RESEARCH AND DEVELOPMENT PROGRAM
FINAL REPORT

Section A: Project overview

1. Project number: AIP-P293

2. Project title: Greater economic returns and enhanced ecosystem services through the expansion of winter wheat production

   Abbreviations:

3. Research team information

a) Principal Investigator	
Name	**Institution**
Ken Coles	Farming Smarter

b) Research team members (List names of all team members. Add more lines as needed)	
Name	**Institution**
Melissa Freeman	West Central Forage Association

4. Project start date (yyyy/mm/dd): 2014/04/01
5. Project completion date (yyyy/mm/dd): 2018/04/30
6. Project final report date (yyyy/mm/dd): 2018/04/30

Section B: Non-technical summary (max 1 page)

Provide a summary of the project results which could be used by XXX for communication to industry stakeholders (e.g., producers, processors, retailers, extension personnel, etc.) and/or the general public. This summary should give a brief background as to why the project was carried out, what were the principal outcomes and key messages, how these outcomes and key messages will advance the livestock and meat industry, how they will impact industry stakeholders and/or consumers, and what are the economic benefits for the industry.

A producer near Medicine Hat, Alberta successfully grazes cattle on late summer seeded winter wheat and winter triticale from October to April and is able to harvest a silage crop in the following year. This raised questions about whether grazing winter cereals has an economic justification? If yes, which winter cereals and varieties would perform the best? This research project addressed those questions and dug into the approach that maximizes returns from the land while minimizing costs associated with stored feed. Farming Smarter partnered with West Central Forage Association (WCFA) and the project received three years funding from Ducks Unlimited Canada (DUC).

Scott Lehr of Short Grass Ranches hosted our plots on land he seeded with winter wheat and grazed throughout the winter. We seeded different plots and then filled in the pathways and spaces so we had a solid seeded field. We believed this would reduce any selection by the animals and reduce overgrazing or avoidance of the plots with the bare ground surrounding them.

Trial 1 # Winter Cereal Grazing (crop type, cultivar, and seed treatment)

This trial tested best options for crop type (fall rye, winter triticale, winter wheat and some blends) a forage vs. grain variety and a fungicide/insecticide seed treatment (Cruiser Maxx Vibrance Cereals (CMVC)) versus non-treatment (Check). Two identical trials were seeded side by side with one grazed and the the other fenced off and not grazed.

Objective:

- Evaluate the economic and agronomic potential of winter grazing systems on winter cereal production
- Effect on biomass (silage) yield
- Differences in crop type and variety
- Differences in winter survival with a seed treatment
- Determine if there is an economic benefit or cost of silage value for grazed vs. ungrazed and potential to carry the crop through to yield

The study showed that cultivar selection had significant effect on fall and spring plant density. Also, grazing significantly lowered spring survival vs. ungrazed (T-test, $P<0.00001$). The same result is seen for winter survival except for the year 2017.
However, winter cereals demonstrated that they can withstand the removal of the above ground biomass and continue to grow after grazing. Between grazed cereals, fall rye (Hazlet 78%, Prima 88%) and winter triticale (Luoma 88%, Fridge 89%) have higher survival rates compared to winter wheat (Moats 69%, Ptatmigan 75%). In general, the study demonstrated that grazing significantly impacted survival in different crops and cultivars, but not by treatment of CMVC and check. Contrary to survival, fall biomass did not show significant differences among the cultivars. Statistically, Fridge winter triticale (11.45 T/ha) had the highest total biomass and Prima fall rye (9.02 T/ha) had the lowest. Fall biomass had significantly richer nutrients for feed value over silage. Also, grazing increased yield in all years. The highest averaged yield belongs to grazed Luoma triticale (91 bu/ha) and the lowest is an ungrazed blend of Ptarmigan winter wheat with

Prima fall rye (66 bu/ha). WCFA collected dry matter data after harvest for winter triticale, fall rye, and some blends cultivars measured by combining four sub samples for each crop and cultivar in check and treated, under grazing and ungrazed. Comparing the dry matter value between check and treated does not illustrate a specific result and it varies highly between different crops in grazed and ungrazed, so we can not say whether or not treatment has a direct effect on dry matter after harvest. More studies and investigation could focus on the effect of different treatments on yield to answer this question.

Comparing feed values between fall and silage biomasses shows that fall biomass has significantly higher amounts of protein, copper, sodium, phosphorous, relative feed value (RFV), total digestible nutrients (TDN), magnesium, potassium, iron, manganese, zinc, sulfur, dry matter intake (DMI), net energy for lactation (NEL), net energy for maintenance (NEM), digestible energy (DE), metabolizable energy (ME), net energy for growth (NEG). But some of the elements, such as neutral detergent fibre (NDF) and acid detergent fibre (ADF), show lower values in fall biomass. However calcium value remained constant in both fall and silage biomasses. The maximum variability between feed elements of different crops and cultivars appeared in iron, manganese, zinc, and RFV respectively. The highest averaged value of iron belongs to fall rye Prima (387.5) and winter wheat Moats (209.3) had the lowest iron. Comparing the feed elements in totall silage and fall biomass shows that iron, zinc, and RFV have the maximum variability between different crops and cultivars in fall biomass. (Appendix 4, Table 5).
Comparing feed elemets of WCFA data, shows that ungrazed triticale Fridge (Cruiser) and Luoma (Check) showed the maximum yearly average values of crude protein (CP) (8.7%) occured in 2015 (Appendix 4, Table 8). Grazed blend of triticale Fridge (Check) and winter wheat Ptarmigan, rye Prima (Check), triticale Fridge (CMVC), and triticale Louma (Check) had the maximum value of TDN (about 70) in 2015 (Appendix 4, Table 9). For the other measured elements by WCFA (potassium, calcium, phosphorus, and magnesium) no obvious variability apparent. More results are in the report details.

Trial 2 # Winter Wheat Seeding Date

This trial looked for the optimum seeding dates for some varieties of fall grazed winter wheat. We performed a two-factor study considering different seeding dates for winter wheat, different winter wheat cultivars and effects of fungicide/insecticide treatment (Cruiser Maxx Vibrance Cereals CMVC) and non-treatment (Check) under grazing and ungrazed.

Objective:

- Determine the effect of different seeding dates on winter wheat varieties Moats and Ptarmigan
- Determine the potential differences between Ptarmigan and Moats
- Quantify potential differences in winter survival with the application of a seed treatment and without

Early seeding from early to mid-August increases the fall biomass, but decreases winter survival and yield. The optimal seeding period for Moats and Ptarmigan winter wheat is the first two weeks of September. Silage biomass (around 8 T/ha) of winter wheat in different seeding dates showed higher values vs fall biomass (around 2 T/ha). The grazed plots showed an increased yield in both wheat cultivars. Moats had an 11 bu/ac higher yield on average than Ptarmigan in the ungrazed plots (Appendix 4, Table 7).

Section C: Project details

1. Project team (max ½ page)

Describe the contribution of each member of the R&D team to the functioning of the project. Also, describe any changes to the team which occurred over the course of the project.

Ken Coles of Farming Smarter led the project and supervised the site in Medicine Hat, AB. Technical staffs are Mike Gretzinger, Jamie Puchinger, Toby Mandel, and Lewis Baarda. Farming Smarter seeded and harvested the Medicine Hat location. Carla Amonson initially managed the WCFA site, and was replaced by Melissa Freeman.

2. Background (max 1 page)

Describe the project background and include the related scientific and development work that has been completed to date by your team and/or others.

Alberta is a region with short growing seasons, therefore cattle producers feed conserved forage more than half of each year. Prolonging the grazing season in fall or spring could have significant economic benefits for ranchers (Baron et al., 1999). Over the past decades on the Canadian prairies, cattle producers experimented with fall-seeded winter crops, such as wheat and rye, as supplemental grazed forage during fall and spring before harvesting (Salmon et al., 1993). Also according to Jefferson et al. 2008, cattle can graze spring-seeded winter annual crops, such as winter wheat, winter triticale and fall rye, during the growing season because the crops do not complete their life cycle and set seed until they are exposed to low temperatures. Some studies found that using fall-seeded wheat and rye for grazing coupled with adverse weather and production conditions could reduce grain yield severely (Christiansen et al., 1989 and Kilcher 1982). Weather, timing and production conditions play vital roles in grain yield success (Holliday 1956).

Under well-controlled production conditions, Sprague (1954) and Poysa (1985) reported an increase in yields of winter wheat and winter triticale (X Triticosecale Wittmack L.) after grazing. Also, May et al. in 2007 showed that oat and barley needs careful timing to avoid yield reduction and they are poor grains for gazing.

Poor timing in seeding and a delay in harvesting both have negative effects on yield and nutrient content. Thus, postponing the harvest will cause a decrease in protein level for most of the crops. The main goal of this study was to determine the feasibility of double cropping winter cereals (grazed and silage crop). It looked at the growing conditions and agronomic practices that provided the best economics of this production system.

3. Objectives and deliverables (max 1 page)

State what the original objective(s) and expected deliverable(s) of the project were. Also, describe any modifications to the objective(s) and deliverable(s) which occurred over the course of the project.

In this research project, our target was to discover optimal agronomic practices that would enhance ecosystem services through the expansion of winter wheat production in southern Alberta. The second goal was to evaluate the economic and agronomic potential of winter grazing systems on winter cereal production.

The project ran for four years (2014-2017) with trials in Medicine Hat and Evansburg observing the following agronomic parameters:

- Different winter crops (F. Rye, W. Wheat, W. Triticale, and some blends),
- Different varieties (Prima and Hazlet for F. Rye, Moats and Ptarmigan for W. Wheat, and Fridge and Luoma for W. Triticale)
- Fall and spring plant count (plant/m^2)
- Fall and silage dry biomass (g/m^2)
- Yield at 0% and 14% (kg/ha)(bu/ac)
- Thousand Kernel Weight (TKW) (g/1000)
- Digestible energy/feed value (Moisture, Protein, Potassium, Calcium, Magnesium, Sodium, Copper, Iron, Manganese, Zinc, Phosphor, Sulfur, etc.)
- A soil sample (N, P, K)

The study observed all these parameters for grazed and ungrazed plots and different seeding dates for winter wheat. Overall project objectives include optimization through the expansion of winter wheat production and evaluation of the economic and agronomic potential of winter grazing systems on winter cereal production.

Objectives:

- ✓ Investigate the economical and agronomical benefits of increasing winter wheat production.
- ✓ Evaluate the effect on biomass and yield production with fall grazing of cattle on winter wheat, fall rye, winter triticale and blends of each.
- ✓ Evaluate the differences in crop type and varietal suitability to this practice.
- ✓ Quantify potential differences in winter survival with the application of a seed treatment.
- ✓ Complete an economic analysis of silage value following grazing vs. ungrazed and the potential to carry the crop through to yield.

Deliverables:

- ✓ A comprehensive report outlining the most suitable strategies for cattle producers to use in winter grazing systems in southern Alberta
- ✓ Facilitate hands-on application of knowledge through educational workshops/ field days
- ✓ Widespread knowledge dispersal to producers, industry developers, and consumers through conferences, presentations, and news/magazine articles
- ✓ Publish a possible scientific paper in Canadian Journal of Plant Science

4. Research design and methodology (max 4 pages)

Describe and summarise the project design, methodology, and methods of laboratory and statistical analysis that were actually used to carry out the project. Please provide sufficient detail to determine the experimental and statistical validity of the work and give reference to relevant literature where appropriate. For ease of evaluation, please structure this section according to the objectives cited above.

Farming Smarter designed plots at Short Grass Ranches to answer the question, "What makes winter cereals able to withstand grazing and still produce a grain crop in southern Alberta?"
Project technicians seeded plots with fall rye, winter wheat, and winter triticale for grazing cattle throughout the winter. The unpredictable behavior of the animals and need to adapt procedures for this type of research presented some challenges.

Experimental Design:

We typically seed plots roughly 2m x 6m with buffers between replications. But in this study, we seeded the plots and then filled in the pathways and spaces to have a solid seeded field. This reduced the chance of animal selection or overgrazing and avoided bare ground surrounding the plots. Figure 1 (pg 7) shows the field design for both trials, winter grazing and winter wheat seeding date under grazing and ungrazed beside each other.
The study design included four replicate randomized complete blocks with a factorial arrangement of treatments and two experiments side by side with the same randomization. The factorial treatments were (a) Factor 1, as a check without treatment and (b) Factor 2, with a insecticide/ fungicide seed treatment.
The field trials took place over three growing seasons (2014-2017) in Medicine Hat; which represents southern Alberta's winter grazing conditions. The winter grazing trial had 18 (9 var x 2 factor) plots in a row consisting of three different winter crops with two different varieties each and three blends in treated (Factor 2) and not treated (Factor 1) conditions with four replications. Each plot had six rows on 9.5" spacing x 6m to 8m long. In total, this trial had 72 plots and 400 seeds per m^2 seeded with different winter cereals. The winter wheat seeding date trial had 12 (2 variety x 3 date x 2 factor) plots with four replications (48 plots) . In each trial, we conducted two experiments with grazing and nongrazing treatments. Due to pesticide restrictions, the fields were grazed no sooner that 45 days after seeding.
Treatment details are in Appendix 1, Table 1 (pg 27) and cultural information is in Table 2 (pg 27).

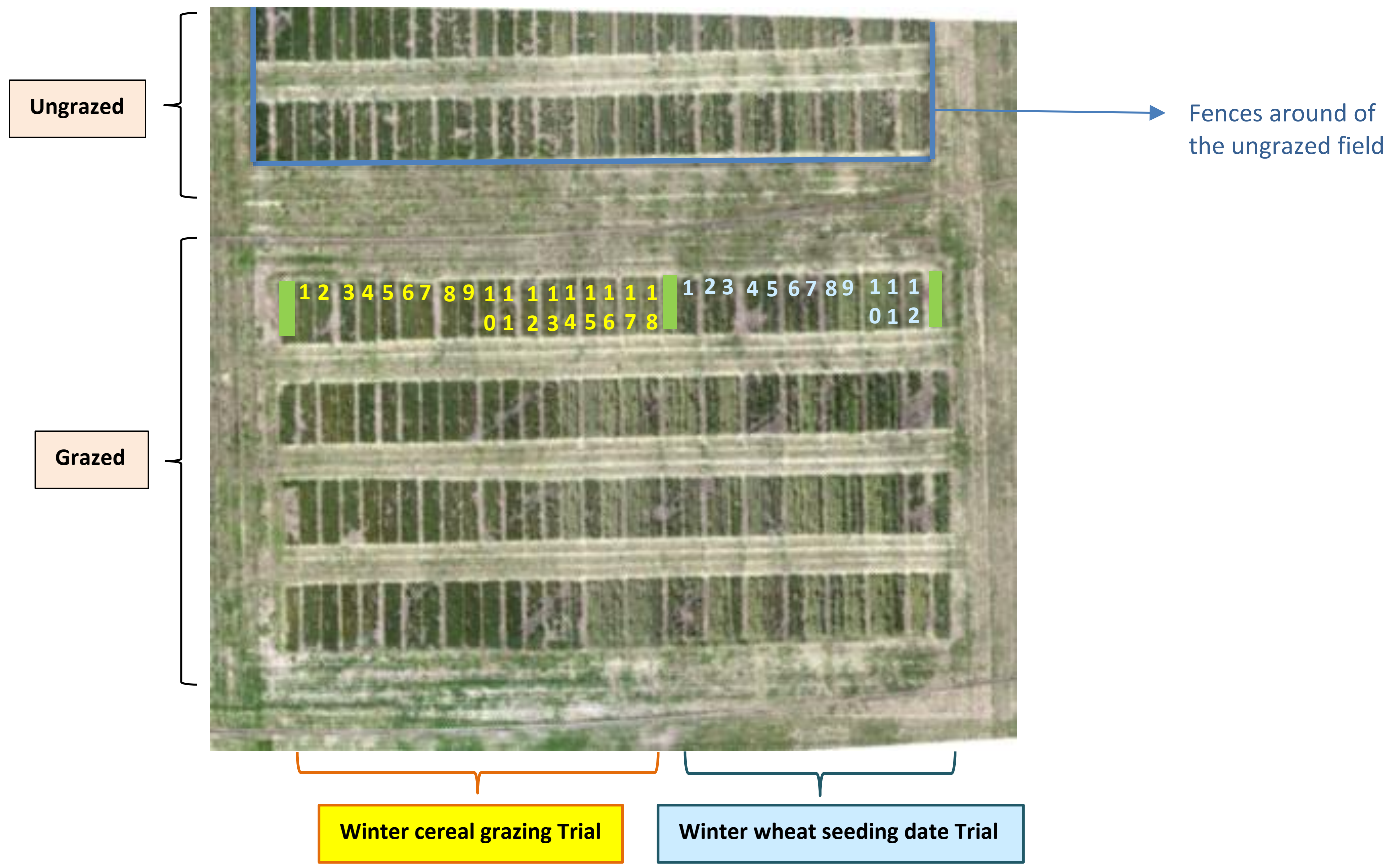

Figure 1: Field and plots design for both trials, grazed, and ungrazed all in one spot beside each other

Site Information, Maintenance, and Preparation:

Environmental:

According to Alberta Agriculture and Forestry ACIS historical weather data, the monthly average weather parameters in the township Medicine Hat (T012R05W4) during the study growing seasons Figure 2 (pg 8) had the highest recorded rainfalls in August 2014, July 2016, May 2016, June 2014 and September 2013. But the years 2015 and 2017 had less precipitation compared with the other years.

Also in August 2013, the first project seeding date, precipitation was very low (9.25 mm) in contrast with the next year, August 2014, that had 105.9 mm and at the beginning of the project, irrigation gave significant value for optimal crop growing conditions.

The monthly average air temperature also shows very cold winters in 2013-2014 and 2016-2017; which may have effected winter survival. However, during the seeding/cultivating month of August, the temperatures remained fairly constant from 2013 to 2017.

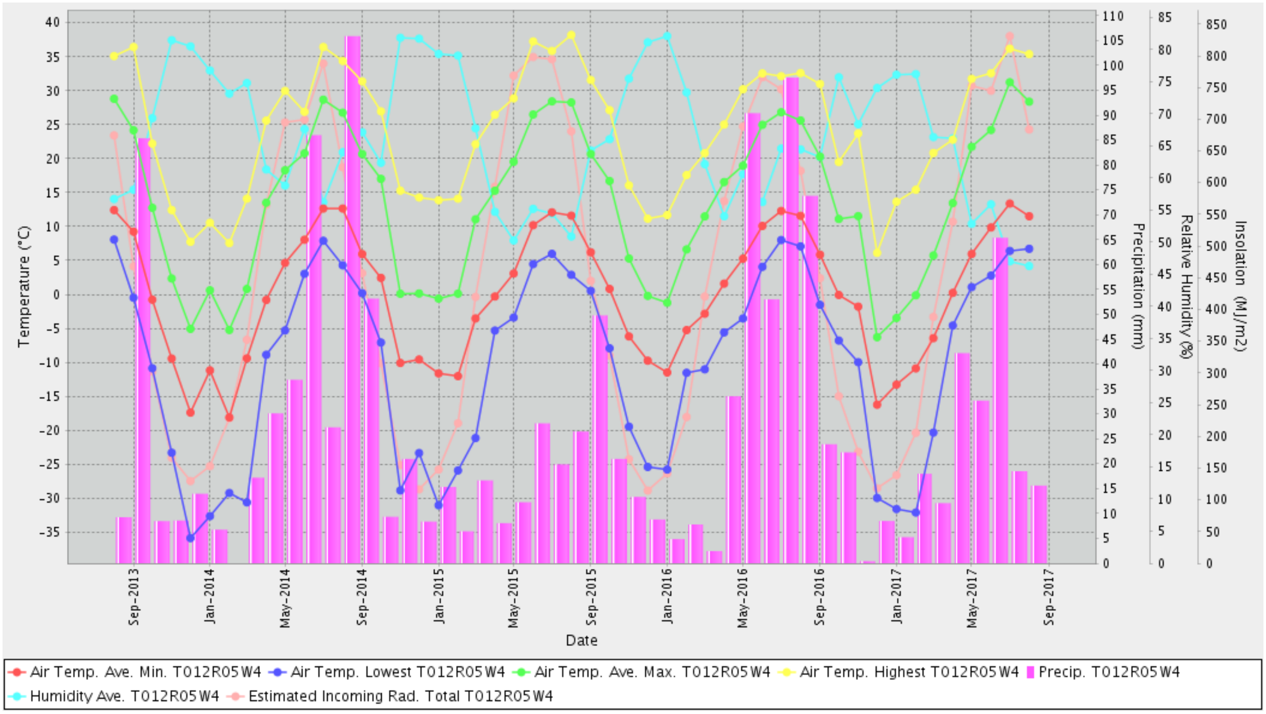

Figure 2: Monthly average of some key weather parameters in Medicine Hat from August 2013 to 2017

Appendix 2, Table 1 (pg 27) shows monthly average min and max temperature and precipitation in August; which is the seeding and harvesting month.

The soil background of Medicine Hat is sandy loam in the brown soil zone with low organic matter. More details about soil profile are in Appendix 2, Table 2 (pg 27).

The producer spread urea on the fields prior to seeding. Each year after the cattle were removed in the spring, technicians applied 100% of soil test recommendation for NPK for a target yield of 120 bu/ac.

Weed control consisted of a tank mix specific to the local weed complex, glyphosate as a pre-seed burndown, Goldwing in 2017, and Reglone in 2015, as a pre-harvest burn off to control an existing issue.

In 2013 – 2015, there was no spring in-crop herbicide application mimacing the producers practices. Ungrazed crops were fully tillered, just before flag leaf, over one foot tall and canopied over. Grazed crops with lower winter survival could not compete with weed pressure without herbicide application. In some years, the grazed crops were not harvested because of the weed issue (see pictures in Figure 6 (pg 12), but the ungrazed were harvested.

Biomass samples were harvested by hand and at maturity, plots were also harvested for grain using a 2013 Wintersteiger Classic plot combine. The combine collected and weighed grain samples using calibrated onboard balance and moisture sensors and a test weight chamber. It also records grain moisture content, so we corrected the yields to 14% mc.

Data Collection:

- Late fall emergence counts (plants/m^2) (2 rows x 1 meter x 2 spots)
- Fall Dry Biomass (Tonnes/ha)
- Digestible energy/feed value of Fall biomass
- Spring survival counts (plants/m^2) (1-row x 1-meter x 2 spots)
- Silage Dry Biomass (Tonnes/ha)
- Digestible energy/feed value of Silage Biomass
- Crop yield (Kg/ha)
- Thousand kernel weights (TKW) (g/1000 seeds)
- WCFA data clection for dry matter (Kg/ha) and quality of grains after harvest

The study maintained objectives, anticipated outcomes, and project design/methodology from the original proposal with a minor modification. The data is analyzed using SAS proc mixed. Appendix 3, Tables 1 & 2 (pg 28) contain more information regarding observed crop and feed data for winter grazing cereals.

5. Results, discussion, and conclusions (max 8 pages)

Present the project results and discuss their implications. Discuss any variance between expected targets and those achieved. Highlight the innovative, unique nature of the new knowledge generated. Describe implications of this knowledge for the advancement of agricultural science. For ease of evaluation, please structure this section according to the objectives cited above.
NB: Tables, graphs, manuscripts, etc., may be included as appendices to this report.

1) Study 1: Forage Trial

This study carried out a two-factor trial with different varieties of fall rye, winter triticale, winter wheat and their blends. The factors were fungicide/insecticide seed treatment Cruiser Maxx Vibrance Cereal (CMVC) vs. non-treatment (check) in grazed and ungrazed situations.

1-(a) Winter Survival, spring and fall plant counts

The study showed a significant difference in the winter survival between the grazed and ungrazed factors. Ungrazed had 100% survival while grazed plots averaged about 63%.
Winter wheat tends to be more susceptible to winter loss than fall rye Prima and winter triticale Luoma; which showed the highest survival. Comparing winter survival between check and CMVC demonstrates that between 2015 to 2017 ungrazed plots showed a higher survival (91%-104%) than grazed (58% -73%) (Figure 3). Survival may be above 100% because spring plant counts include newly emerged plants that may not have germinated the year before.
Figure 3 (pg 10) presents the percentage of winter survival of different cultivars in grazed and ungrazed treatments.
Comparing years and treatments, 2016 had the least survival in ungrazed at 90%. Also, grazed CMVC in 2017 showed 73% of survival; which is the highest among grazed (Table 1). In general,

the study showed no significant difference between check and CMVC under both, grazed and ungrazed conditions. Figure 4 (pg 11) shows the percentage of winter survival under CMVC fungicide treatment and without treatment (check) in grazed and ungrazed conditions.

Grazed trials had significantly lower spring plant counts. As a result, grazing significantly reduces spring survival (T-test, $P<0.00001$). Fall and spring plant counts are significantly impacted by choice of crop cultivar, but not seed treatment. The statistics of winter survival under different conditions is shown in Appendix 4, Table 1a (pg 29) and data related to fall plant count (pl/m2) under different conditions and LSD analysis is displayed in Table 1b (pg 29) and spring plant count in table 1c (pg 30).

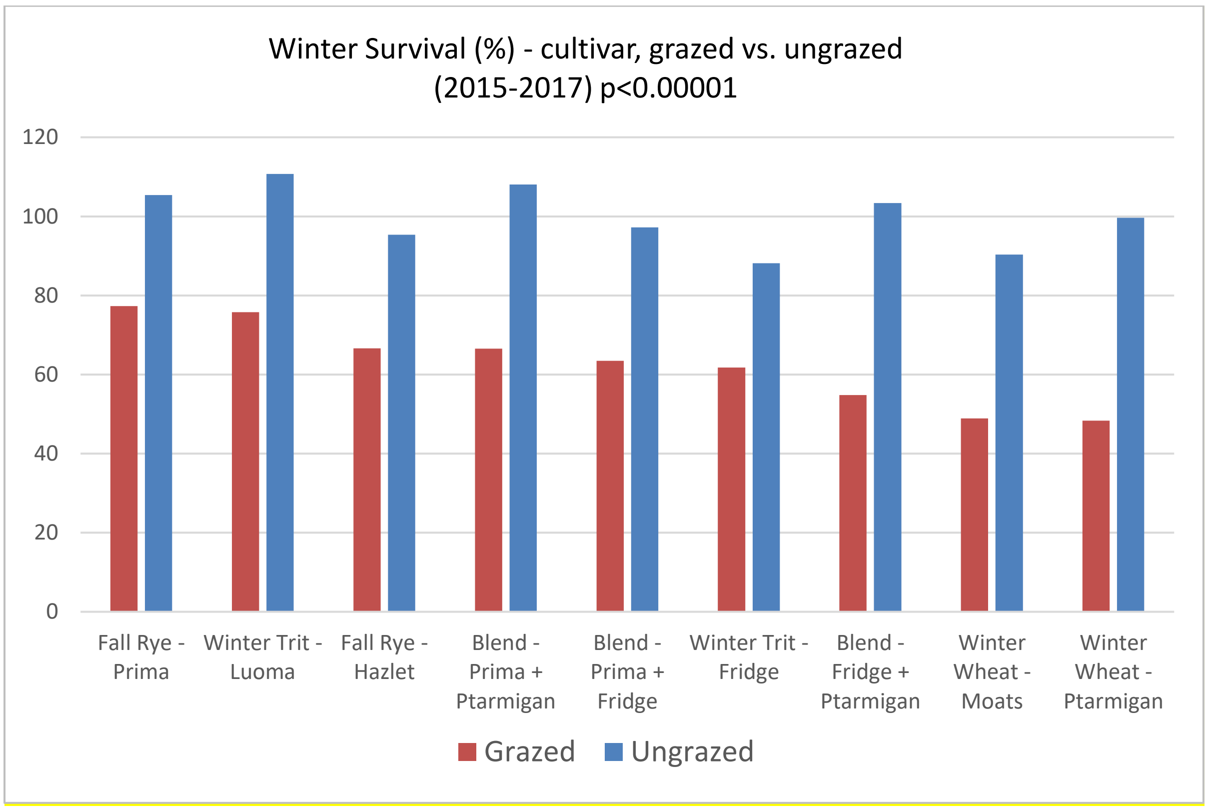

Figure 3: Percentage of winter survival of different cultivars under grazing and ungrazed

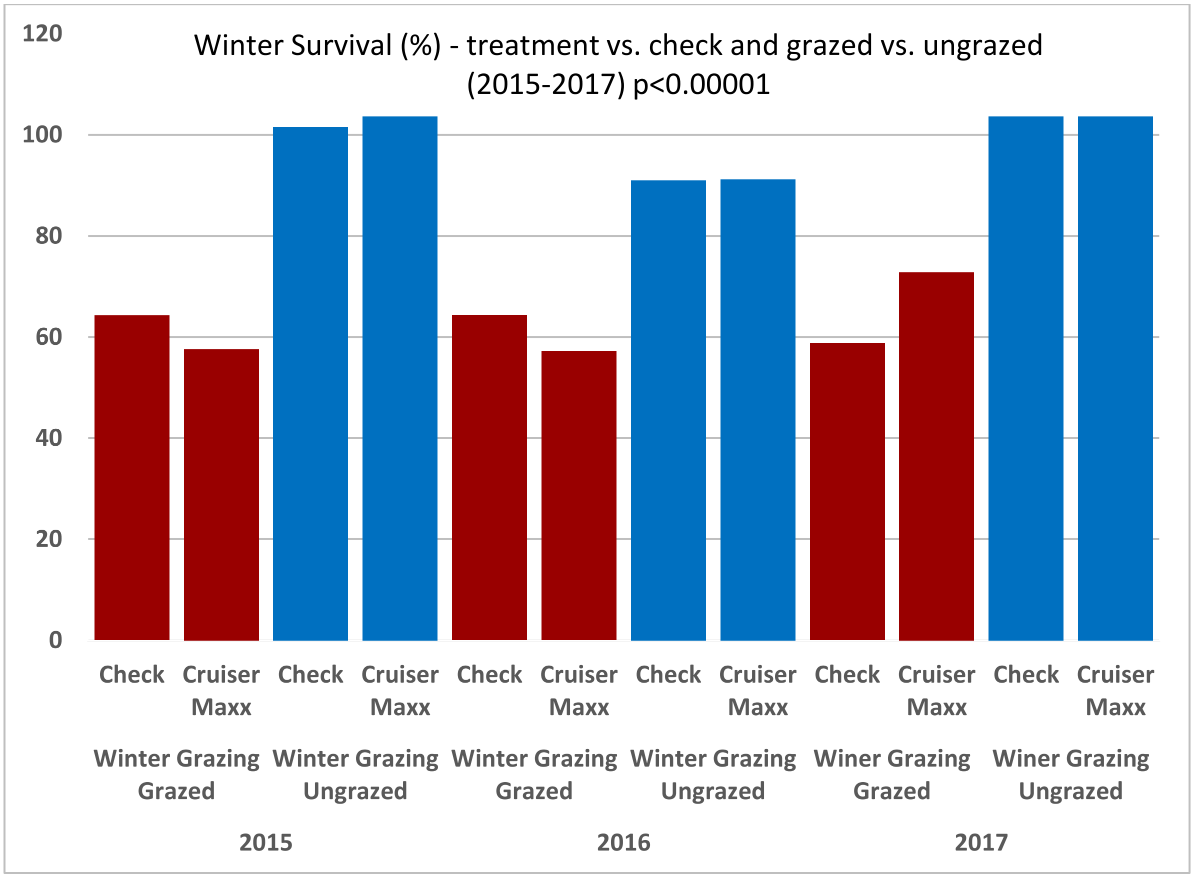

Figure 4: Percentage of winter survival of fungicide treatment and check under grazing and ungrazed

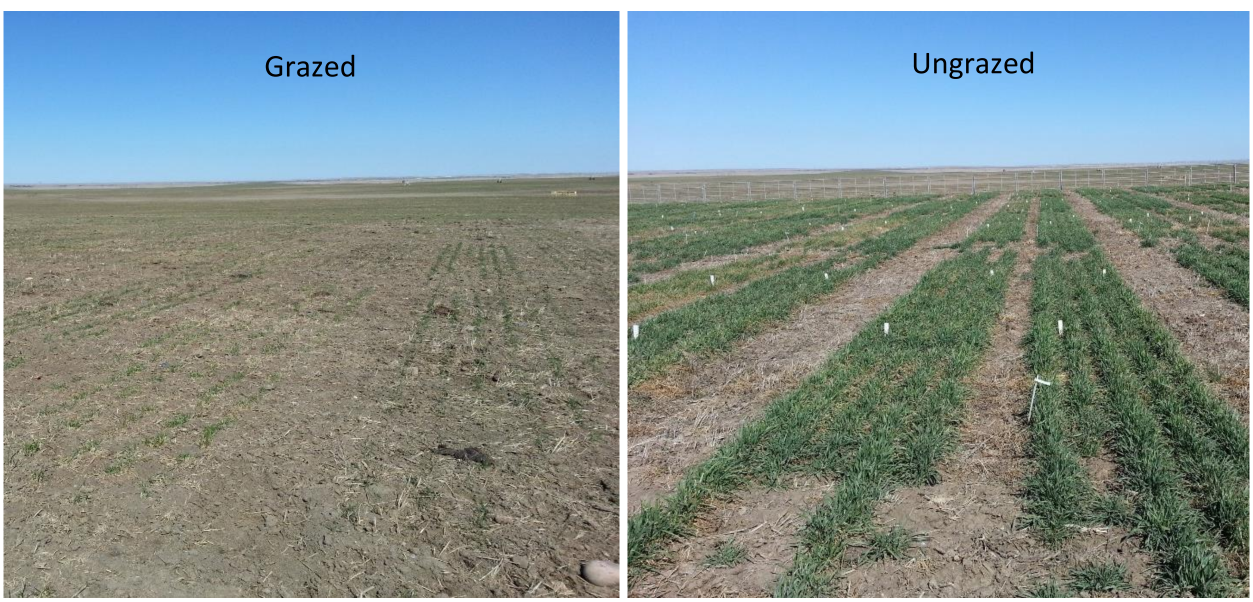

Figure 5: The field conditions under grazed and ungrazed conditions

As seen in the above pictures (Figure 5), the grazed plots have a high percentage of bare ground, but it also shows that winter cereals can withstand the removal of the above ground biomass and continue to grow after grazing.

However, due to the bare ground in the grazed trials, the lack of crop competition allowed weed proliferation. In the other words, a good stand of winter wheat helps to control weeds through crop competition.

Normally the farmer cooperator doesn't spray an in-crop herbicide because he intercrops with tillage radish. In the previous years, he re-seeded his field because there was not a good enough plant stand left in the spring. To overcome the issue, we added a fall application of Pyroxasulfone (focus herbicide) with the burndown to gain some residual control. We also added an broadleaf incrop herbicide application (2,4-D) early in the spring, before the crop reached flag leaf. Figure 6 clearly shows this weed problem.

Figure 6: Weed problem in the grazed trial in fall 2015

1-(b) Biomass

Fridge (triticale) and a blend of Fridge (triticale) with Prima (rye) showed a higher fall biomass than other cultivars of winter wheat, triticale, and other blends.
Fridge triticale had the highest silage biomass yield with 9.1 T/ha while Prima fall rye and a blend of Prima and Fridge had the lowest biomass yield with 6.8 T/ha. Between the other crops and blends, there is no significant difference. Figure 7 (pg 13) presents the values of fall, silage and total biomass for all cultivars and blends.
Appendix 4, Tables 2 & 3 (pg 30) show detailed statistics related to grazed and ungrazed fall and silage biomass with LSD analysis. The data shows that in 2017, silage biomass was significantly different depending on crop cultivar (P=0.003) and grazing significantly decreased sileage biomass (T-test, P=0.05).

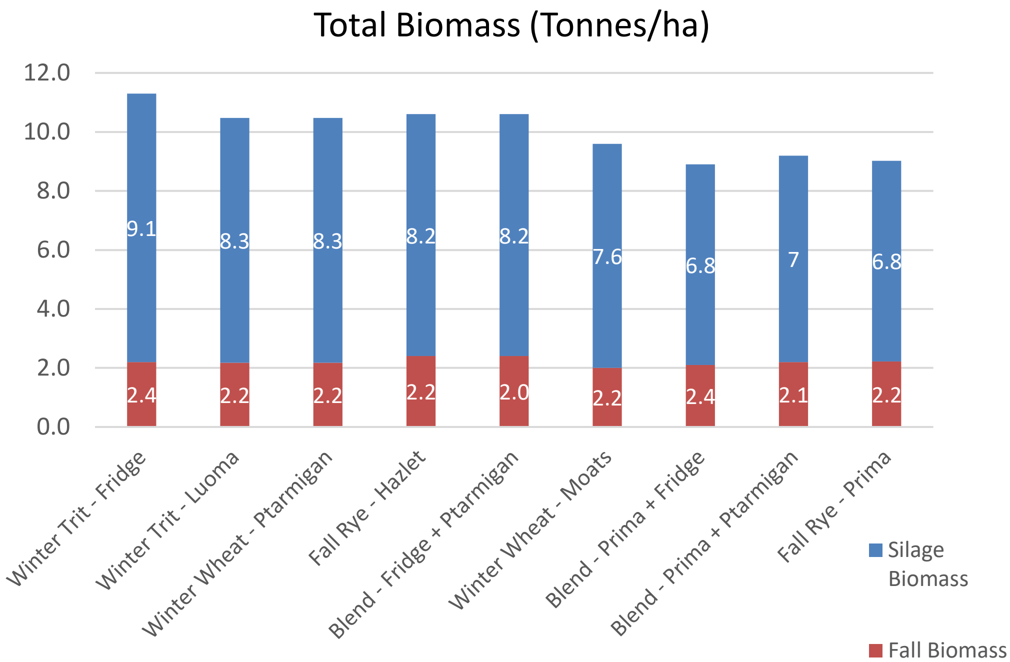

Figure 7: Fall, Silage and total biomass for all cultivars in 2015-2017

1-(c) Feed elements

The study looked at some elements of feed value such as Protein, Copper, Sodium, Neutral Detergent Fibre (NDF), Calcium, Phosphorous, Relative Feed Value (RFV), Total Digestible Nutrients (TDN), Acid Detergent Fibre (ADF), Magnesium, Potassium, Iron, Manganese, Zinc, Sulfur, Dry Matter Intake (DMI), Net Energy for Lactation (NEL), Net Energy for Maintenance (NEM), Digestible Energy (DE), Metabolizable Energy (ME), and Net Energy for Growth (NEG).
Replicate samples were bulked for each treatment and analysed by Down to Earth Labs in Lethbridge, Alberta. Comparing feed values between fall and silage biomasses shows that fall biomass has a significantly higher feed values. Average values were: protein (27.1%), copper (7.2%), sodium(0.07%), phosphorous (0.34%), relative feed value (RFV) (190), total digestible nutrients (TDN) (74.1%), magnesium (0.24%), potassium (4.15%), iron (272.6), manganese (50.9%), zinc (32.8%), sulfur(0.26), dry matter intake (DMI) (3.27%), net energy for lactation (NEL) (1.7 Mcal/kg), net energy for maintenance (NEM)(1.8 Mcal/kg), digestible energy (DE) (3.3 Mcal/kg), metabolizable energy (ME)(2.7 Mcal/kg), net energy for growth (NEG) (1.14). But neutral detergent fibre (NDF) shows less value for fall biomass (36.2%) rather than silage biomass (62%) and also acid detergent fibre (ADF) is 19.7% for fall biomass which is less than for silage biomass (38.7%). The amount of calcium (0.4%) is the same in all conditions. Appendix 4, Table 4 (pg 31) shows statistics related to the feed values for fall biomass and silage biomass.
Overall, the study found no significant difference between grazed and ungrazed for silage biomass (Appendix 4, Table 6, pg 33) and also between check and fungicide-treated (CMVC)

(Appendix 4, Table 5, pg 33).

Fall biomass was collected in Evansburg (WCFA) but none of trials survived the winter due to the colder environment. Data was collected for dry matter (DM) (kg/ha) for winter triticale, fall rye, and some of the blends (Appendix 4, Tables 8, 9, 10, pg 35, 36, 37).

Figure 8 (pg 15) visualizes the average value of the mentioned feed parameters of fall biomass for all crops and cultivars. The maximum variability between different crops and cultivars is seen in iron (see the red circle in the Figure 8) and after that, manganese, zinc, and RFV. The highest value of iron belongs to fall rye Prima and the lowest is observed in Moats winter wheat.

Figure 9 (pg 15) presents the same graph but for silage biomass. In this figure, almost like as fall biomass, iron, zinc, and RFV show the maximum variability between different crops and cultivars but here the variability is not as high as the fall biomass.

For verifying the quality of crops, WCFA measured the total digestible nutrients (TDN), potassium (K), calcium (Ca), phosphorus (P), magnesium (Mg), and crude protein (CP) - the total amount of protein present as calculated from the total nitrogen present. Corresponding data are in Appendix 4, Tables 8 & 9, pg 35 & 36 for ungrazed and grazed, respectively. Also Table 10 (pg 37) presents the average value of these feed elements for all grains and cultivars, treated and check together. The average values of the quality elements do not show any significant difference between different crops, trials, and treatment. The only highlight is the value of phosphorus related to Louma (Cruiser) winter triticale, from 0.2 to 3.3 in 2016 between check and CMVC, the reason is not clear to us.

Comparing the averaged value of all crops, cultivars, and treatment between both grazed and ungrazed conditions show that, the maximum values of CP and TDN are seen for ungrazed triticale Louma in 2015. The maximum values of calcium are in 2015 as well for ungrazed Louma and Hazlet (Cruiser) and also in the blend of Prima and Luoma (Check). The highest potassium value is seen in ungrazed blend of Prima and Fridge (Cruiser) in 2016. Magnesium as a micro element does not show a significant difference between the crops and cultivars. Overall, Comparing the average values of all grains, grazed and ungrazed of WCFA data shows that in 2015 and 2016 ungrazed had higher dry matter in feed value (458,482.27 and 1,815,390.46 kg/ha) but in 2017 grazed showed more dry matter(639,290.07 kg/ha) (Appendix 4, Table 10, pg 37).

Dry matter is measured at the lab; comprised of four sub samples for each cultivar in check and treated, under grazing and ungrazed. WCFA statistics are displayed in Appendix 4, Tables 8, 9, 10 (pg 35, 36, 37). Table 10 (pg 37) show the average value of all grains and cultivars and treated or check together. The dry matter data of 2017, represented in these Tables, is just for one plot / sample not for four. Because of this, we compare only 2015 and 2016 together, which present the average dry matter of 4 plots / samples. The highest ungrazed dry matter belongs to fall rye Prima (Cruiser) with 4345147 Kg/ha in 2016 and the lowest is seen in 2015 for Fridge winter triticale (Check) with the value of 249998 Kg/ha. In grazing, The highest ungrazed dry matter belongs to Fridge winter triticale (Cruiser) with 1774405.5 Kg/ha in 2016 and the lowest is seen in 2015 for fall rye Hazlet (Check) with the value of 196148.36 Kg/ha. In 2017, fall rye Hazlet (Check) had the highest dry matter in compare to the other crops in both grazed (1202727.3 Kg/ha) and ungrazed (1186027.4 Kg/ha) trials. Comparing the dry matter value between check and Cruiser treated shows that in some crops and cultivars treatment has higher yield but it is not seen in all crops and very different under grazing and ungrazed, so we can not say that treatment has a direct effect on yield or not. More studies are needed to address this question.

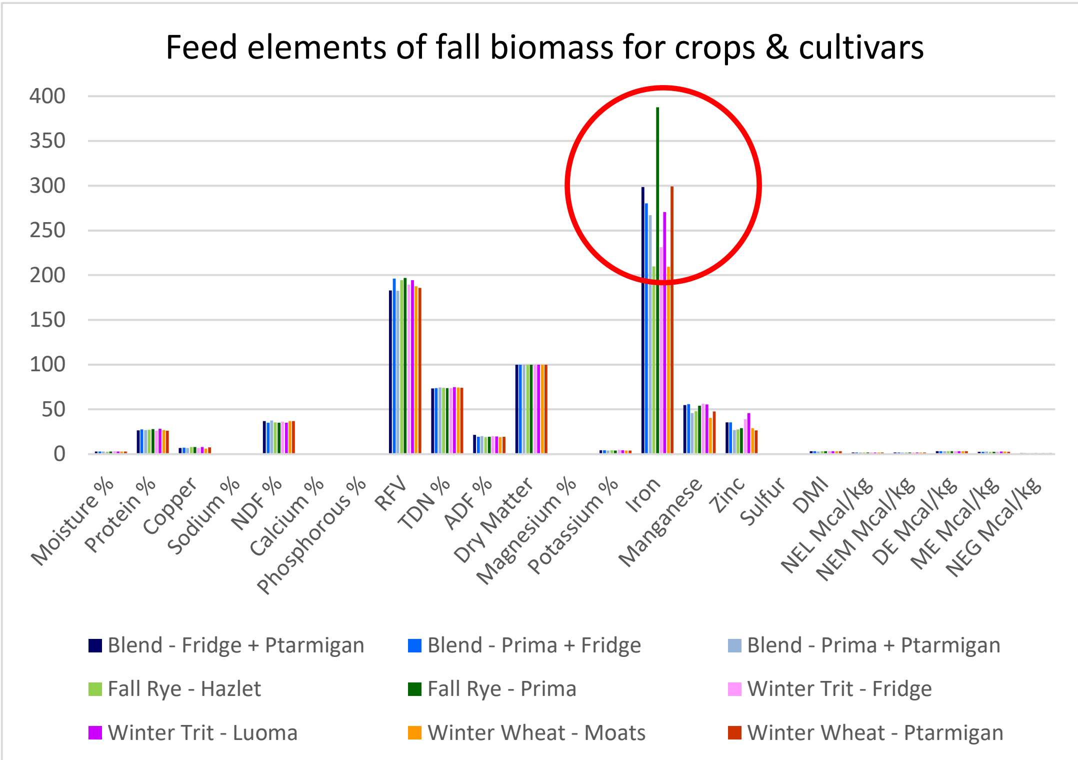

Figure 8: Fall biomass averaged values of feed parameters for all crops and cultivars

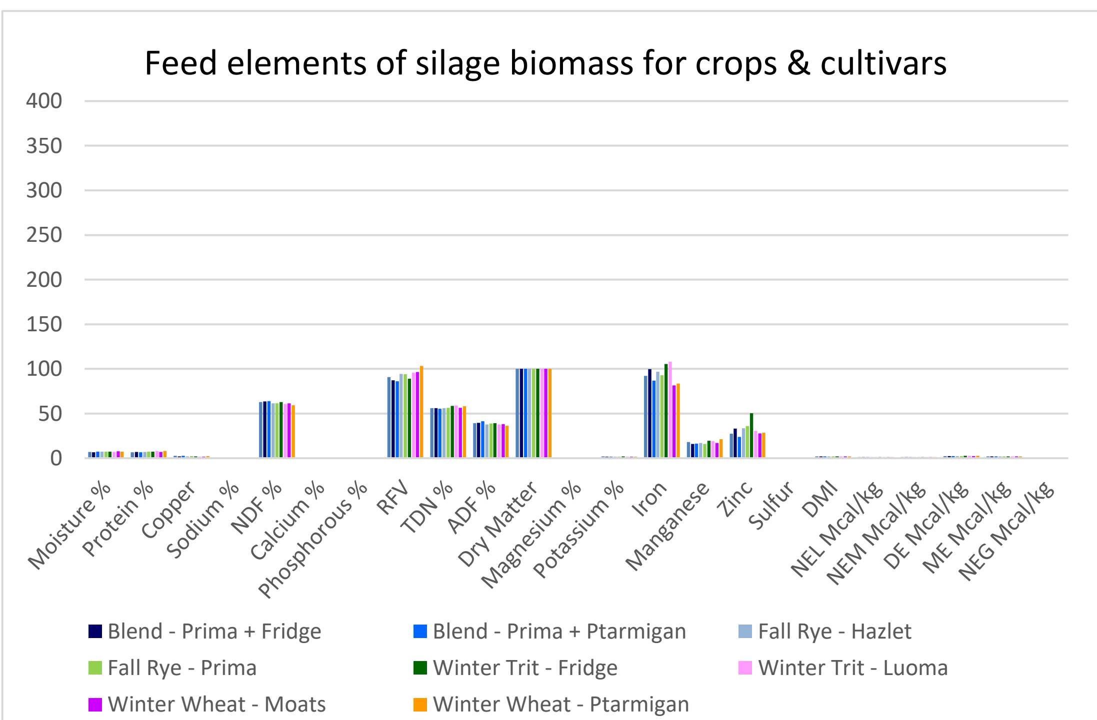

Figure 9: Silage biomass averaged values of feed parameters for all crops and cultivars

1-(d) Yield

Cruiser did not affect the yield in any year. Grain yield data exists for 2015 and 2017. Unfortunately, we were unable to harvest the grazed trials in 2016 due to poor survival and weed competition. The highest yield seen was Luoma triticale during 2015 and 2017 between different cultivars in grazed and ungrazed factors. It produced 6684 kg/ha under grazing in 2017. The next highest yield was ungrazed Hazlet fall rye with 6070 kg/ha in 2015. The lowest yield belongs to ungrazed Ptarmigan with 2525 kg/ha in 2016. We saw slightly higher yields in 2015 grazed plots and significantly higher in 2017. Thus, grazing proved to increase yield in all years, when survival and weed competition was managed proficiently.

Table (7) in Appendix 4 (pg 34) shows all the yield data in (Kg/ha) and an average of all years in (bu/ac) with LSD analysis. Figure (10) displays averaged yields. The graph also demonstrates the highest yield for a grazed treatment; which is Luoma triticale (91 bu/ac) and the lowest for a blend of Prima fall rye and Ptarmigan wheat with the value of 57 (bu/ac), ungrazed.

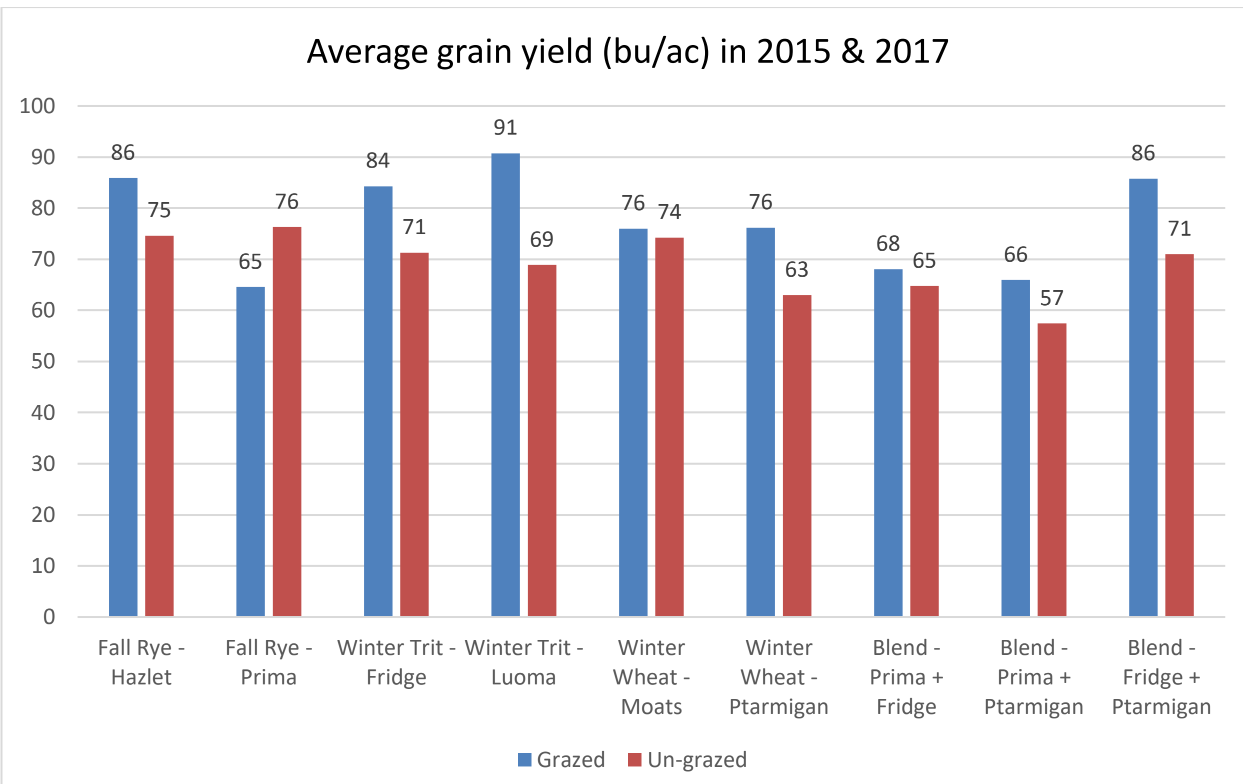

Figure 10: Average of yield for all cultivars between 2015-2017

2) Study 2: Winter wheat seeding date

In this parallel study, we conducted a 3-factor trial with two varieties of winter wheat, Moats and Ptarmigan, fungicide/insecticide seed treatement (Cruiser Maxx Vibrance Cereals vs. check) and three target dates for seeding August 1, August 20, and September 10. Again, two identical trials were conducted with one grazed and one fenced off (not grazed). Winter survival, silage and grain yield were key parameters studied.

As Mother Nature doesn't always cooperate, we had to modify target seeding dates. In fall 2014, we seeded on Aug 20, Sept 17, and Oct 3. In fall 2015, we seeded on Aug 10, Aug 28, and Sept 28. In fall 2016, we seeded on Aug 24, Sept 7, and Sept 28. The second year when we seeded in early August (Aug 10) we noticed that the plants grew substantially more than the other plantings; which may have caused higher winter mortality and certainly created a negative effected on the grain yield.

We conducted similar data collection for this study as the forage trial such as plant counts, fall and summer biomass, and grain yield.

2-(a) Fall and Silage biomass

The blue bars in Figure 11 demonstrate that the earlier we seeded (Aug 10) the higher fall biomass we saw. Thus, early seeding increases the forage quantity but decreases winter survival and yield. Silage biomass shown with red bard indicate grzing trial had more plant material.
Silage biomass data comes from 2015 and 2017. The second seeding dates (Sept 17, 2014 and Sept 7, 2016) show less biomass before freeze-up than the earlier seeding date in both the grazed and ungrazed trials. Figure 11 displays data from fall and silage biomass in 2015 and 2017 under grazed and ungrazed.
If we look at Figure 7 (pg 13) again, it is clear that between wheat cultivars, Ptarmigan has higher silage biomass (8.3 T/ha) than Moats (7.6 T/ha).

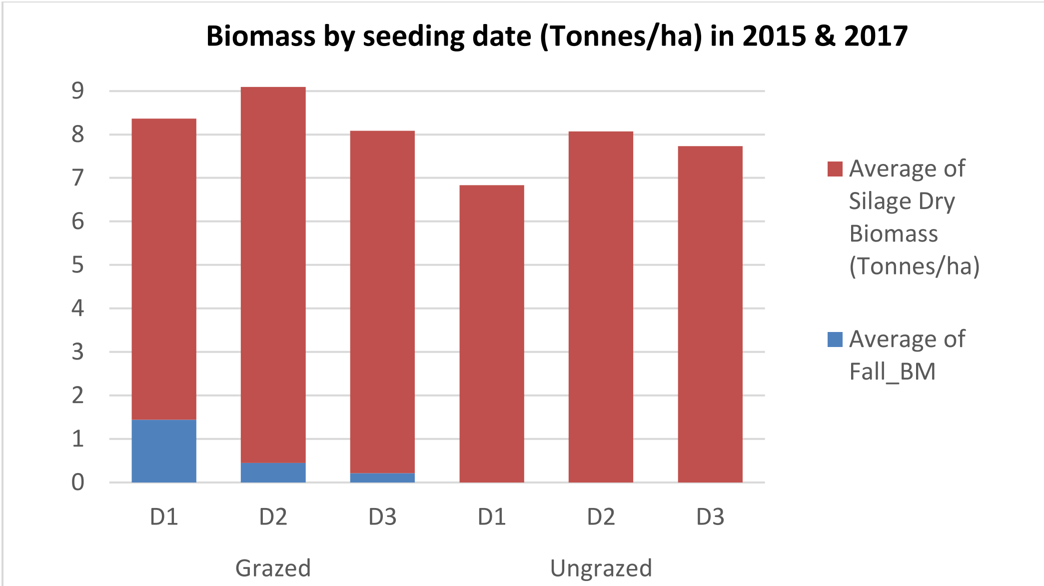

Figure 11: Fall and Silage biomass (T/ha) in the years 2015 and 2017

2-(b) Yield

According to the results in Figure 12, the optimal seeding period for Moats and Ptarmigan is the first two weeks of September. Early seeding (Aug 10) caused the lowest yield. Both varieties showed higher yield with grazed (76 bu/ac) vs. ungrazed where Moats had a higher yield (74 bu/ac) than Ptarmigan (63 bu/ac).

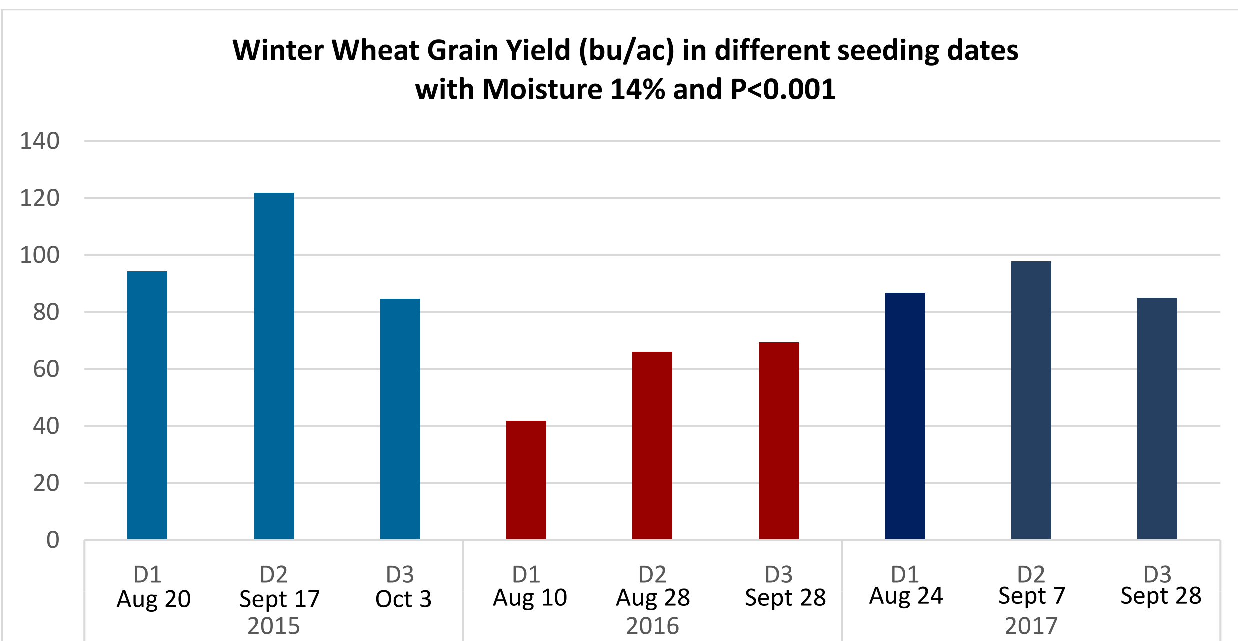

Figure 12: Winter wheat yield (bu/ac) in 2015-2017

Conclusion

During this study, we evaluated optimal agronomic practices that will help producers choose the most profitable seeding date for winter wheat varieties in a winter grazing scenario. We also assessed the agronomic potential of winter grazing on winter cereal production.

In conclusion, we saw a good potential to fall graze winter cereals with a high feed quality. Grazing proved to increase yield, but compromised winter and spring survival and must be managed accordingly.

However, Prima fall rye and Luoma winter triticale showed the highest survival and Hazlet fall rye and a blend of Fridge triticale and Ptarmigan winter wheat, had the highest fall biomass. Fridge winter triticale had the highest total biomass and Prima rye was the lowest.

Overall, winter survival is significantly impacted by crops, cultivars and grazing, but not by seed treatment of CMVC.

The highest averaged yield was grazed Luoma triticale and the lowest is the ungrazed blend of Ptarmigan winter wheat and Prima fall rye. Dry matter yield was highly variable between different crops in grazed and ungrazed.

Fall biomass feed quality was significantly higher than silage for most of the feed elements and nutrients, including: Protein, copper, sodium, phosphorous, relative feed value (RFV), total digestible nutrients (TDN), magnesium, potassium, iron, manganese, zinc, sulfur, dry matter intake (DMI), net energy for lactation (NEL), net energy for maintenance (NEM), digestible energy (DE), metabolizable energy (ME), net energy for growth (NEG). But silage biomass showed a higher amounts of neutral detergent fibre (NDF) and acid detergent fibre (ADF). Calcium did not show any significant difference in both fall and silage biomasses. For fall biomass, a high variability is seen between different crops and cultivars in iron, manganese, zinc, and RFV, respectively. The highest value of iron belongs to Prima fall rye and the lowest is observed in Moats winter wheat.

For silage biomass, iron, zinc, and RFV showed a high variability between different crops and cultivars with less changes at fall biomass.

The average values of the quality elements of winter triticale, fall rye, and some of the blends after harvest, do not show any significant difference between crops, trials, and treatment.

The winter wheat seeding date showed that an early seeding date increases fall biomass but decreases summer silage and grain yield. However, the optimal seeding period for Moats and Ptarmigan is the first two weeks of September. Grazed treatments yielded higher than ungrazed, and Moats yielded higher than Ptarmigan.

To continue our understanding of the interactions between grazing and subsequent crop yields, future work should include looking into grazing intensity, timing and duration. It should also consider studing grazing management with current best management practices to maxmimize spring survival such as fall seeding rates and herbicide management.

6. Literature cited

Provide complete reference information for all literature cited throughout the report.

Baron, V. S., Dick, A. C., Salmon, D. F., & McLeod, J. G. (1999). Fall seeding date and species effects on spring forage yield of winter cereals. Journal of Production Agriculture, 12(1), 110-115.

Christiarsen, S., Svejinr, T. and Phillips, W. A. (1989). Spring and fall cattle grazing effects on components and total grain yield of winter wheat. Agron. J. 8l: 145-160.

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May, W. E., Klein, L. H., Lafond, G. P., McConnell, J. T., & Phelps, S. M. (2007). The suitability of cool-and warm-season annual cereal species for winter grazing in Saskatchewan. Canadian Journal of plant science, 87(4), 739-752.

Poysa, V. W. (1985). Effect of forage harvest on grain yield and agronomic performance of winter triticale, wheat, and rye. Can. J. Plant Sci. 65: 879-888.

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Sprague, M. A. (1954). The effect of grazing management on forage and grain production from rye, wheat, and oats. Agron. J. 46 29-33.

7. Benefits to the industry (max 1 page; respond to sections *a)* and *b)* separately)

a) *Describe the impact of the project results on Alberta's agriculture and food industry (results achieved and potential short-term, medium-term and long-term outcomes).*

Beef cattle production is an important business in southern Alberta. Researchers and producers alike are searching for ways to extend grazing periods and minimize the time in feedlots where stored feed is required. This study demonstrated clearly to producers that early seeded winter cereals can indeed extend the grazing period through the fall and winter with an extremely nutrient dense feedstock. Animal health is likely better and manure is spread by the animals saving spreading costs.

Winter survival is certainly negatively impacted by grazing but, with good stands a yield benefit can also be achieved with grazing. Giving the right combination of agronomic factors and appropriate weather, this technique can greatly increase net returns. Futher work is needed to better understand the impact of timing of grazing and intensity to improve winter survival.

Nevertheless, the downside risk of this practice is not large. If winter survival is poor, the producer can terminate the crop and seed a spring crop. If the crop survives well, the producer has the option of taking the crop for forage or may deside to harvest for grain depending on feed stores and grain prices.

In the the colder location (Evansburg), winter survival was very poor, so this practice may be limited to certain areas in the prairies. More work is need to test this practice in different environments.

b) *Quantify the potential economic impact of the project results (e.g., cost-benefit analysis, potential size of market, improvement in efficiency, etc.).*

Our study showed an average of 2.2 tons / hectare of dry matter fall biomass. With an assumed comsumption rate of 13.6 kg / day / cow, this adds 161 feeding days per hectare X $1.3/cow/day = $210 / hectare. An adoption of 100,000 ha of this practice would add approximately 21 million dollars just from the fall biomass alone.

Custom spreading of manure costs appromixately $250 / ha and thus over 100,000 ha, this practice would save producers approximately $25 million.

With an assumed yield increase of 20% for winter cereals over barley and an estimated value of barley silage at $250 / ha, this would result in $250 * 0.2*100,000 = $5 million.

In total, the potential added value with 100,000 ha of fall grazed winter cereals is approximately $21 + $25 + $5 = $51 million

8. Contribution to training of highly qualified personnel (max ½ page)

Specify the number of highly qualified personnel (e.g., students, post-doctoral fellows, technicians, research associates, etc.) who were trained over the course of the project.

Farming Smarter (7)
AAFC (1)
West Central Forage Association (3)

9. Knowledge transfer/technology transfer/commercialisation (max 1 page)

Describe how the project results were communicated to the scientific community, to industry stakeholders, and to the general public. Please ensure that you include descriptive information, such as the date, location, etc. Organise according to the following categories as applicable:

a) *Scientific publications (e.g., scientific journals); attach copies of any publications as an appendix to this final report*

Is under preparation.

b) *Scientific presentations (e.g., posters, talks, seminars, workshops, etc.)*

June 22, 2017 – AIP Agronomy webinar

c) *Industry-oriented publications (e.g., agribusiness trade press, popular press, etc.); attach copies of any publications as an appendix to this final report*

Farming Smarter. Spring 2017. Learning in the field at Farming Smarter. Farming Smarter Magazine
Arnason, Robert. 2016 March 10. Dual purpose cereal crops a win-win? The Western Producer
Blair, Jennifer. 2016, January 28. Grazing winter cereals can work. Alberta Farmer Express
Baerg, Madeleine. Fall 2014. Double whammy crop production. Farming Smarter Magazine
Hart, Lee. 2014, April 10. Winter Cereals pressed into double duty. Grainews
Hart, Lee. Spring 2014. Winter cereals do double duty – pasture and silage. Farming Smarter Magazine

d) *Industry-oriented presentations (e.g., posters, talks, seminars, workshops, etc.)*

October 26, 2017 – Cypress Conference at Medicine Hat Lodge; *93 participants*
June 2, 2016 – Medicine Hat Plot Hop; *30 participants*
December 8 & 9, 2015 – Farming Smarter Conference at Lethbridge Coast Hotel; *288 participants*
October 27, 2015 – Medicine Hat Workshop presentation at Medicine Hat Lodge; *80 participants*

e) *Media activities (e.g., radio, television, internet, etc.)*

f) *Any commercialisation activities or patents*

Fill out the table below with the total number of each performance measure:

Number of scientific publications / presentations	1
Number of industry communications	10
Number of patents / licenses	0

N.B.: Any publications and/or presentations should acknowledge the contribution of each of the funders of the project.

Appendix 1. Experimental Design

Crop	Variety
Fall Rye	Hazlet
Fall Rye	Prima
Winter Triticale	Fridge
Winter Triticale	Luoma
Winter Wheat	Moats
Winter Wheat	Ptarmigan
Blend1	Fridge + Ptarmigan
Blend2	Prima + Fridge
Blend3	Prima + Ptarmigan

***Table 1**. Information about the seeded winter crops and the different varieties and blends*

Seeding Information	2014	2015	2016	2017
Seeding Date:	16-Aug-13	20-Aug-14	10-Aug-15	24-Aug-16
Harvesting Date:	not harvested	06-Aug-15	17-Aug-16	03-Aug-17
Rate:	400 seeds/m2 totals	400 seeds/m2	400 seeds/m2	400 seeds/m2
Depth:	1.5"	0.75"	0.75"	0.75"
Soil moisture conditions:	good Irrigated prior to seeding	average	average	average
GPS/Plot spacing (m):	2m	2m	2m	2m
Numbers of rows seeded:	6 rows of plot*	6 rows of plot	6 rows of plot	6 rows of plot
Seeding equipment:	plot seeder	SARA seeder	SARA seeder	SARA seeder
Trimmed plot length:	6m	8 m	8 m	8 m

***Table 2**. General information about the seeding condition (* two* outside of W. Wheat Bellatrix*)*

Appendix 2. Environmental Data

Date	Air Temp. Ave. Min. (°C)	Air Temp. Ave. Max. (°C)	Precip. (mm)
2013-08	12.414	28.821	9.25
2014-08	12.651	26.765	105.89
2015-08	11.605	28.271	26.45
2016-08	11.576	25.615	73.81
2017-08	11.515	28.396	15.61

***Table 1**. Description of the monthly average of min and max temperature and precipitation in August (the seeding and harvesting month) in Medicine Hat*

Soil type	Soil Zone	Nitrogen	Phosphorus	Potassium	Sulphur	PH	OM
sandy loam	Brown	<50 kg/ha	<20 kg/ha	560+ kg/ha	<20 kg/ha	7.5-7.8	1.8%-2.5%

***Table 2**. Description of soil profile at Medicine Hat*

Appendix 3. Collected Data

Year	Trial	Fall PC	Fall Dry Biomass	Spring PC	Sileage Dry Biomass	Yield
2014	Grazed	check & cruiser	check & cruiser			
	Ungrazed	check & cruiser				
2015	Grazed	check & cruiser	check	check & cruiser	check & cruiser	check & cruiser*
	Ungrazed	check & cruiser		check & cruiser	check & cruiser	check & cruiser
2016	Grazed	check & cruiser	check	check & cruiser		
	Ungrazed	check & cruiser		check & cruiser	check & cruiser	check & cruiser
2017	Grazed	check & cruiser	check & cruiser	check & cruiser	check & cruiser	check & cruiser
	Ungrazed	check & cruiser		check & cruiser	check & cruiser	check & cruiser

Table 1. *Observed crop data for winter grazing cereals*

Year	Sample	Trial	Protein	NDF	TDN	Calcium	Phosphorus	RFV
2014	Fall Biomass 2013	Grazed	check & cruiser	check & cruiser	check & cruiser	check & cruiser	check & cruiser	check & cruiser
	Silage Biomass 2014	Grazed & Ungrazed						
2015	Fall Biomass 2014	Grazed	check	check	check	check	check	check
	Silage Biomass 2015	Grazed & Ungrazed	check	check	check	check	check	check
2016	Fall Biomass 2015	Grazed	check	check	check	check	check	check
	Silage Biomass 2016	Grazed & Ungrazed	check	check	check	check	check	check
2017	Fall Biomass 2016	Grazed	check & cruiser	check & cruiser	check & cruiser	check & cruiser	check & cruiser	check & cruiser
	Silage Biomass 2017	Grazed & Ungrazed	check & cruiser	check & cruiser	check & cruiser	check & cruiser	check & cruiser	check & cruiser

Table 2. *Observed feed data for winter grazing cereals*

Appendix 4. Results and Conclusion

Row Lables	Average of Survival (%)
2015	**82**
Winter Grazing Grazed	**61**
Check	64
Cruiser Maxx	58
Winter Grazing Ungrazed	**103**
Check	102
Cruiser Maxx	105
2016	**76**
Winter Grazing Grazed	**61**
Check	64
Cruiser Maxx	57
Winter Grazing Ungrazed	**91**
Check	91
Cruiser Maxx	91
2017	**85**
Winer Grazing Grazed	**66**
Check	59
Cruiser Maxx	73
Winer Grazing Ungrazed	**104**
Check	104
Cruiser Maxx	104
Grand Total	**81**

Table 1 (a). *Winter survival percentage under different conditions*

Crop-cultivar	2014		2015		2016		2017	
	Grazed	Ungrazed	Grazed	Ungrazed	Grazed	Ungrazed	Grazed	Ungrazed
Fall Rye - Hazlet	231c	234bc	162	170	125d	142	208a	164
Fall Rye - Prima	278ab	223c	164	173	123d	142	172b	149
Winter Trit - Fridge	281ab	268ab	147	160	124d	143	132d	124
Winter Trit - Luoma	256bc	230bc	148	167	130cd	143	121d	130
Winter Wheat - Moats	301a	311a	149	162	137bc	152	170b	156
Winter Wheat - Ptarmigan	276ab	257bc	159	164	149a	151	125d	137
Blend - Prima + Fridge	256bc	259bc	153	174	134bcd	145	160bc	150
Blend - Prima + Ptarmigan	263bc	251bc	158	174	143ab	148	145cd	145
Blend - Fridge + Ptarmigan	271ab	245bc	149	170	140abc	146	125d	132

Table 1 (b). *Fall plant count (pl/m^2) under different conditions and LSD analysis*

Crop-cultivar	2015		2016		2017	
	Grazed	Ungrazed	Grazed	Ungrazed	Grazed	Ungrazed
Fall Rye - Hazlet	91bcd	141	108a	123c	112a	151
Fall Rye - Prima	127a	167	107a	127bc	115a	158
Winter Trit - Fridge	71de	188	88ab	140abc	76b	155
Winter Trit - Luoma	88cd	180	95a	154a	112a	109
Winter Wheat - Moats	92bcd	177	52c	127bc	77b	106
Winter Wheat - Ptarmigan	59e	186	37c	146ab	98ab	114
Blend - Prima + Fridge	113ab	166	85ab	123c	77b	143
Blend - Prima + Ptarmigan	111abc	180	83ab	121c	102ab	174
Blend - Fridge + Ptarmigan	73de	164	63bc	140abc	80b	162

Table 1 (c). *Spring plant count (pl/m^2) under different conditions and LSD analysis*

Crop-Cultivar	2014	2015	2016	2017	Average
	Grazed	Grazed	Grazed	Grazed	
Fall Rye - Hazlet	2.1 ab	1.9 ab	1.5 a	3.9 a	2.4
Fall Rye - Prima	2.3 ab	1.7 b	1.5 a	3.2 ab	2.2
Winter Trit - Fridge	2.4 a	1.8 ab	1.4 a	3.1 ab	2.2
Winter Trit - Luoma	2 b	2.2 a	1.4 a	3 ab	2.2
Winter Wheat - Moats	2.1 ab	1.5 b	1.7 a	2.6 b	2.0
Winter Wheat - Ptarmigan	2.2 ab	1.9 ab	1.7 a	3.1 ab	2.2
Blend - Prima + Fridge	2.2 ab	1.7 b	1.5 a	3.1 ab	2.1
Blend - Prima + Ptarmigan	2.4 ab	1.8 ab	1.6 a	3.1 ab	2.2
Blend - Fridge + Ptarmigan	2.3 ab	2 ab	1.4 a	3.8 ab	2.4

Table 2. *Fall Dry Biomass only grazed (Tonne/ha) with LSD analysis*

Crop-cultivar	2015		2016		2017		average
	Grazed	Ungrazed	Grazed	Ungrazed	Grazed	Ungrazed	
Fall Rye - Hazlet	8.0 ab	9.2 b	NA	10.5	8.2 ab	9.8	8.2
Fall Rye - Prima	7.4 ab	7.5 ab	NA	9.0	6.8 d	10.7	6.8
Winter Trit - Fridge	7.6 ab	9.5 a	NA	10.3	9.1 a	8.6	9.1
Winter Trit - Luoma	7.2 ab	8.0 ab	NA	12.4	8.3 ab	8.9	8.3
Winter Wheat - Moats	7.1 ab	6.7 ab	NA	9.7	7.6 bcd	8.8	7.6
Winter Wheat - Ptarmigan	4.9 b	5.7 b	NA	9.0	8.3 ab	6.9	8.3
Blend - Prima + Fridge	7.6 ab	7.7 ab	NA	9.8	6.8 d	7.9	6.8
Blend - Prima + Ptarmigan	7.2 ab	7.2 ab	NA	8.3	7 cd	7.2	7
Blend - Fridge + Ptarmigan	9.7 a	8.4 ab	NA	9.7	8.2 abc	8.0	8.2

Table 3. *Silage Biomass grazed and ungrazed (Tonne/ha) with LSD analysis*

Cereal/cultivar	Protein %	Copper	Sodium %	NDF %	Calcium %	Phosphorous %	RFV	TDN %	ADF %	Magnesium %	Potassium %	Iron	Manganese	Zinc	Sulfur	DMI	NEL Mcal/kg	NEM Mcal/kg	DE Mcal/kg	ME Mcal/kg	NEG Mcal/kg
Fall Biomass																					
Blend - Fridge + Ptarmigan	26.47	6.73	0.08	36.92	0.39	0.30	183.04	73.31	21.36	0.20	4.30	298.53	54.85	35.50	0.25	3.22	1.68	1.80	3.29	2.70	1.11
Blend - Prima + Fridge	27.44	7.17	0.06	35.15	0.44	0.33	196.01	73.90	19.38	0.26	4.32	280.21	55.70	35.54	0.27	3.33	1.69	1.82	3.28	2.69	1.13
Blend - Prima + Ptarmigan	26.82	6.89	0.07	37.62	0.37	0.35	182.51	74.34	20.14	0.25	3.99	267.06	45.89	27.00	0.26	3.06	1.70	1.83	3.34	2.74	1.14
Fall Rye - Hazlet	27.11	7.77	0.06	35.62	0.50	0.38	194.23	74.28	19.12	0.28	4.37	209.60	48.11	27.43	0.26	3.29	1.70	1.83	3.20	2.62	1.14
Fall Rye - Prima	28.04	7.90	0.05	35.17	0.46	0.33	197.03	73.92	19.27	0.30	3.85	387.50	54.02	29.04	0.27	3.43	1.69	1.82	3.28	2.69	1.13
Winter Trit - Fridge	26.18	6.78	0.09	36.26	0.42	0.37	189.28	73.72	20.13	0.23	4.60	231.08	56.34	39.08	0.27	3.23	1.69	1.81	3.32	2.72	1.12
Winter Trit - Luoma	28.42	7.82	0.06	35.22	0.42	0.35	194.53	74.86	19.88	0.23	4.18	270.54	55.34	45.70	0.27	3.40	1.72	1.85	3.37	2.77	1.16
Winter Wheat - Moats	26.99	5.99	0.09	36.90	0.35	0.31	187.64	74.47	18.90	0.21	3.85	209.34	40.41	28.99	0.26	3.29	1.71	1.84	3.34	2.74	1.15
Winter Wheat - Ptarmigan	26.27	7.71	0.07	37.03	0.31	0.32	185.83	74.02	19.41	0.21	3.88	299.30	47.64	26.53	0.26	3.21	1.70	1.82	3.32	2.72	1.13
Fall Biomass Total	**27.08**	**7.20**	**0.07**	**36.21**	**0.41**	**0.34**	**190.01**	**74.09**	**19.73**	**0.24**	**4.15**	**272.57**	**50.92**	**32.76**	**0.26**	**3.27**	**1.70**	**1.83**	**3.30**	**2.71**	**1.14**
Silage Biomass																					
Blend - Fridge + Ptarmigan	6.81	2.89	0.02	62.89	0.38	0.15	90.95	56.00	39.21	0.19	1.89	92.23	18.12	27.60	0.21	1.98	1.23	1.17	2.46	2.02	0.61
Blend - Prima + Fridge	7.04	1.95	0.02	63.73	0.41	0.15	87.28	56.23	39.46	0.20	1.78	99.85	16.15	33.03	0.18	1.92	1.24	1.18	2.47	2.03	0.62
Blend - Prima + Ptarmigan	6.50	2.59	0.02	63.88	0.38	0.13	86.18	55.30	41.37	0.16	1.73	86.93	16.35	23.83	0.16	1.94	1.22	1.15	2.43	2.00	0.60
Fall Rye - Hazlet	7.14	2.15	0.02	61.47	0.39	0.16	94.35	56.10	37.99	0.18	1.78	96.83	17.23	33.38	0.21	2.02	1.23	1.18	2.47	2.03	0.61
Fall Rye - Prima	7.38	2.27	0.02	61.39	0.37	0.17	94.10	56.43	38.75	0.18	1.74	93.15	15.93	35.93	0.21	2.03	1.24	1.19	2.48	2.04	0.62
Winter Trit - Fridge	7.44	1.99	0.01	62.91	0.43	0.15	89.20	58.45	39.35	0.18	1.84	105.38	19.53	50.33	0.24	1.95	1.29	1.26	2.57	2.11	0.68
Winter Trit - Luoma	8.17	1.72	0.02	60.82	0.39	0.15	96.03	58.98	37.98	0.16	1.62	108.10	19.05	30.75	0.19	2.05	1.30	1.27	2.59	2.13	0.70
Winter Wheat - Moats	6.97	1.73	0.02	61.58	0.27	0.12	96.40	56.58	38.16	0.15	1.64	81.40	16.98	27.90	0.17	2.05	1.25	1.19	2.49	2.04	0.63
Winter Wheat - Ptarmigan	8.07	2.20	0.02	59.33	0.36	0.16	103.50	58.30	36.39	0.19	1.79	83.55	21.25	28.38	0.18	2.15	1.29	1.25	2.57	2.10	0.68
Silage Biomass Total	**7.28**	**2.18**	**0.02**	**62.00**	**0.37**	**0.15**	**93.11**	**56.93**	**38.74**	**0.18**	**1.75**	**94.16**	**17.84**	**32.34**	**0.19**	**2.01**	**1.25**	**1.20**	**2.50**	**2.05**	**0.64**

Table 4*. Feed data of fall and silage biomass*

Cereal/cultivar	Protein %	Copper	Sodium %	NDF %	Calcium %	Phosphorous %	RFV	TDN %	ADF %	Magnesium %	Potassium %	Iron	Manganese	Zinc	Sulfur	DMI	NEL Mcal /kg	NEM Mcal /kg	DE Mcal /kg	ME Mcal /kg	NEG Mcal /kg
Fall Biomass-Check																					
Blend - Fridge + Ptarmigan	26.28	6.58	0.06	36.97	0.37	0.30	181.79	74.42	21.92	0.21	4.51	266.26	53.77	36.95	0.25	3.23	1.70	1.83	3.39	2.78	1.14
Blend - Prima + Fridge	27.01	7.04	0.06	35.29	0.44	0.35	195.85	75.07	19.05	0.26	4.65	218.88	50.75	34.10	0.28	3.30	1.72	1.85	3.37	2.76	1.16
Blend - Prima + Ptarmigan	26.78	6.87	0.07	38.27	0.36	0.38	179.18	75.65	20.54	0.24	4.12	211.87	42.98	26.51	0.26	3.02	1.74	1.86	3.46	2.84	1.18
Fall Rye - Hazlet	27.04	7.92	0.07	36.27	0.54	0.37	188.77	74.69	20.15	0.28	4.55	213.51	46.60	27.04	0.27	3.22	1.71	1.83	3.24	2.66	1.15
Fall Rye - Prima	27.53	8.12	0.05	35.75	0.46	0.33	192.18	74.27	20.20	0.30	4.00	492.75	56.56	31.36	0.26	3.29	1.70	1.82	3.34	2.74	1.14
Winter Trit - Fridge	26.03	6.74	0.10	37.42	0.43	0.38	180.86	74.36	20.95	0.23	4.83	255.60	59.26	41.57	0.28	3.15	1.70	1.82	3.41	2.80	1.14
Winter Trit - Luoma	28.85	7.83	0.05	35.24	0.41	0.35	193.53	76.55	20.30	0.23	4.35	276.05	56.27	49.73	0.28	3.31	1.76	1.89	3.48	2.85	1.20
Winter Wheat - Moats	27.12	6.00	0.09	37.60	0.37	0.32	183.25	75.34	19.34	0.21	3.92	226.88	38.68	32.48	0.26	3.22	1.73	1.85	3.43	2.81	1.17
Winter Wheat - Ptarmigan	25.91	8.43	0.07	37.47	0.30	0.31	184.12	75.14	19.20	0.20	4.03	264.04	46.75	27.87	0.27	3.20	1.72	1.85	3.43	2.82	1.16
Check Total	**26.95**	**7.28**	**0.07**	**36.70**	**0.41**	**0.34**	**186.61**	**75.05**	**20.18**	**0.24**	**4.33**	**269.54**	**50.18**	**34.18**	**0.27**	**3.22**	**1.72**	**1.84**	**3.40**	**2.79**	**1.16**
Fall Biomass- CMVC																					
Blend - Fridge + Ptarmigan	26.73	6.92	0.10	36.84	0.41	0.29	184.79	71.76	20.57	0.19	4.01	337.26	56.14	33.75	0.25	3.18	1.64	1.77	2.98	2.44	1.07
Blend - Prima + Fridge	28.04	7.32	0.07	34.95	0.45	0.31	196.23	72.28	19.85	0.27	3.86	353.81	61.65	37.25	0.27	3.40	1.65	1.79	2.99	2.45	1.09
Blend - Prima + Ptarmigan	26.88	6.91	0.07	36.70	0.38	0.31	187.17	72.51	19.59	0.26	3.81	333.29	49.38	27.59	0.25	3.19	1.66	1.79	2.99	2.45	1.10
Fall Rye - Hazlet	27.22	7.60	0.04	34.72	0.44	0.38	201.88	73.70	17.68	0.28	4.12	204.92	49.93	27.91	0.25	3.50	1.69	1.83	3.08	2.52	1.13
Fall Rye - Prima	28.76	7.63	0.06	34.37	0.45	0.33	203.82	73.44	17.96	0.31	3.64	261.21	50.98	26.25	0.28	3.84	1.68	1.82	3.09	2.53	1.12
Winter Trit - Fridge	26.39	6.84	0.08	34.65	0.41	0.36	201.07	72.82	18.98	0.23	4.29	201.65	52.83	36.10	0.25	3.46	1.67	1.80	3.04	2.49	1.10
Winter Trit - Luoma	27.81	7.80	0.06	35.18	0.43	0.33	195.93	72.50	19.29	0.23	3.94	263.94	54.22	40.87	0.26	3.65	1.66	1.79	3.06	2.51	1.10
Winter Wheat - Moats	26.80	5.98	0.07	35.93	0.31	0.29	193.80	73.26	18.30	0.21	3.74	188.29	42.49	24.81	0.26	3.50	1.68	1.81	3.06	2.51	1.12
Winter Wheat - Ptarmigan	26.77	6.85	0.07	36.40	0.31	0.32	188.22	72.44	19.70	0.22	3.66	341.62	48.70	24.92	0.25	3.24	1.66	1.79	2.98	2.44	1.09
CMVC Total	**27.27**	**7.09**	**0.07**	**35.53**	**0.40**	**0.32**	**194.77**	**72.74**	**19.10**	**0.25**	**3.90**	**276.22**	**51.81**	**31.05**	**0.26**	**3.44**	**1.66**	**1.80**	**3.03**	**2.48**	**1.10**
Fall Biomass Total	**27.08**	**7.20**	**0.07**	**36.21**	**0.41**	**0.34**	**190.01**	**74.09**	**19.73**	**0.24**	**4.15**	**272.57**	**50.92**	**32.76**	**0.26**	**3.27**	**1.70**	**1.83**	**3.30**	**2.71**	**1.14**

Silage Biomass-Check																					
Blend - Fridge + Ptarmigan	6.81	2.89	0.02	62.89	0.38	0.15	90.95	56.00	39.21	0.19	1.89	92.23	18.12	27.60	0.21	1.98	1.23	1.17	2.46	2.02	0.61
Blend - Prima + Fridge	7.04	1.95	0.02	63.73	0.41	0.15	87.28	56.23	39.46	0.20	1.78	99.85	16.15	33.03	0.18	1.92	1.24	1.18	2.47	2.03	0.62
Blend - Prima + Ptarmigan	6.50	2.59	0.02	63.88	0.38	0.13	86.18	55.30	41.37	0.16	1.73	86.93	16.35	23.83	0.16	1.94	1.22	1.15	2.43	2.00	0.60
Fall Rye - Hazlet	7.14	2.15	0.02	61.47	0.39	0.16	94.35	56.10	37.99	0.18	1.78	96.83	17.23	33.38	0.21	2.02	1.23	1.18	2.47	2.03	0.61
Fall Rye - Prima	7.38	2.27	0.02	61.39	0.37	0.17	94.10	56.43	38.75	0.18	1.74	93.15	15.93	35.93	0.21	2.03	1.24	1.19	2.48	2.04	0.62
Winter Trit - Fridge	7.44	1.99	0.01	62.91	0.43	0.15	89.20	58.45	39.35	0.18	1.84	105.38	19.53	50.33	0.24	1.95	1.29	1.26	2.57	2.11	0.68
Winter Trit - Luoma	8.17	1.72	0.02	60.82	0.39	0.15	96.03	58.98	37.98	0.16	1.62	108.10	19.05	30.75	0.19	2.05	1.30	1.27	2.59	2.13	0.70
Winter Wheat - Moats	6.97	1.73	0.02	61.58	0.27	0.12	96.40	56.58	38.16	0.15	1.64	81.40	16.98	27.90	0.17	2.05	1.25	1.19	2.49	2.04	0.63
Winter Wheat - Ptarmigan	8.07	2.20	0.02	59.33	0.36	0.16	103.50	58.30	36.39	0.19	1.79	83.55	21.25	28.38	0.18	2.15	1.29	1.25	2.57	2.10	0.68
Check Total	**7.28**	**2.18**	**0.02**	**62.00**	**0.37**	**0.15**	**93.11**	**56.93**	**38.74**	**0.18**	**1.75**	**94.16**	**17.84**	**32.34**	**0.19**	**2.01**	**1.25**	**1.20**	**2.50**	**2.05**	**0.64**
Silage Biomass Total	**7.28**	**2.18**	**0.02**	**62.00**	**0.37**	**0.15**	**93.11**	**56.93**	**38.74**	**0.18**	**1.75**	**94.16**	**17.84**	**32.34**	**0.19**	**2.01**	**1.25**	**1.20**	**2.50**	**2.05**	**0.64**

***Table 5**. Feed data of fall and silage biomass check and treated (CMVC)*

Cereal/cultivar	Protein %	Copper	Sodium %	NDF %	Calcium %	Phosphorous %	RFV	TDN %	ADF %	Magnesium %	Potassium %	Iron	Manganese	Zinc	Sulfur	DMI	NEL Mcal /kg	NEM Mcal /kg	DE Mcal /kg	ME Mcal /kg	NEG Mcal /kg
Grazed Fall	27.08	7.20	0.07	36.21	0.41	0.34	190.01	74.09	19.73	0.24	4.15	272.57	50.92	32.76	0.26	3.27	1.70	1.83	3.30	2.71	1.14
Grazed Silage	7.25	2.13	0.01	62.32	0.35	0.14	91.50	56.36	39.86	0.17	1.72	84.45	18.35	29.53	0.18	2.00	1.24	1.18	2.48	2.03	0.62
Ungrazed Silage	7.30	2.22	0.02	61.67	0.40	0.15	94.72	57.49	37.61	0.19	1.79	103.86	17.33	35.16	0.20	2.01	1.27	1.22	2.53	2.08	0.65

***Table 6**. Feed data of fall and silage biomass grazed and ungrazed*

Crop-cultivar / Yield (kg/ha)	2015		2016		2017		Averaged Yield (bu/ac)	
	Grazed	**Ungrazed**	**Grazed**	**Ungrazed**	**Grazed**	**Ungrazed**	**Grazed**	**Ungrazed**
Fall Rye - Hazlet	5776	6070	NA	3074 b	5757 ab	3949	86	75
Fall Rye - Prima	4920	5009	NA	2608 cd	3751 c	5239	65	76
Winter Trit - Fridge	5852	5604	NA	3111 ab	5463 b	3965	84	71
Winter Trit - Luoma	5498	4895	NA	3692 ab	6684 ab	4356	91	69
Winter Wheat - Moats	4772	5191	NA	2765 cd	5432 b	4772	76	74
Winter Wheat - Ptarmigan	4858	4454	NA	2525 d	5368 b	4001	76	63
Blend - Prima + Fridge	5099	5321	NA	2830 bcd	4033 c	3374	68	65
Blend - Prima + Ptarmigan	4713	4458	NA	2986 bc	4144 c	3251	66	57
Blend - Fridge + Ptarmigan	5822	5775	NA	3014 bc	5696 ab	3758	86	71

Table 7. *Yield grazed and ungrazed (kg/ha) and an average of grazed and ungrazed (bu/ac) with LSD analysis*

Ungrazed	2015							2016						
Combine Sub-Sam 1,2,3 &4	C.P.%	TDN	Ca	P	K	MG	Kg/ha DM	C.P.%	TDN	Ca	P	K	MG	Kg/ha DM
FALL RYE Check Hazlet	7.8	67.5	0.21	0.17	0.83	0.1	475,759.97	6.88	63	0.21	0.19	1.08	0.09	1,161,091.42
FALL RYE Cruiser Hazlet	6.9	61.7	0.31	0.14	0.89	0.11	402,651.52	7	62	0.22	0.18	1.24	0.09	1,607,980.77
FALL RYE Check Prima	8.6	68.12	0.16	0.18	0.8	0.1	502,576.35	6.5	62.2	0.2	0.18	1.05	0.1	1,565,695.97
FALL RYE Cruiser Prima	7.2	64.3	0.28	0.16	0.89	0.12	625,819.33	6.7	62	0.26	0.18	1.2	0.12	4,345,146.96
WINTER TRIT Check Fridge	8.6	64.1	0.26	0.19	0.81	0.1	249,997.98	6.5	62.56	0.23	0.18	1.12	0.09	1,469,983.23
WINTER TRIT Cruiser Fridge	8.7	66.5	0.2	0.19	0.78	0.11	839,839.49	6.4	63.3	0.2	0.19	0.94	0.1	NA
WINTER TRIT Check Louma	8.7	68.9	0.2	0.21	0.73	0.12	311,961.63	5.7	60.9	0.22	0.18	1.18	0.11	1,651,349.21
WINTER TRIT Cruiser Louma	8.6	66.5	0.3	0.2	0.89	0.12	419,427.88	4.77	60.1	0.18	0.15	0.95	0.08	2,237,901.12
BLEND Check Prima + Fridge	6	62.2	0.3	0.18	0.85	0.12	435,455.13	5.7	64.2	0.16	0.2	0.92	0.08	1,396,345.64
BLEND Crusier Prima+ Fridge	7.8	64.9	0.24	0.17	0.86	0.11	492,486.44	6.7	59	0.23	0.17	1.25	0.1	1,272,008.87
BLEND Check Prima+Ptarmigan	6.5	66.8	0.28	0.19	0.84	0.11	543,488.41	7.14	64	0.24	0.2	1.11	0.1	1,669,605.07
BLEND Crusier Prima+Ptarmigan	8.13	66.5	0.19	0.18	0.77	0.1	339,476.01	7	62.8	0.26	0.18	1.01	0.1	1,648,364.58
BLEND Check Fridge + Ptarnigan	8.07	66.8	0.24	0.21	0.79	0.11	372,376.16	6.4	62.8	0.2	0.18	1.01	0.1	2,023,665.89
BLEND Crusier Fridge + Ptarmigan	8.6	66.3	0.25	0.18	0.92	0.11	407,435.52	6.2	62.5	0.21	0.16	0.97	0.08	1,550,937.30
FALL RYE Check Hazlet	5.98	64.27	0.19	0.16	0.8	0.08	1,186,027.40	2017						
FALL RYE Cruiser Hazlet	6.41	67.31	0.17	0.17	0.77	0.09	660,307.69							
FALL RYE Check Prima	5.57	64.8	0.18	0.18	0.84	0.08	793,972.60							
FALL RYE Cruiser Prima	5.85	65.34	0.18	0.18	0.81	0.1	410,619.47							
WINTER TRIT Check Fridge	6.08	63.68	0.16	0.17	0.91	0.07	414,915.25							
WINTER TRIT Cruiser Fridge	5.82	62.83	0.16	0.17	0.92	0.07	293,592.23							
WINTER TRIT Check Louma	6.49	64.57	0.13	0.17	0.8	0.08	317,142.86							
WINTER TRIT Cruiser Louma	6.46	62.94	0.16	0.18	0.91	0.08	313,793.10							
BLEND Check Prima + Fridge	5.78	62.97	0.18	0.17	0.83	0.09	850,000.00							
BLEND Crusier Prima+ Fridge	6	63.52	0.2	0.19	0.88	0.08	320,289.86							
BLEND Check Prima+Ptarmigan	6.4	64.1	0.19	0.18	0.86	0.08	184,800.00							
BLEND Crusier Prima+Ptarmigan	4.26	61.94	0.18	0.17	0.87	0.08	630,000.00							
BLEND Check Fridge + Ptarnigan	5.73	63.13	0.16	0.19	0.91	0.09	227,368.42							
BLEND Crusier Fridge + Ptarmigan	5.42	64.91	0.14	0.18	0.8	0.08	651,176.47							

***Table 8.** Ungrazed yield and quality of grains after harvest. check and treated (CMVC) from WCFA*

Grazed	2015							2016						
Combine Sub-Sam 1,2,3 &4	C.P.%	TDN	Ca	P	K	MG	Kg/ha DM	C.P.%	TDN	Ca	P	K	MG	Kg/ha DM
FALL RYE Check Hazlet	8.33	68.1	0.22	0.21	0.73	0.1	196,148.36	7.16	65.8	0.19	0.19	1.02	0.09	1,161,974.78
FALL RYE Cruiser Hazlet	7.26	66.13	0.17	0.19	0.74	0.1	316,937.54	7.2	65	0.12	0.18	1.01	0.08	1,230,425.63
FALL RYE Check Prima	8.6	70.6	0.18	0.2	0.63	0.11	338,236.52	6.5	64.1	0.18	0.2	0.89	0.06	1,520,764.82
FALL RYE Cruiser Prima	7.5	68.9	0.19	0.2	0.7	0.1	295,606.80	5.9	65.3	0.18	0.19	0.84	0.08	1,373,399.50
WINTER TRIT Check Fridge	8.1	67.2	0.23	0.18	0.67	0.1	274,784.30	5.8	63.5	0.2	0.18	0.96	0.08	1,340,428.41
WINTER TRIT Cruiser Fridge	8.13	69.5	0.16	0.2	0.59	0.1	312,549.84	6.1	63.2	0.19	0.19	1.06	0.08	1,774,405.50
WINTER TRIT Check Louma	8.64	70	0.18	0.2	0.63	0.11	326,987.76	6.4	65	0.2	0.2	1.01	0.09	1,145,570.32
WINTER TRIT Cruiser Louma	8.2	66.9	0.2	0.19	0.77	0.11	NaN	6.8	64.2	0.17	NaN	1.1	0.09	1,270,741.03
BLEND Check Prima + Fridge	7.5	68.2	0.18	0.18	0.65	0.1	NaN	7.14	65.9	0.21	0.18	0.97	0.09	1,375,191.56
BLEND Crusier Prima+ Fridge	7.5	65.9	0.16	0.16	0.77	0.09	366,382.90	7.45	65.7	0.16	0.12	0.99	0.09	1,481,244.96
BLEND Check Prima+Ptarmigan	7.9	67.2	0.22	0.17	0.67	0.09	328,569.39	NaN	NaN	NaN	NaN	NaN	NaN	1,449,017.59
BLEND Crusier Prima+Ptarmigan	6.9	68.19	0.14	0.21	0.67	0.08	NaN	3.28	64.2	0.19	0.2	1.02	0.08	1,576,370.62
BLEND Check Fridge + Ptarnigan	8.18	69.99	0.2	0.19	0.68	0.11	364,440.84	5.8	63.6	0.19	0.21	1.04	0.1	1,552,257.33
BLEND Crusier Fridge + Ptarmigan	8.12	67.5	0.21	0.19	0.71	0.1	348,278.47	6.4	62.8	0.22	0.2	1.09	0.1	1,104,514.09

2017	C.P.%	TDN	Ca	P	K	MG	Kg/ha DM
FALL RYE Check Hazlet	7.19	65.08	0.19	0.15	0.81	0.08	1,202,727.27
FALL RYE Cruiser Hazlet	6.64	64.04	0.23	0.14	0.84	0.09	1,042,342.342
FALL RYE Check Prima	7.03	59.61	0.24	0.15	0.97	0.1	513,488.37
FALL RYE Cruiser Prima	6.2	65.16	0.19	0.18	0.82	0.1	580,183.49
WINTER TRIT Check Fridge	7.9	66.03	0.16	0.2	0.97	0.09	324,697.99
WINTER TRIT Cruiser Fridge	8	61.82	0.18	0.19	1	0.09	263,823.53
WINTER TRIT Check Louma	7.21	61.69	0.14	0.18	0.94	0.08	409,090.91
WINTER TRIT Cruiser Louma	7.17	61.45	0.17	0.18	0.93	0.08	540,000.00
BLEND Check Prima + Fridge	7.05	62.46	0.21	0.15	0.09	0.09	1,061,666.67
BLEND Crusier Prima+ Fridge	6.71	64.51	0.2	0.19	0.89	0.09	792,475.25
BLEND Check Prima+Ptarmigan	7.06	66.77	0.16	0.17	0.73	0.09	755,662.65
BLEND Crusier Prima+Ptarmigan	7.39	63.76	0.24	0.16	0.9	0.09	447,954.55
BLEND Check Fridge + Ptarnigan	8.11	8.11	0.15	0.19	0.98	0.09	757,391.30
BLEND Crusier Fridge + Ptarmigan	7.63	63.66	0.18	0.17	0.98	0.08	258,556.70

Table 9. *Grazed yield and quality of grains after harvest. check and treated (CMVC) from WCFA*

	Ungrazed							Grazed						
	C.P.%	**TDN**	**Ca**	**P**	**K**	**MG**	**Kg/ha DM**	**C.P.%**	**TDN**	**Ca**	**P**	**K**	**MG**	**Kg/ha DM**
2015	7.87	65.79	0.24	0.18	0.83	0.11	458,482.27	7.92	68.17	0.19	0.19	0.69	0.1	315,356.61
2016	6.40	62.24	0.22	0.18	1.07	0.10	1,815,390.46	6.30	64.48	0.18	0.43	1	0.09	1,382,593.30
2017	5.88	64.02	0.17	0.18	0.85	0.08	518,143.24	7.24	59.58	0.19	0.17	0.85	0.09	639,290.07

Table 10. *Average values of dry matter and quality of grains check and treated (CMVC) after harvest in both grazed and ungrazed conditions (from WCFA)*