016	A	0.165	**0.380**	0.126	0.45	0.141	0.099	3.67
	B	0.180	**0.326**	0.119	0.50	0.143	0.096	3.70
Redvers 2016	A	**0.258**	**0.215**	0.141	**0.35**	0.131	0.084	4.20
	B	**0.281**	**0.164**	0.153	**0.54**	0.147	0.082	4.32
Yorkton 2016	A	0.224	0.192	0.157	0.60	0.128	0.070	**4.46**
	B	0.235	0.193	0.145	0.61	0.112	0.075	**3.45**
Lanigan 2017	A	0.203	**0.271**	**0.129**	**0.80**	**0.197**	**0.093**	3.70
	B	**0.179**	**0.190**	**0.103**	**0.95**	**0.250**	**0.081**	3.69
Melfort 2017	A	**0.220**	0.207	**0.165**	0.92	**0.343**	**0.099**	**4.85**
	B	0.223	0.192	**0.151**	0.93	**0.431**	**0.091**	**4.24**
Outlook 2017	A	0.141	**0.409**	**0.156**	**0.83**	0.191	0.099	4.01
	B	0.127	**0.357**	**0.140**	**0.96**	0.169	0.100	4.21
Redvers 2017	A	**0.203**	**0.230**	0.176	**0.88**	**0.246**	0.080	**5.76**
	B	**0.183**	**0.274**	0.167	**1.06**	**0.353**	0.081	**6.26**
Scott 2017	A	**0.210**	0.241	0.128	1.01	0.236	0.094	4.47
	B	**0.228**	0.241	0.130	0.99	0.226	0.097	4.13
Yorkton 2017	A	0.194	0.216	0.125	0.59	**0.203**	**0.091**	3.79
	B	0.194	0.205	0.120	0.64	**0.258**	**0.083**	3.89
Lanigan 2018	A	**0.229**	**0.243**	**0.200**	1.09	0.077	**0.113**	5.03
	B	**0.202**	**0.160**	**0.148**	1.07	0.087	**0.095**	4.68
Melfort 2018	A	0.201	**0.263**	**0.149**	0.91	0.092	0.095	4.83
	B	0.186	**0.212**	**0.129**	0.93	0.093	0.090	4.56
Outlook 2018	A	0.200	0.216	**0.169**	0.84	0.150	0.119	4.77
	B	0.207	0.204	**0.151**	0.92	0.186	0.114	4.95
Redvers 2018	A	0.133	**0.228**	**0.177**	1.13	0.069	0.088	5.72
	B	0.134	**0.188**	**0.150**	1.19	0.056	0.083	5.66
Scott 2018	A	0.243	0.293	**0.191**	1.29	0.086	0.119	4.93
	B	0.250	0.272	**0.177**	1.30	0.108	0.116	4.92

Table C-5. Mean P, Ca, Mg, K, Cl, S, and ash concentration (%) by site-year. Means followed by the same letter are not significantly different.

Site-Year	P	Ca	Mg	K	Cl	S	Ash
Lanigan 2016	0.236 bc	0.193 f	0.141 fg	1.10 bc	0.253 c	0.100 bc	4.64 bc
Melfort 2016	0.194 f	0.146 g	0.139 fg	0.84 f	0.376 a	0.080 gh	3.90 efg
Outlook 2016	0.173 g	0.353 a	0.123 h	0.48 h	0.142 efg	0.097 bcd	3.69 g
Redvers 2016	0.269 a	0.189 f	0.147 ef	0.45 h	0.139 efg	0.083 efg	4.26 cdef
Yorkton 2016	0.229 bcd	0.192 ef	0.151 def	0.60 g	0.120 fgh	0.073 h	3.96 efg
Lanigan 2017	0.191 fg	0.231 cde	0.116 h	0.88 ef	0.224 vf	0.087 ef	3.70 g
Melfort 2017	0.221 cde	0.200 ef	0.158 cde	0.92 def	0.387 s	0.095 cd	4.54 bcd
Outlook 2017	0.134 h	0.383 a	0.148 ef	0.90 ef	0.180 fr	0.100 bc	4.11 defg
Redvers 2017	0.193 f	0.252 bc	0.172 abc	0.97 de	0.300 n	0.081 fg	6.01 a
Scott 2017	0.219 cde	0.241 cd	0.129 gh	1.00 cd	0.231 c	0.095 cd	4.30 cde
Yorkton 2017	0.194 f	0.210 def	0.123 h	0.61 g	0.231 c	0.087 ef	3.84 fg
Lanigan 2018	0.216 de	0.201 ef	0.174 ab	1.08 bc	0.082 h	0.104 b	4.86 b
Melfort 2018	0.193 f	0.237 cd	0.139 fg	0.92 def	0.092 hi	0.092 de	4.70 bc
Outlook 2018	0.204 ef	0.210d ef	0.160bcde	0.88 ef	0.168 hi	0.116 a	4.86 b
Redvers 2018	0.134 h	0.208 def	0.163 bcd	1.16 b	0.062 df	0.086 efg	5.69 a
Scott 2018	0.246 b	0.283 b	0.184 a	1.30 a	0.097 ghi	0.117 a	4.92 b

Appendix D – Supplementary Economic Data

Table D-1. Breakdown of “Variable” and “Other” Expenses for Corn Production (Crop Planning Guide, 2018).

	Soil Zones		
	Black	**Dark Brown**	**Brown**
Expenses Per Acre			
Variable Expenses/Acre			
Seed	$87.00	$87.00	$87.00
Fertilizer			
Nitrogen	50.91	38.53	43.57
Phosphorous	23.51	17.86	20.22
Sulphur and Other	0.00	0.00	0.00
Chemical			
Herbicide	35.76	35.76	35.76
Insecticide/Fungicide	0.00	0.00	0.00
Seed Treatment/Inoculants	0.00	0.00	0.00
Machinery Operating			
Fuel	24.73	22.26	21.14
Repair	12.11	10.87	9.81
Custom Work and Hired Labour	54.96	42.18	45.74
Crop Insurance Premium	11.93	11.93	11.93
Utilities and Miscellaneous	4.97	4.31	3.28
Interest on Variable Expenses	7.65	6.77	6.96
Total Variable Expenses (D)	**$313.53**	**$277.47**	**$285.41**
Other Expenses/Acre			
Building Repair	$0.84	$0.62	$0.46
Property Taxes	7.46	4.92	3.76
Business Overhead	3.37	2.87	1.88
Machinery Depreciation	50.09	44.98	40.59
Building Depreciation	1.90	1.40	1.05
Machinery Investment	35.11	31.53	28.45
Building Investment	1.16	0.86	0.64
Land Investment	48.26	43.12	37.18
Total Other Expenses (E)	**$148.19**	**$130.30**	**$114.01**

* Note the standard cost of seed and nitrogen in the above table was omitted in the total costs analysis, as these costs were accounted for using per/unit costs so that the varying seeding/nitrogen rates could be accounted for.

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