EVALUATION OF ANNUAL AND PERENNIAL FORAGES FOR LATE FALL/EARLY WINTER STOCKPILE GRAZING OF BEEF CATTLE IN MANITOBA

A Thesis Submitted to

The Faculty of Graduate Studies of

The University of Manitoba

By

BRITTAINY S. HEWITT

In partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Department of Animal Science
University of Manitoba
Winnipeg, MB

ACKNOWLEDGEMENTS

I would like to extend a thank-you to my co-advisors Dr. Emma McGeough and Dr. Doug Cattani. Thank you for your guidance, understanding, encouragement, and devotion to myself and this project. It was a pleasure conducting research with you both and each of you have taught me valuable life skills. Thank you for all the opportunities you have bestowed upon me including attending various conferences across the country and participating in hands-on cattle research. To Dr. Gary Crow and Dr. Kim Ominski, thank you for your expertise, input, and advice in statistics and forage-based beef cattle production systems, respectively. I am grateful to Dr. Kim Ominski and Dr. Yvonne Lawley for sitting on my committee.

Thank you to Animal Science technicians Deanne Fulawka, Terri Garner, and Janice Haines for your assistance with data collection, processing, and submissions. Terri and Deanne, thank you for your friendship and support while I was in a new province away from home. I will be forever grateful for the times we spent together on and off the field. Thank you to the summer students whom helped with data collection during the long field seasons and sample processing including Britney Knockaert, Elisia Jones, Katya Melnick, Josée Grégoire, and Natalie Desaulniers.

Thank you to the staff and students at the University of Manitoba Ian N. Morrison Research Farm in Carman, MB for assistance with plot establishment and maintenance. Thank you to the staff and students at Parkland Crop Diversification Foundation (PCDF) in Roblin, MB and Prairies East Sustainable Agriculture Initiative Inc. (PESAI) in Arborg, MB for their help with plot establishment, maintenance, and data collection. Thank you to the Beef Cattle Research Council for funding this project.

A special thank you goes out to my parents, Patricia Hewitt and Donald Drinkill, for helping me pursue my educational adventure, emotionally and financially, for helping me to move to and from Manitoba, and for their unconditional support.

LIST OF ABBREVIATIONS

Abbreviation	**Definition**
AB	Alberta, Canada
ADF	Acid detergent fibre (DM)
ADG	Average daily gain
AOAC	Association of Analytical Communities
AR+AL	Perennial treatment Armada Meadow Brome and Algonquin Alfalfa
AR+O	Perennial treatment Armada Meadow Brome and Oxley II Cicer Milkvetch
AR+Y	Perennial treatment Armada Meadow Brome and Yellowhead Alfalfa
BCS	Body condition score
Ca	Calcium (DM)
CGD ha^{-1}	Cow grazing days per hectare
CHU	Crop heat units
CP	Crude protein (DM)
C+AL	Perennial treatment Courtenay Tall Fescue and Algonquin Alfalfa
C+O	Perennial treatment Courtenay Tall Fescue and Oxley II Cicer Milkvetch

C+Y	Perennial treatment Courtenay Tall Fescue and Yellowhead Alfalfa
d	Day
DE	Digestible energy (DM)
DM	Dry matter
DMI	Dry matter intake
ES	Early stockpile
FOR	Forage treatment
F+AL	Perennial treatment Fleet Meadow Brome and Algonquin Alfalfa
F+O	Perennial treatment Fleet Meadow Brome and Oxley II Cicer Milkvetch
F+Y	Perennial treatment Fleet Meadow Brome and Yellowhead Alfalfa
FOR×SP	Forage-stockpile interaction
GDD	Growing degree days
ha	Hectare
Hd d^{-1}	Head per day
K	Potassium (DM)
Kg d^{-1}	Kilograms per day
K+AL	Perennial treatment Killarney Orchardgrass and Algonquin Alfalfa

K+O Perennial treatment Killarney Orchardgrass and Oxley II Cicer Milkvetch

K+Y Perennial treatment Killarney Orchardgrass and Yellowhead Alfalfa

LS Late stockpile

LSM Least squared means

MB Manitoba, Canada

ME Metabolizable energy (DM)

Mg Magnesium (DM)

N Nitrogen

NDF Neutral detergent fibre (DM)

NO_3 Nitrate (DM)

NRC National Research Council

P Phosphorous (DM)

PCDF Parkland Crop Diversification Foundation

PESAI Prairies East Sustainable Agriculture Initiative Inc.

RCBD Randomized complete block design

RFV Relative feed value (DM)

S Sulphur (DM)

SE Standard error

SK Saskatchewan, Canada

SOM	Stage of maturity
SP	Stockpile
SY	Site-year(s)
S+AL	Perennial treatment Success Hybrid Brome and Algonquin Alfalfa
S+O	Perennial treatment Success Hybrid Brome and Oxley II Cicer Milkvetch
S+Y	Perennial treatment Success Hybrid Brome and Yellowhead Alfalfa
T	Treatment
TDN	Total digestible nutrients (DM)
TMR	Total mixed ration
TP	Timepoint
TP1	Timepoint 1 (1st week of August)
TP2	Timepoint 2 (1st week of September)
TP3	Timepoint 3 (1st week of October)
TP4	Timepoint 4 (3rd week of October)
WBDC	Western Beef Development Centre
WCCS	Western Canadian Cattle Survey

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Hewitt, Brittainy Stockwell. M. Sc., The University of Manitoba, 2018. Annual and perennial forages for stockpiled fall/winter grazing in Manitoba.

Advisors: E.J McGeough and D.J. Cattani

The intent of this study was to evaluate the yield and nutritive value of seven annual forage species, five perennial grass and three perennial legume forage species in pure stands and binary grass-legume mixtures, in an ES (early stockpile) and LS system (late stockpile), for their potential usage for stockpile grazing of beef cows. Forage samples were cut in late October 2014 and 2015 (perennial 2015 only) for DM (dry matter) and yield calculations, which were then ground and analyzed using wet chemistry to determine nutritive value. Corn and C+O (Courtenay + Oxley II) TDN (Total Digestible Nutrients) and CP (crude protein) values would meet the nutritional requirements of a dry beef cow (up to 648 kg) in the middle trimester of pregnancy. Corn and C+O on the ES system demonstrated good potential for high yield and adequate nutritive value for extending the grazing season for beef cows in Manitoba.

FORWARD

This thesis is written in manuscript style for potential publication in the Canadian Journal of Animal Science. Each manuscript has an abstract, introduction, materials and methods, results, discussion, tables/figures, and conclusions. There is also a general abstract, general introduction, literature review, general discussion, a list of references and appendices.

1. GENERAL INTRODUCTION

Cost of feeding is the greatest financial input for cow-calf beef producers in Canada, particularly during the winter. Costs associated with overwintering cattle in conventional drylot pens include increased feed requirements, storage and delivery of feed, providing wind breaks/shelter, manure removal, and heating of water (McCartney et al. 2004a; Saskatchewan Forage Council 2011; Sheppard et al. 2015; McCartney 2016). As a result, an increasing number of cow-calf producers are utilizing in-field overwintering strategies on more marginal land to remain competitive, profitable and sustainable in a time of increased competition for acres from annual cropping (Jungnitsch et al. 2011; Sheppard et al. 2015).

In the Northern Great Plains (USA), total annual production costs were \$828.81 cow^{-1} with feed costs accounting for 67% (\$555.30) of the cost cow^{-1} (USDA 2010). According to the Western Beef Development Centre (2015), 2008 production costs were \$573.54 cow^{-1} per year with a revenue of \$462.65 cow^{-1} for a profit margin of (–) \$110.89 cow^{-1}. Larson (2013) calculated that the net margin in 2012 for cow-calf producers was \$46.54 cow^{-1} (\$0.07 kg^{-1} liveweight). Total annual costs cow^{-1} was estimated to be \$630.48 of which 50% (\$314.87) is total feed cost and 30% (\$189.14) is winter feed and bedding. Thus, reduction in winter feed costs could increase profit margins for western Canadian beef producers. If all beef cows and replacement heifers in Canada were grazed for one more day every fall, the beef industry could potentially save \$3.5 million annually (National Beef Research Strategy 2012).

Extending the grazing season for beef cattle in western Canada offers economic benefits for beef producers compared to conventional confined feeding (Baron et al. 2014; McCartney 2016). In extended grazing systems, manure is directly deposited into the ecosystem, potentially improving the nutrient profile of the grazed land and mitigating the requirements for synthetic fertilizer (Jungnitsch et al. 2011; Penner et al. 2015; Kulathunga et al. 2016). Additionally, labour and machinery costs are reduced (MA 2008; Baron et al. 2014; Penner et al. 2015; Kulathunga et al. 2016). Cumulatively, economic benefits may be seen throughout the production system.

Many options exist for extended grazing including bale grazing, swath grazing, and stockpiled grazing with suitability dependent on several factors including winter precipitation, wind, physiology of cattle (i.e. cow, heifer, grower) and associated nutrient requirements (NRC 2016; Baron et al. 2003; McCartney et al. 2004a; Baron et al. 2005). One option for extending the grazing season is stockpile grazing which refers to grazing in the fall/winter, of forage growth accumulated from earlier in the growing season (Baron et al. 2005). Although maintaining nutritive value of standing forage late in the season may limit its use for cattle with high nutrient requirements, winter grazing of annual and perennial stockpiled forages offers potential for low cost grazing of beef cows (Sheppard et al. 2015). According to Statistics Canada (2018), this class of cattle represents the predominant proportion of cattle in Manitoba and they have lower nutrient requirements than growing or finishing cattle (NRC 2016). The Western Canadian Cow-Calf Survey (WCCS; WBDC 2015) states that 76% of producers practice winter grazing including, standing corn (6%) and/or stockpiled grazing (18%) out of 411 producers that responded to the survey.

Challenges associated with extended grazing have been reported by Sheppard et al. (2015) who observed that 30% of surveyed beef farms chose not to winter graze for the following reasons; either concern about wastage, animal welfare, decreased animal performance, and/or too much snow. Much focus by scientists has been placed on addressing these concerns and this project aims to fill knowledge gaps associated with stockpile grazing of perennial and annual forages under Western Canadian conditions.

There are few publications that study nutritive quality retention in annual forages for stockpile grazing in concert with animal performance. More research regarding winter stockpile grazing of annual and perennial forages in Manitoba will help beef producers to better understand which forages are best suited for Manitoba winter climate. Testing nutritive value and measuring yield throughout the growing season will allow for identification of forages that are suitable for stockpile grazing in the late fall/early winter under Manitoba conditions. Forages that maintain their nutritive value into the fall, produce high yields, and can be accessed by cattle under the snow are favourable.

Cool-season perennial forages tend to maintain their nutritive value later in the growing season (Villalobos 2015). Bromegrass, orchardgrass, tall fescue, and alfalfa are species that have been successfully used as monocrops and/or grass-legume mixtures for stockpile grazing beef cattle (Baron et al. 2005; Karn et al. 2005; Drapeau et al. 2007; Thompson 2013). Perennial forage stands can be maintained over several years unlike annual forages which require reseeding each year. However, forage yield potential tends to decrease over time (Drapeau et al. 2007). Annual forage grazing systems are becoming more prevalent due to the need to extend the grazing season and reoccurring drought in times of perennial forage shortage (McCartney et al. 2008). Annual forages may be of particular interest to producers, as their dry matter yield tends to peak near the end of the growing season, providing an additional food source in the fall (McCartney et al. 2008). Seeding annual forage crops has higher input costs (i.e. tillage, typically more fertilization, weed/pest control) compared to perennials but since there is less mechanical intervention, and overall this strategy could be economically sustainable for beef farmers (McCartney et al. 2004b), notwithstanding consideration of all input costs associated with individual forages being essential.

1.2 RESEARCH HYPOTHESIS AND OBJECTIVES

1.2.1 Hypothesis

There is a knowledge gap in the literature regarding persistence of nutritive value and forages that are resistant to lodging and maintain uprightness (can remain accessible to cattle under late fall/early winter conditions) in the Canadian prairies. A greater understanding of forage nutritive quality, suitable species for stockpile grazing, and pasture management (early vs. late stockpiling) is needed to improve access potential of stockpile grazing by beef producers. The hypothesis of this study was that there will be significant differences in performance between pure annual forages and pure perennial forages and/or perennial forage mixtures, that there would be differences between stockpile accumulation time for perennials and that one or more treatments would be suitable for stockpile grazing for the beef industry in Manitoba. Specifically, one study aimed to compare eight perennial forage species in pure and grass-legume mixtures in either an early stockpile (ES) or late stockpile (LS) system. A second study investigated seven annual cereals and grasses in pure stands to evaluate their potential suitability for grazing in the late fall/early winter by assessing yield, nutritive value and standing height in small plot studies. Forage treatments will be considered to have potential for stockpile grazing if (at least one annual and one perennial forage treatment on either the ES or LS) yield exceeds 2000 kg ha^{-1}, and the nutritive value meets the requirements of a mid gestation cow. Each forage treatment was assessed to determine potential carrying capacity and if nutritive value would meet the requirements of beef cows in Manitoba.

1.2.2 Objectives

The overall objective of this work is to identify forage species or mixtures that can retain their nutritive value and produce high yields in the late fall/early winter under Manitoba conditions to provide low-cost pasture-based feeding options. Specific objectives of this thesis include: (i) the assessment of eight perennial forages in pure and mixed stands under either an early or late stockpiling system for late fall/early winter yield and nutritive value; (ii) assessment of seven annual forage treatments in pure stands for late fall/early winter yield, stage of maturity, and nutritive value; (iii) to measure standing height in the late fall/early winter to assess potential accessibility of the stockpile forages for winter grazing by cattle; (iv) to assess plant stage of maturity following early/late stockpiling of forage at fall/winter harvest of perennial forages; (v) to compare the nutritive value and yield of the forages to cow nutrient and DMI requirements and therefore estimate relative carrying capacity.

2. LITERATURE REVIEW

2.1 THE BEEF INDUSTRY IN CANADA

The Canadian beef industry is a multi-billion-dollar industry and is a significant contributor to the Canadian economy (National Beef Research Strategy 2012; Statistics Canada 2011). From 2012 to 2016, beef production contributed an annual average of $16 billion to the Canadian economy (Canadian Beef 2016). There are approximately 60 000 beef farms in Canada with an average herd size of 69 cows (Canadian Beef 2016). According to Statistics Canada (2018), there were 439 600 beef cows in Manitoba as of January 1, 2018 out of a total inventory of 1.06 million cattle for the province.

There are several categories of cattle production in the beef industry including cow-calf, backgrounding and finishing (Statistics Canada 2011). Cow-calf operations focus on producing calves that will either become replacement heifers (10 – 20%) for the herd or move to backgrounding operations at six to eight months of age (Livestock Marketers of Saskatchewan 2018). Replacement heifers are bred at 15 months of age and are two years of age at calving. Average cow weight in Manitoba is 612 kg (MA 2015). In the Canadian prairies, producers try to avoid calving in January due to extreme cold and additional associated labour; calving generally begins between February and April (Sheppard et al. 2015). At this stage of production, cows and heifers are grazed on grass and/or legume pastures during the growing season and typically employ some sort of extended grazing over winter (Lardner et al. 2014). In the winter months these cows and replacement heifers are often grazed extensively using practices including stockpile grazing, swath grazing, bale grazing, corn grazing, or rolled/processed forage in confinement (Sheppard et al. 2015).

Mature dry beef cows have the lowest nutritional needs of all classes of beef cattle followed by heifers, and lactating cows (NRC 2016). A mid gestation cow with a mature body weight of 648 kg requires 500 g kg^{-1} TDN and 78 g kg^{-1} CP (AARD 2011). Heifers require more energy than gestating cows due to growth demands as they have not reached their full weight/size potential. Requirements are highest for lactating cows owing to the energy and protein requirements of milk production and nursing a calf (NRC 2016). Dry beef cows are the focus of the current study.

Backgrounding is typically the next stage of production in the beef industry; although some animals go directly to finishing. Post-weaning, non-replacement heifers and steers are typically fed a forage-based total mixed ration in confinement prior to entering the finishing phase at approximately 410 kg (McKinnon 2016; Livestock Marketers of Saskatchewan 2018). Rates of gain for backgrounders range from 1.0 to 1.2 kg d^{-1} (McKinnon 2016).

In the feedlot, cattle are "finished" or fattened with the goal of adding more muscle and intramuscular fat to achieve a high carcass grade quality at slaughter (Livestock Marketers of Saskatchewan 2018). Cattle typically spend four months in a confined feedlot where they are fed primarily an energy dense grain-based diet to achieve high rates of gain and fat cover at a rate of 1.47 kg d^{-1} (Horton et al. 1981; MA 2017).

Forage is the primary feed ingredient of dry cow diets. Beef producers are faced with increased competition for land from demand for annual crop production and from urban expansion (Statistics Canada 2016). Production and utilization of forages from available land area can be maximized by increasing yield of crops/pastures, choosing plant species appropriate for the grazing system, and by selecting grazing systems that reduce direct and indirect costs (i.e. labour, fuel, machinery, bedding, manure removal), as described by Aasen et al. 2004; McCartney et al. 2004; McCartney et al. 2009. Extended grazing systems may reduce accumulation of manure that would otherwise occur in confined winter feeding systems and may reduce nutrient runoff in the spring as manure is more dispersed (Jungnitsch 2011; Kelln et al. 2012).

2.2 EXTENDING THE GRAZING SEASON

In Western Canada, there are typically 200 winter feeding days required per year, presenting a major opportunity for cow-calf and backgrounding operations to reduce feed costs by extending the grazing season i.e. maintaining cattle on pasture for longer (McCartney et al. 2004; McCartney et al.2009). According to Manitoba Agriculture (2015), the cost of winter feed is \$1.90 $head^{-1}$ da^{-1} versus extended grazing at a cost of \$0.615 $head^{-1}$ da^{-1} for potential savings of \$1.285

head^{-1} da^{-1}. A survey conducted by Sheppard et al. (2015) assessed 1009 beef operations in Canada and found that 585 practiced some form of winter grazing with more than 65% of those 585 operations located in the prairies. Typically, winter grazing is more common in the west than the east as greater moisture accompanied by freeze-thaw cycles in the east can easily compromise nutrient value of swathed and stockpiled forages via nutrient leaching. The eastern provinces also tend to get greater snow accumulation than the west making it more difficult for cattle to acquire feedstuff and higher soil moisture conditions unsuitable for grazing (Sheppard et al. 2015).

For the purpose of this literature review, the focus will be on stockpile grazing and its role in overwintering beef systems, however, a brief discussion of other methods will be provided.

2.3 NUTRITIONAL REQUIREMENTS OF CATTLE DURING WINTER

Nutritional requirements of cattle are dependent on many factors including breed, sex, physiological state (i.e. lactating, gestation), weight, and ambient temperature (Fox et al. 1988; McCartney et al. 2004). Energy and protein needs are based on maintenance requirements of the animal as well as additional requirements for desired gain, lactation, or gestation (Fox et al. 1988; McCartney et al. 2004). According to the National Research Council (NRC 2016), maintenance energy requirements increase by up to 20% for grazing animals compared to penned animals (McCartney et al. 2004). Animals in extended grazing systems spend more time in the search and acquisition of feed and are exposed to colder ambient temperatures (Sheppard et al. 2015), greater exposure to wind (McDonald et al. 2002; Aasen et al. 2004) and lack of a heated bedding pack (Boadi et al. 2004), thus their nutrient requirements can be higher than animals in confinement. Therefore, meeting nutrient requirements is often a challenge as stockpiled forage quality is lowest during the winter months, and meeting the animal’s needs requires careful management and knowledge of feed quality. As plants mature, crude protein and energy decline while crude fibre and cellulose levels increase (McDonald et al. 2002; Mathis and Sawyer 2007). Dry cows in mid to late gestation (September to April) require 70 – 90 g kg^{-1} of crude protein of feed intake but this can vary slightly depending on ambient temperatures with colder temperatures increasing energy demands (Aasen et al. 2004).

In western Canada, periods of prolonged, extreme cold are common (Environment Canada 2018), thus resulting in higher feed requirements to meet maintenance energy requirements for normal physiological body processes (Young 1986). Increased feed intake results in decreased feed digestibility owing to faster rate of passage through the intestinal tract (Young 1986).

Lower rates of gain for dry cows are acceptable during the winter feeding period as high rates of gain would not be cost efficient and could potentially have other negative consequences including calving difficulty (Peel 2003; Hickson et al. 2006). Typically, cows are the cattle of choice when it comes to extending grazing environments as other cattle (i.e., backgrounding and finishing) have higher energy and protein requirements (NRC 2016). A mid gestation cow with a mature body weight of 648 kg and an expected calf birth weight of 39 kg requires a DM intake of 11.66 kg d^{-1} (1.8% of BW), 500 g kg^{-1} TDN, and 78 g kg^{-1} CP under early winter conditions in Manitoba (AARD 2011).

2.4 STOCKPILE GRAZING

In stockpile grazing systems, annual or perennial grass/legume crops accumulate throughout the growing season, or in the case of perennial forages, following an early season haying or grazing and are then grazed in the late fall/winter (Cuomo et al. 2012). Grazing of stockpile forages represents 29% of overwintering feeding strategies in Canada (Sheppard et al.

2015). Unlike other methods of extended grazing, the forage is not mechanically harvested and plants are harvested directly by the animal when they are released to pasture. For this reason, the nutritive value of stockpiled standing forages is often lower owing to the advanced stage of plant maturity at feeding (Mathis and Sawyer 2007). However, as the requirements of beef cows in early-mid gestation are lower than other classes of cattle such as backgrounders, stockpiled winter grazing is potentially a suitable option for this class of cattle (Aasen et al. 2004; Cuomo et al. 2012).

With stockpile grazing, as with most plants, there is often a trade-off between nutritive quality and yield; as yield increases, protein and energy decrease while neutral detergent fibre (NDF), acid detergent fibre (ADF) and lignin concurrently increase (Mathis and Sawyer 2007; Cuomo et al. 2012). Biligetu et al. (2014) found that over a seven-year study period, alfalfa-grass mixtures produced greater yields than grass monocultures or other mixtures, with DM yields of 2449 to 2758 kg ha^{-1} in late summer (August, September). Alfalfa-grass mixtures also had the greatest CP concentrations compared to the other treatments (Biligetu et al. 2014). Further, as the level of nitrogen fertilizer increased, so did the DM yield and leaf content (Cuomo et al. 2012). Dry matter yield is also impacted by stockpile initiation date with a June 15^{th} initiation resulting 2903 kg ha^{-1} and leaf content was 69% versus stem (Cuomo et al. 2012). Stockpile yield should be above 2000 kg ha^{-1} as yields below this threshold reduce grazing efficiency and provide insufficient available biomass for cattle (Coleman 1992; Dick et al. 2008).

2.4.1 Plant species selection for stockpile grazing

2.4.1.1 Perennial legumes

Legumes and/or grasses are commonly used for stockpile grazing (Sheppard et al. 2015; Biligetu et al. 2014). Alfalfa and cicer milkvetch are perennial legumes species that are commonly used in stockpile grazing systems to increase the concentration of protein in the offered feed (Acharya 2001; Sheppard et al. 2015; Biligetu et al. 2014). However, challenges exist for alfalfa due to leaf loss after frost compared with other legumes such as cicer milkvetch, and alfalfa which is less winter hardy (Loeppky et al. 1996; Acharya 2009). A study by Biligetu et al. (2014) found alfalfa to have greater yields than cicer milkvetch ($P < 0.05$) when grown as a monocrop. A study by Loeppky et al. (1996) found that cicer milkvetch takes longer to establish than alfalfa on a silty clay soil in SK, but cicer milkvetch had greater yield than alfalfa by the end of the growing season, over a seven-year period. When considering the use of legume plants in winter grazing systems to increase nutritive value it is important to note that alfalfa can cause bloat in cattle although this is not likely to be an issue in mature alfalfa stands (Loeppky et al. 1996; McCartney and Fraser 2010). Cicer milkvetch is a good alternative as it is a non-bloating legume that also retains a high nutritive value later into the season (Loeppky et al. 1996; Cuomo et al. 2012).

2.4.1.2 Perennial grasses

Cool season perennial grasses are typically favoured over warm season grasses for extended grazing. Warm season grasses such as big bluestem and switchgrass, while retaining nutritive value in the fall, often exhibit lower yield than cool season perennial grasses such as crested wheatgrass and meadow bromegrass (Biligetu et al. 2014) thus their suitability for grazing in late fall/early winter may be limited due to lower carrying capacity. Baron et al. (2005) found that meadow bromegrass grown at Lacombe, AB produced greater stockpile yields over a three-year period compared to other grasses including red fescue, Kentucky bluegrass, smooth bromegrass, and orchardgrass. Meadow bromegrass had yields ranging from 4480 to 5740 kg ha^{-1} with an accumulation period from mid-July to mid-October (Baron et al. 2005). Meadow bromegrass was of sufficient quality to meet the nutrient requirements of cows in mid-pregnancy through September and October (Baron et al. 2005). Research on cv. 'Success' hybrid bromegrass suggests that this hybrid of a meadow and smooth bromegrass has greater yields than either of the parental species which could be promising for fall stockpile grazing, however, there is no literature on grazing performance of this cultivar (Coulman 2006). The use of perennial species rather than annual species can also reduce costs associated with seed and seeding (McCartney and Fraser 2010). A study conducted in Lanigan, SK examined steer performance when grazing cool season perennial grass stockpiled pastures composed of wheatgrass, smooth bromegrass, and Kentucky bluegrass from August to October with and without supplemental feedstuffs (Anez-Osuna et al. 2015). Pasture average CP and DE throughout the study period was 90 g kg^{-1} and 2.4 Mcal kg^{-1}, respectively (Anez-Osuna et al. 2015). The nutritional value of the grass pasture in this study did not meet the protein and energy requirements for 1 kg d^{-1} gain for steers (Anez-Osuna et al. 2015) but would have met the nutritional requirements for dry cows as their nutrient requirements are lower (NRC 2016).

Orchardgrass is a cool-season perennial grass that exhibits a bunch growth habit, has good heat tolerance, performs well with legumes, and can grow in a range of soil textures and soil depths (Islam 2018). Orchardgrass produces more summer growth than smooth bromegrass, however, smooth bromegrass is comparable to the nutritive value of other cool-season grass (Hall 2008). Similar to orchardgrass, smooth bromegrass is drought tolerant and heat tolerant and can be grown in a variety of soil types (Hall 2008; Islam 2018). Orchardgrass and tall fescue have a high tolerance to frequent harvests whereas smooth bromegrass has a low tolerance (Hall 2008). Tall fescue is a bunch grass which is moderately winter hardy, moderately drought tolerant, and grows best in open, sunny areas which makes it adapted to Western Canada (Najda and Yoder 2005).

2.4.1.3 Perennial grass-legume mixtures

Perennial grass-legume mixtures are commonly used for stockpile grazing (Sheppard et al. 2015; Biligetu et al. 2014). Alfalfa and cicer milkvetch are perennial legumes species that can be incorporated with grass species in stockpile grazing systems to increase the concentration of protein of the stockpile (Acharya 2001; Sheppard et al. 2015; Biligetu et al. 2014). A study by Biligetu et al. (2014) found that alfalfa-grass mixtures had the greatest yields compared to legume monocrops in a seven-year study conducted in Saskatchewan. In Iowa, smooth bromegrass and a tall fescue-alfalfa mixture have been stockpiled (not grazed or hayed in summer) and used successfully for winter grazing by dry pregnant beef cows (Karn et al. 2005). A two-year study conducted in British Columbia found that grass-alfalfa mixtures yielded 14% more, had higher CP and lower NDF than grass monocultures (Thompson 2013). Another study conducted over four years at Brandon, MB found that incorporating alfalfa into meadow bromegrass pastures improved carrying capacity by 28% and met the requirements of lactating beef cows (Kopp et al. 2003). This meadow bromegrass-alfalfa mixture had yields ranging from 3120 to 3880 kg ha^{-1}, CP concentrations of 133 to 143 g kg^{-1}, and a carrying capacity of 164 to 200 CGD ha^{-1} (Kopp et al. 2003).

2.4.1.4 Annuals

Spring annual cereals are an option for stockpile grazing, but it is important that they are planted later in the season to avoid reaching full maturity when grazed in late fall (McCartney et al. 2004; Penner et al. 2015; Sheppard et al. 2015). Desired stage of maturity is the early dough stage by the first frost for cereal crops (Hutton et al. 2004; McCartney et al. 2004; Penner et al. 2015). Research by Kallenbach et al. (2003) suggests that annual ryegrass could be a high-quality stockpile grazing option for beef cattle during winter in the Midwestern United States. Annual ryegrass grows rapidly in the fall and can achieve yields of 3000 kg ha^{-1}; when sampled monthly from mid-December through mid-March from 1998 to 1999 stockpiled annual ryegrass yields ranged from 825 to 2356 kg ha^{-1} (Kallenbach et al. 2003). Westerwold ryegrass is relatively new to Canada and may also be a suitable candidate as an annual forage for stockpile grazing as it has been developed from early producing Italian ryegrass and cannot survive Canadian winters for growth in subsequent years (McCartney et al. 2004b).

Grazing standing corn is a strategy currently used for winter grazing in gestating beef cows, accounting for 7.1% of extended grazing strategies in Canada (Sheppard et al. 2015). Corn is a high energy and potentially higher yielding crop relative to other annual forages (Baron et al. 2003). Corn is becoming a more popular choice to extend the grazing season and there have been breeding programs to develop corn more suited to grazing opportunities in Western Canada, i.e. requiring fewer heat units for growth, a factor that has limited widespread growth of corn in areas of Canada with fewer growing days (Baron et al. 2003). Pioneer, Monsanto, and Hyland have high-yielding corn varieties with average dry matter yields ranging from 26 687 to 29 158 kg ha^{-1}, TDN ranging from 571 to 665 g kg^{-1}, and CP from 670 to 970 g kg^{-1} (Lardner et al. 2012). In comparison, Fusion RR is a cultivar of corn that has been bred for forage production, with yields of 18 039 kg ha^{-1} and 15 740 kg ha^{-1} when grown at Elm Creek, MB in 2014 and 2015, respectively (Seed Manitoba 2015, 2016). Grazing corn compared to small cereal grains is advantageous due to greater yield, adequate nutritive value, and a reduced risk of acidosis as cows become accustomed to grazing and learn the cobs are abundant, thus consuming more leaves and stem (Lardner and Glen 2015). Grazing corn may also offer potential benefits due to reduced lodging, providing shelter and mitigating the effects of extreme cold stress (i.e. wind chill) on cattle productivity, however, limited research exists in this area to date.

Other studies have found that cereal grain forage production meets the nutrient requirements of beef cows. In a study by Aasen et al. (2004), late fall and early winter swath grazing trials were conducted to determine whether nutritional requirements of dry and lactating cows were met using monocrops of barley, oat, and field pea as well as mixtures with each other and mixtures with fall rye or Italian ryegrass. Most swathed monocrops and mixtures including field peas or fall rye met the protein requirements of dry cows; however, only field pea and grass mixtures met the protein requirements of the lactating cows. Similarly, stockpiled red fescue and meadow bromegrass met the nutrient requirements of mid gestation beef cows through September and October in the Canadian prairies (Baron et al. 2005).

Longer plant growth periods result in greater yields, but nutritive value declines with plant maturation and leaf senescence (Baron et al. 2005; Mathis and Sawyer 2007). McCartney et al. (2009) however reported live weight gains of 1 kg d^{-1} for dry cows grazing corn crop residue post-harvest indicating the residue had adequate nutrients for animal growth.

2.5 OTHER METHODS OF EXTENDED GRAZING

2.5.1 Bale grazing

Bale grazing is a traditional method for extending the grazing system throughout the winter and represents 42% of extended grazing practices in Canada (Sheppard et al. 2015). Bale grazing is more commonly practiced in eastern Canada (69%) than in the Prairie Provinces (36%), as moisture in eastern Canada limits beef producers' ability to successfully use swaths and stockpile grazing (Sheppard et al. 2015). Bales are placed in rows approximately six m apart and strip grazed using electric fencing typically moved every two to five days (McCartney 2017). Bale grazing costs have, however, been reported to be higher than swath or stockpile grazing with estimates of \$1.35 hd d^{-1} (Havens et al. 2006) owing to additional machinery for harvest, transport and storage (Jose et al. 2017). In a study by Jose et al. (2017) in the Canadian prairies, grazing round bale barley hay (\$3.21 hd d^{-1}) exceeded other winter feeding system total costs including grazing whole plant corn (\$2.54 hd d^{-1}) and swathed barley (\$2.35 hd d^{-1}). Other studies have reported that the cost of feeding round bales was estimated to be 37% higher than the cost of swath grazing due to increased mechanical inputs (Volesky et al. 2002).

Forage species used in bale grazing systems can be either perennial or annual forages. In a three-year study by Kelln et al. (2011), round bale barley hay contained 125 g kg^{-1} to 140 g kg^{-1} CP and 614 g kg^{-1} to 708 g kg^{-1} TDN. In a study conducted in Saskatchewan, oat residue and pea residue had significantly lower CP and TDN than grass-legume hay suggesting that although the former was a lower cost system, the nutrient requirements of beef cows would not be met, and additional protein supplementation would be required, whereas the grass-legume hay did meet the requirements of beef cows (Krause et al. 2013).

2.5.2 Swath grazing

Swath grazing is an extended grazing method by which forages are cut at an optimal stage of maturity and placed in windrows where they were cut. It represents 25% of extended grazing practices in Canada (Sheppard e al. 2015). In general, as the plants in these grazing systems mature, protein availability decreases and NDF and ADF increases (Aasen et al. 2004; Mathis and Sawyer 2007). Therefore, there is a trade-off between nutritive quality and yield; as yield increases, protein and energy decrease while NDF and ADF increase (Mathis and Sawyer 2007; Cuomo et al. 2012). According to Alberta Agriculture Food and Rural Development, barley and oats are the most common crops used in swathed winter grazing systems (Hutton et al. 2004). Swath grazing also has the potential to improve soil nutrient concentration via increasing crop residue and recycling nutrients into the soil from manure (Hutton et al. 2004).

Freeze and thaw cycles can reduce the amount of nutrients in a swathed crop through leaching into the soil and reduce the nutritive value of the swath (Baron et al. 2005). Nutrients levels in the swath may decrease over time and more so under moist conditions (i.e. eastern provinces), therefore some producers find it necessary to provide supplemental feed (Peel 2003; McCartney et al. 2004; Sheppard et al. 2015). Sheppard et al. (2015) noted that approximately 85% of Canadian beef operations that practiced winter grazing also practiced supplemental feeding including baled hay and grains. A study conducted in Saskatchewan compared yield and nutritive value of millet and oat swaths and found oat had higher yield than millet, 8088 kg ha^{-1} compared to 6948 kg ha^{-1}, however, millet had superior nutritive value to oats, 110 g kg^{-1} CP and 609 g kg^{-1} TDN compared to 100 g kg^{-1} CP and 576 g kg^{-1} (Lardner and Larson 2011). Nutritive value of a swath can be increased by including additional plant species that have a high leaf to stem ratio and high leaf retention such as clover, cicer milkvetch, or other legumes (Aasen et al. 2004). Timing of seeding and timing of cutting also determines yield and nutritive value. In general, the longer the growing season, the greater the yield, however the more mature the plant, the lesser the nutritive value, as described above. Baron et al. (2012) examined the impact of delayed planting date on triticale and barley yield and nutritive value. These authors demonstrated that yield declined for barley (35 – 39%) when seeding was delayed from late May to early June but increased for oat and triticale (8% and 10%, respectively).

Aasen et al. (2004) found that swathed annual cereals (fall rye, barley, oats) and field pea crops had lower or similar nutrient losses (i.e. nutrient leaching from precipitation) compared to stockpiled perennial forages. All swathed treatments in the study provided the minimum requirements during fall and early winter for cows that were in mid to late stages of gestation (Aasen et al. 2004). By spring, however, only mixtures or monocrops involving field pea or fall rye met minimum energy requirements to support late gestating cows, and only the field pea monocrop or field pea mixtures with ryegrass or fall rye would support lactating cows (Aasen et al. 2004). They concluded that the nutritional losses were due to above average weathering of the swathed crops caused by late fall and winter precipitation from 1998 to 1999 (Aasen et al. 2004).

2.6 ANIMAL CONSIDERATIONS/PASTURE MANAGEMENT IN EXTENDED GRAZING SYSTEMS

Ambient temperature affects the nutritional requirements of cattle and impacts the time they will spend grazing (Prescott et al. 1994). These authors found that the amount of time spent grazing in a day decreased with decreasing mean daily temperature (temperature range from 8 to –13°C). However, this trend had a short lag time of two days which indicated that the cattle acclimated quickly to the changing ambient temperatures (Prescott et al. 1994). Both Prescott et al. (1994) and Beaver and Olson (1996) suggested that cattle adjust quickly to short term cold stress by changing their behaviour including grazing areas and frequency of grazing and that cattle better adapt to extended grazing systems over time.

Access to water in extended grazing systems is essential to successful winter grazing (Barnhart 2010). Although cattle can consume snow to meet their water requirements, windblown or trampled snow can form a hard crust under extreme conditions and limit cattle access to snow as a water source, so installation of freeze resistant portable or permanent water systems needs to be considered (Hutton et al. 2004; Barnhart 2010).

Wind breaks are also required for their cattle, particularly in the Prairie Provinces as there can be harsh environmental conditions during the winter months (Prescott et al. 1994; Beaver and Olson 1996). Portable wind breaks and bedding are recommended to help offset the negative impacts, particularly on cow performance, of prairie weather (Jose et al. 2017). If no trees are available for shelter it is important to include movable wind breaks in the extended grazing system (Prescott et al. 1994; Beaver and Olson 1996). Cattle may select more protected areas when ambient temperatures and wind chills are below -23ºC (Prescott et al. 1994; Beaver and Olson 1996). In a study by Prescott et al. (1994), cow daily grazing time was recorded using a vibracorder during the winter for 53 consecutive days and results indicated that cows grazed for less time as mean daily temperature decreased and when short-term thermal stress increased, sought protected areas during the short-term thermal stress i.e. cold and windy periods (Prescott et al. 1994). A three-year study by Beaver and Olson (1996) suggested that heifers and steers were learning this behavioural adaptation to the cold from mature cattle that had experienced previous winters on pasture. Heifers and steers that were not yet adapted to the land lost more backfat and weight throughout the winter compared to mature cattle.

Portable tensile electric fencing reduces the level of selective grazing and maximizes utilization if used appropriately in accordance to DMI requirements, nutrient requirements, and number of head in the herd (Hutton et al. 2004; Karn et al. 2005). Fencing is moved to achieve adequate nutrition for most cattle, but accessibility of forages under the snow may be reduced depending on snow depth (Hutton et al. 2004; Karn et al. 2005; Hamilton 2006). Minimum yields of 2000 kg ha^{-1} are required in order for cows to efficiently graze through snow and be able to access forages (Coleman 1992). Energy and crude protein content of forages in extended grazing systems are usually the primary concern, however, physical uprightness, affecting access to forage especially under snow conditions, and access to water/minerals are equally as important (Yoshihara et al. 2013). Generally, cattle will gain access to forages beneath the snow by kicking with their hooves and digging with their nose unless the snow is too firmly packed or iced over (Hutton et al. 2004; Karn et al. 2005; Hamilton 2006). Cattle can find forages under the snow up to depths of 25 cm in hard snow and up to 0.6 m in soft snow; however, snow depths beyond this can reduce forage intake (Hutton et al. 2004; Hamilton 2006).

Accessibility to forage was not a concern in a study by Jose et al. (2017), where cows winter grazing barley swaths had greater DM intake than cows grazing stockpiled whole corn, consuming 16 kg d^{-1} and 10 kg d^{-1}, respectively. Average monthly temperatures during the three-year period ranged from -16°C to -21°C for December, -12°C to -17°C for January, and -13°C to -22°C for February (Jose et al. 2017). During this study, cows winter grazed on barley swaths gained 9 kg whereas cows grazed on standing corn gained 26 kg over the course of the three-year study period, however, there was no significant difference between cow final body weight between the two forage treatments (Jose et al. 2017). The differences in body weight gain was likely due to cows selectively grazing for cobs, accounting for the lesser forage utilization of 50% and potentially consuming higher TDN and CP than reported from nutritional analysis of standing whole plant corn. Body condition scoring (BCS) uses numeric scoring to estimate energy reserves on cattle (NRC 2016). According to Jose et. al (2017), all cows in the study had a BCS of 2.7 by the end of the winter grazing season and thus there were no effects on cow reproduction (threshold: BCS below of 2.5 negatively impacts reproduction. The Government of Saskatchewan (2017) advises producers to expect greater voluntary feed intake on winter days when temperatures are below -20°C at mid-day and to add grain to the ration if feeding low-quality forage to increase the energy component of the feed.

Elevated nitrate content in forages are of concern in stockpile grazing (NRC 2016). Nitrate levels in forages exceeding 5 g kg^{-1} NO_3 are toxic to cattle (NRC 2016). Annual forages are typically of greater concern than perennials and elevated levels can lead to inefficient transport of oxygen and ultimately respiratory distress (Hunt 2003).

Weed competition can have a negative effect on establishment and yield for certain plant species used in extended grazing (Aasen et al. 2004). Field pea, for example, is less competitive with weeds than barley or oats. Intercropping (i.e. legumes and grasses) is generally an effective method for reducing weed abundance and increases competitiveness of the stand (Strydhorst et al. 2008). Therefore, when using field peas for extended grazing, intercropping annuals with field peas should be considered (Aasen et al. 2004). Farm surveys in Alberta revealed that yield losses due to weed competition occurred in 67% of stands surveyed for field peas and 27% for barley (Aasen et al. 2004). Where weeds are difficult to control, lower cost methods, mowing of the stand for example, should be utilized (McCartney and Fraser 2010). As mentioned previously, millet may be a good species for extended grazing and can also withstand warm summer temperatures;

however, it is a poor competitor and there is a lack of weed control options for this species (McCartney et al. 2009).

2.7 CONCLUSIONS

Use of winter grazing, in particular, use of stockpiled forages, is an effective strategy to reduce feed costs for cow-calf and backgrounding operations in western Canada. Further, management of extended grazing systems depends on region, soil type, weather, winter precipitation, physiological state of cattle, and producer preference.

As the purpose of these grazing systems is low cost pasture-based, non-confined feeding, identification of forages that can retain their nutritive value and produce high yields is desirable. There are gaps in the literature regarding winter stockpile grazing of annuals in Prairie Canada as well as a lack of information of new, adapted cultivars of perennials grown under Manitoba climatic conditions. The objectives of this study were to compare seven forage varieties of cereal grains, corn, soybean, and annual grasses for stockpile grazing and eight perennial forage species, in pure or mixed stands, in both an early stockpile (ES) and late stockpile (LS) system and to evaluate their suitability for stockpile grazing in the late fall/early winter by assessing changes in yield, nutritive value, and plant height into the fall.

3.0 MANUSCRIPT I: Evaluation of seven annual forages for fall/winter stockpile grazing of beef cattle

3.1 ABSTRACT

This study evaluated the yield and nutritive value of seven annual forage species for their potential use for stockpile grazing of beef cows. Small scale plots were seeded at three locations in Manitoba: PCDF, Roblin and PESA, Arborg in late May/early June in 2014 and 2015 and at the Ian N. Morrison Research Farm, Carman in June 2015. At each site, seven species were seeded at commercial seeding rates and fertilized as per provincial recommendations in a Randomized Complete Block Design (RCBD) with four blocks. The annual forages selected were: "Haymaker" oats (*Avena sativa*); "Hazlet" fall rye (*Secale cereale*); "Maverick" barley (*Hordeum vulgare*); "Aubade" westerwold ryegrass (*Lolium multiflorum westerwoldicum*); "Golden German" foxtail millet (*Setaria italica*); "Fusion" corn (*Zea mays*); and "Mammoth" soybean (*Glycine max*). Forage samples were cut from each plot to estimate yield and DM content using a 0.25 m^2 quadrat during the 1st week of August, 1st week of September, 1st week of October and the 3rd week of October at each site, in each year. Samples were then ground and analyzed using wet chemistry to determine nutritive value. Corn was the highest yielding treatment ($P < 0.05$) for all site-years except for Roblin in 2014 where oats and barley were higher. Fall rye and/or soybean had the highest CP ($P < 0.05$) for all site-years ranging from 142 – 234 g kg^{-1}. Corn and/or soybean had the highest TDN across all sites and sampling dates ranging from 642 – 733 g kg^{-1} at final harvest, except for Roblin 2014 where oats, fall rye, and barley had higher TDN ($P < 0.05$). Corn had the highest RFV at all sites in 2015. Barley and soybean had the highest RFV ($P < 0.05$) in 2014, at

Roblin and Arborg, respectively. Values for TDN and CP for corn, fall rye, and westerwold ryegrass in 2015 would meet the nutritional requirements of a dry beef cow (up to 648 kg) in the middle trimester of pregnancy, however yield of the latter two were significantly lower than corn thus carrying capacity on the same land base would thus be lower and supplemental feed perhaps required. Stockpile annual forages, especially corn, demonstrated good potential for high yield and adequate nutritive value for extending the grazing season for beef cows in Manitoba.

Keywords: annual forages, beef, stockpile grazing, yield, forage quality

3.2 INTRODUCTION

Extending the grazing season for beef cattle in western Canada can reduce overwintering costs for beef producers compared with confined feeding as these grazing systems often require fewer inputs. As a result, an increasing number of cow-calf producers are utilizing in-field wintering systems (Jungnitsch et al. 2011; Sheppard et al. 2015). Stockpile grazing refers to grazing in the fall/winter, of forage growth accumulated from earlier in the growing season. The Western Canadian Cow-Calf Survey (WCCS) conducted in 2014 was compared to a previous survey conducted in 1998. In 2014, approximately 50% of 411 producers that responded to the survey invested in feed nutritional quality analyses compared with 30% in 1998 and more producers were utilizing extensive winter feeding systems (76%) including swath grazing, standing corn and/or stockpiled grazing at17%, 6% and 18%, respectively (WBDC 2015).

In extended grazing systems, mechanical inputs are only required for seeding and weed control as there is little to no harvesting required (McCartney et al. 2004a). Manure is deposited directly onto the land being grazed, so costs associated with manure removal are eliminated (Aasen et al. 2004; McCartney et al. 2004a; Jungnitsch et al. 2011). Furthermore, manure deposition directly onto the grazing systems allows for nitrogen and phosphorus cycling which reduces fertilizer costs and/or fuel costs associated with spreading manure or chemical fertilizer in the spring (Jungnitsch et al, 2011; Kelln et al. 2012). Swath grazing has been estimated to require about 40% less labour than confined feeding which suggests that stockpile grazing should require even less labour and result in greater financial savings for producers (Aasen et al. 2004; McCartney et al. 2004a). Total input costs of grazing swathed barley are estimated to be \$2.35 $head^{-1}$ day^{-1} with \$1.43 accounting for feed costs and \$0.35 for labour costs (Jose et al. 2017).

There is limited research that demonstrates the potential of grazing stockpile annual forages in western Canada. Planting annuals, compared to perennials, for stockpile grazing has higher input costs (i.e. tillage, typically more fertilization) but there is less mechanical intervention overall compared to conventional drylots and swath/bale grazing. Annual stockpile grazing could be economically sustainable for beef farmers, however, consideration of all input costs associated with the individual forages is essential.

Annual forage use in winter grazing systems is becoming more prevalent due to reoccurring drought resulting in perennial forage shortages (McCartney et al. 2008). In 2011, out of the 1009 farms surveyed in Canada, 803 beef farms practiced grazing, 58% practiced some form of winter grazing and of that 58%, 68% were producers in the prairies (Sheppard et al. 2015). On stockpile grazing systems, annuals may be seeded in the spring or summer and grow until the fall or early winter, when cattle are turned onto pasture. Cool-season forages tend to maintain their nutritive value over time and are therefore preferred in stockpile grazing systems (Villalobos 2015). Warm-season forages however can be used successfully on stockpile grazing systems when summers are warm and dry (Crummett 2015). Annual forages are of particular interest to producers as their yields tend to peak near the end of the growing season providing an additional feed source in the fall (McCartney et al. 2008). Annual ryegrass and fall rye have desirable characteristics in terms of nutritive value for stockpile grazing as quality remains higher into the fall when the nutritive value of perennial species begins to diminish (McCartney et al. 2004b). Annuals also have more flexibility in timing of seeding as they grow faster than perennials, allowing producers to plant later into the season if a lower yield, less mature and higher quality forage is desired (McCartney et al. 2008).

Our hypothesis was that there were significant differences between annual species performance and that one or more of the forages would be a suitable candidate for stockpile grazing trials. The objective of this study was to compare seven forage species of cereal grains, corn, soybean, and annual grasses and evaluate their suitability for stockpile grazing in the late fall/early winter by assessing changes in yield and nutritive value into the fall as well as assessing plant uprightness.

3.3 MATERIALS AND METHODS

3.3.1 Sites

Experimental sites selected were Arborg, Roblin, and Carman, Manitoba on the basis of beef farm abundance and to provide a range of soil types to conduct evaluation of forage quality retention on a small plot scale (Figure A1). The Roblin site, at the Parkland Crop Diversification Foundation (PCDF), is located at 51°11'00.2"N 101°21'21.0"W. Soil type in Roblin was humic luvic greysol with relatively poor drainage. This is a loam soil that is weak to moderately calcareous with fine loamy to clayey sediments in depressional areas of fine loamy morainal till

(Eilers 1983). The Arborg site, at the Prairies East Sustainable Agriculture Initiative Inc. (PESAI), is located at 50°54'17.5"N 97°16'21.6"W. The soil at the Arborg site is a combination of fyala and tarno soils. Fyala and tarno are regohumic gleysol clay soils with poor drainage (Podolsky 1982). The Carman site at the Ian N. Morrison Research Farm of the University of Manitoba, is located at 49°29'42.7"N 98°02'26.7"W. The soils at Carman are characteristic of Red River Valley soils which are primarily lacustrine clay ranging in particle size from coarse loamy to clay. There is also deltaic soil overlaying lacustrine in some areas. These soils are dominantly well to imperfectly drained (Mills and Haluschak 1993).

3.3.2 Experimental Treatments

Seven annual species were seeded as monocrops to assess their potential for stockpile grazing: Haymaker oats (*Avena sativa*); Hazlet fall rye (*Secale cereale*); Maverick barley (*Hordeum vulgare*); Aubade westerwold ryegrass (*Lolium multiflorum westerwoldicum*); Golden German foxtail millet (*Setaria italica*); Roundup Ready Fusion corn (*Zea mays*); and Mammoth soybean (*Glycine max*). This experiment was a randomized complete block design with four replicated plots per treatment at each site in two site-years.

At final harvest (3^{rd} week of October) in 2015, one quadrat plot^{-1} was taken at each site. Plots were randomized within each replicate as to whether a quadrat would be taken from the front half or back half of the plot. This change in sample collection was so that some forage remained on site over the winter in order to assess yield and nutritive value in the spring for another project. At Arborg and Carman, the half of the plot which had a quadrat removed was cut down to 10 cm either manually with clippers and a sickle (in the case of corn) or with an Alfalfa-Omega plot master with forage harvester from R-Tech Industries Ltd. The same process was used at Roblin except that a Swift Forage Harvester was used for mechanical forage cutting. The remainder of the vegetation in that half of the plot was left to overwinter to assess yield and quality in the late winter/early spring.

3.3.3 Plot Establishment

Soil samples were taken at depths of 0 – 15 cm and 15 – 60 cm prior to seeding at each site and in each year, to assess the soil nutrient levels. For the 0 – 15 cm and 15 – 60 cm depth samples, a core was collected from 4 randomly selected areas within each plot for the four replicates and composited. Soil samples were sent to Agvise Laboratories (North Dakota, USA) and a soil test was done to determine N, P, K, pH, salts, S, Zn, and organic matter. Based on soil tests for N, P, K and S, fertilizer was applied by pre-plant banding to meet the nutrient requirements of the forage with the highest requirement for each site based on provincial recommendations for the province of Manitoba (https://www.gov.mb.ca/agriculture /crops/soil-fertility/soil-fertility-guide/pubs/soil_fertility_guide.pdf).

Herbicide was sprayed on the annuals pre-seeding and mid-summer at each site. A pre-seeding glyphosate burn of plot area was applied followed by an in-crop application of Roundup mid-summer for corn and soybean and a 2,4-D for the other annual forages according to label recommendations.

Two types of inoculant were applied to Mammoth soybean: Cell-Tech Granular Inoculant, Monsanto BioAg applied at seeding at a rate of 1.5 g $m^{2\ -1}$ and BYSI-N Liquid inoculant applied prior to seeding at a rate of 2.2 mL per kg of seed.

Plot seeding rates were based on recommended rates of: 115 kg ha^{-1} for oats; 125 kg ha^{-1} for fall rye; 160 kg ha^{-1} for barley; 37 kg ha^{-1} for westerwold ryegrass; 37 kg ha^{-1} for foxtail millet;

21 kg ha^{-1} for corn; and 68 kg ha^{-1} for soybean. For both sites in both years, seeding depth was 2 cm for westerwold ryegrass and foxtail millet and seeding depth was 4 cm for soybean, fall rye, barley, oats, and corn. In 2014 and 2015, all plots were seeded into fallow land. In 2014, plot size was 1.8 m x 7 m at Roblin and Arborg. Wheat guard plots were planted on either side of all replicates except at Arborg in 2015 where fall rye was used as a guard. Plots were seeded on June 3 and June 11 at Arborg and Roblin, respectively, in 2014 with 20 cm row spacing. In 2015, corn was seeded by hand into two rows with 47 cm row spacing. In 2015 at Arborg, annual plots were 1.4 m x 7 m with six rows per plot with 28 cm row spacing. At Carman, annual plots were 2.1 m x 8 m with 19 cm row spacing and were seeded on June 1, 2015. Fusion corn was seeded to a depth of 4 cm by hand into six rows with 52.5 cm row spacing with plots in each replicate being 4.2 m x 8 m. Fusion corn plot size was double compared to 2014. At Roblin, annual plots were 1.2 m x 7 m, except for Fusion corn plots, which were 2.4 m x 7 m and seeding was on May 26, 2015. The same seeder was used in both years at Roblin, however, hoe-type openers used in 2014 were replaced with offset double disc openers in 2015. Thus, seeding depth and seeding rate remained the same but the number of rows and row spacing was changed. There were six rows per plot with 17 cm row spacing. Corn was seeded by hand into six rows with 30 cm row spacing in 2015 to accommodate the required row spacing in the absence of a corn seeder.

3.3.4 Plant measurements

3.3.4.1 Emergence:

Emergence counts took place at 7, 14, 21 and 70 days post-seeding. Three 0.25 m^2 quadrats were randomly placed within each plot and the two rows of plants (50 cm of each row) were counted.

3.3.4.2 Yield/nutritive value:

To assess changes in plant chemical composition and estimate yield in late summer/early fall, 0.25 m² plant samples were collected from each plot as follows: 1st week of August; 1st week of September; 1st week of October; and the 3rd week of October. A 0.25 m² quadrat was randomly placed within each plot and the vegetation within the quadrat was cut at a height of 10 cm and placed in a labeled 40.6 cm x 45.7 cm delnet mesh bag (Delstar Technologies, Delaware, USA). The wet mass of each sample and average delnet bag(s) mass, minus the dry bag weight was recorded and samples were then subsequently dried at 60°C in a forced-air oven for a minimum of 48 hrs. Clippers (Flisch Holding SA, Les Geneveys-sur-Coffrane, Switzerland) were used to chop corn prior to drying. The mass of the dried samples was then recorded and used to estimate DM (g kg^{-1}) of DM for each plot. Samples for yield and quality in 2014 were taken from the Roblin on July 29 (westerwold ryegrass only), August 5, September 1, October 1, and October 15. Samples were taken from the Arborg plots on July 31 (westerwold ryegrass only), August 6, September 2, October 2, and October 16. Samples for yield and quality in 2015 were taken from the Roblin plots on: July 23 (westerwold ryegrass only), August 4, September 1, October 1, and October 19. Samples were taken from the Arborg plots on August 4, September 2, October 2, and October 15. Samples were taken from the Carman plots on July 21 (westerwold ryegrass only), August 6, September 3, October 2, and October 14.

3.3.4.3 Stage of maturity:

Several maturity indices were used to assess the stage of maturity (SOM) of the annual forages: the Hanway and Ritchie (Hanway and Ritchie 1984) scale was used for corn, the Zadoks scale (Zadoks et al. 1974) was used for oats, barley, and foxtail millet, the Moore scale (Moore et al. 1991) was used for fall rye and westerwold ryegrass, and the Pedersen scale (Pedersen 2008) was used for soybean. For all four sampling dates, one quadrat plot^{-1} was taken. Wet mass was recorded and approximately 200 g from each quadrat was staged based on maturity and a mean (numeric) and/or median (alpha-numeric) SOM was calculated from all the stems. All cobs within a quadrat for corn were staged. The stage of maturity of the westerwold ryegrass across the four sampling dates was irregular because of mowing of the plots during the season to maintain vegetative forage at anticipated time of sampling in mid October.

3.3.4.4 Plant height:

Height of stand (three measurements plot^{-1}) was measured for each plot during each of the four sampling dates. Lodging was also noted in oats and barley. If lodging was noted, six height measurements were taken per plot; three for non-lodged areas and three for lodged areas. For barley or oat plots that were completely lodged, only three heights were recorded. Westerwold ryegrass was managed throughout the season to keep it as vegetative as possible. For all site-years, after the August sampling, the entire plots of westerwold ryegrass were cut down to 10 cm to allow vegetative regrowth. Only one cut was done per growing season. For each plot, an average of all recorded heights was taken to have one representative height per plot.

3.3.4.5 Forage analysis:

At final harvest in 2014, four 0.25 m^2 quadrats (not previously sampled) were taken from each plot at each site. Three were used for DM and yield estimates and nutritional analysis (pooled at grinding) and the remaining quadrat was used to assess SOM of each plot. At Roblin, a Swift Forage Harvester was used to remove the material down to 10 cm and the vegetation removed from each plot and weighed. At Arborg, a Haldrup forage harvester (Haldrup F-55, Logstor, Denmark) with a sickle bar cutter was used to cut the remainder of material on the annual plots down to 10 cm. Total mass of individual plots was recorded using an electronic scale attached to the weigh basket of the Haldrup. At Carman, all plots were harvested at a 10 cm cutting height with an Alfalfa-Omega plot master with forage harvester (R-Tech Industries Ltd, Homewood, Manitoba). The forage harvester was equipped with a Model 300 Digital Weight Indicator by Reliable Scale Corporation to permit weighing of fresh cut forage.

3.3.5 Chemical Analyses

Samples were dried, then ground using a Thomas Wiley Laboratory Mill Model #4 (Thomas Scientific, Swedesboro, NJ) with a 1 mm screen. Ground forage samples were submitted to Central Testing Laboratory Ltd. (Winnipeg, MB) for forage quality analysis. DM determination, grinding, and wet chemistry analyses at Central Testing Laboratory Ltd. were the same in both years. Wet chemistry analyses were conducted to determine: acid detergent fibre (ADF), neutral detergent fibre (NDF), crude protein (CP), relative feed value (RFV), digestible energy (DE), metabolizable energy (ME), total digestible nutrients (TDN), and minerals (potassium (K), phosphorus (P), magnesium (Mg), calcium (Ca)). Review of the method used for ADF and NDF are available in section 08-26-06 of the ANKOM (2006). The following official methods of analysis can be found in AOAC (2005): CP AOAC 990.03; nitrate in forages 986.31; and mineral is a modification of AOAC 968.08, 935.13A. More details on nutritional analysis methods can be found at the end of the appendix.

3.3.6 Statistical Analysis

Data were analyzed using the PROC MIXED procedure of SAS 9.4 (SAS Inst. Inc., Cary, NC). Two statistical models were used to analyse the data. Model 1 analyzed data from the final harvest only, with that particular timepoint being the main focus of the study as the third week of October corresponds to the time of stockpile grazing initiation. The model was applied in separate analyses of each site-year (Roblin and Arborg in 2014 and 2015; Carman in 2015, i.e. five site-years). At each site-year there were seven treatments applied to four replicate blocks in a randomized complete block design (i.e. 28 plots). The model (1) used was:

$$Y_{ij} = \mu + T_i + R_j + e_{ij}$$

where Y_{ij} is the observation of the dependent variable, μ is the mean for the variable, T_i is the fixed effect of treatment (species), R_j is the effect of the j'th replicate and e_{ij} is the random error associated with the observation.

Dependent variables for model 1 were: yield, DM, CP, DE, ME, TDN, RFV, nitrates, NDF, height, Ca, Mg, P, and K. Soybean was removed from model 1 for site-year Roblin 2014 due to establishment failure. Denominator degrees of freedom for this model were adjusted using the Kenward-Roger option to account for unequal variance among forage treatments.

The null and alternate hypotheses for model 1 were: H_0: there is no significant difference between treatments; H_A: there is a significant difference between one or more treatments. For each site-year, differences between treatment means were determined using Tukey-Kramer's multiple range test and were considered significant when $P < 0.05$. Tukey-Kramer's multiple range test is less conservative than the regular Tukey's for only slightly unbalanced designs and is more conservative when differences among samples sizes are bigger.

Model 2 analyzed data from all site-years and four timepoints (sampling dates) in one analysis in order to understand the changes in yield and nutritive value over time and provide an overarching perspective of treatments, site-years and timepoints as well as their interactions. From the plots described above for Model 1, subsamples were taken at each of the four timepoints from each of the 28 plots at each site-year. Each treatment (n= 7) within each replicate (r= 4) was considered an experimental unit for a total of 28 experimental units over each of the four timepoints (n = 112) across five site-years (Roblin 2014, Arborg 2014, Roblin 2015, Arborg 2015, Carman 2015). The model (2) used was:

$$Y_{ijkl} = \mu + SY_i + R_{ij} + T_k + TP_l + SY*T_{ik} + SY*TP_{il} + T*TP_{kl} + SY*T*TP_{ikl} + e_{ijkl}$$

where Y_{ijkl} is the response variable (e.g. yield), μ is mean for the variable, (SY_i) is the fixed effect of site and year (deemed site-year), R_{ij} is random effect of replicate within each site-year, T_k is the fixed effect of treatment (species), TP_l is the fixed effect of sampling time, $SY*T_{ik}$ is the interaction of site-year with treatment (fixed), $SY*TP_{il}$ is the interaction of site-year with sampling time (fixed), $T*TP_{kl}$ is the interaction of treatment with sampling time (fixed), $SY*T*TP_{ikl}$ is the three-way interaction of site-year with treatment and sampling time (fixed) and e_{ijkl} is the residual error.

Dependent variables for model 2 were the same as model 1 with the exclusion of height. The data for the independent variable "yield" was $\log_{10}$ transformed due to a large range of variability and to normalize the range. No other response variables were transformed. Denominator degrees of freedom for testing hypotheses in model 2 were of equal variance between treatments/timepoints/site-years. The hypotheses for model 2 were: H_0: there is no significant difference between treatments, timepoints, and/or site-years; and H_A: there is a significant difference between one or more treatments, timepoints, and/or site-years. Interactions were considered significant when $P < 0.05$.

Least squared means (LSM) were compared using the LSD test and were considered significant when $P < 0.05$. Least squared means for yield were statistically tested using $\log_{10}$ transformed data; however, non-transformed values and SE from SAS were reported in the results. For model 2, LSM difference test was used instead of Tukey-Kramer's multiple range test as it is less conservative in testing interactions.

Main effect and interaction percent contributions to the overall sum of squares were calculated to determine their independent variable contribution to overall variation in model 2. Although *P* values may indicate significance, sum of squares of interactions contributing to less than 10% to the overall sum of squares will not be discussed. If the SY*T*TP interaction is greater than 10%, T*TP, SY*T, and SY*TP will not be discussed as they are part of the three-way interaction. For each variable in model 2, the greatest main effect/s contribution/s will also be discussed.

3.4 RESULTS

3.4.1 Main effects and interactions on plant measurements

In model 1, there were significant differences ($P < 0.05$) between treatments for all variables at each site-year (final harvest only) with the exception of nitrates in Arborg 2014 (Table 1, Table 2).

Model 2 was used to compare all dependent variables across site-years, timepoints, and treatments and to understand differences across these independent variables by relating them to their interactions. There were significant differences for all main effects and interactions for all other variables in model 2 ($P < 0.001$). There were significant differences for all main effects and interactions for all variables ($P < 0.001$) except for nitrates where T*TP was not significant (Table 3).

For NDF, DE, ME, RFV, and TDN, the contribution of the SY*T*TP to the variation in the model was greater than 10%. For yield and Mg, the contribution of SY*T to the variation in the model was greater than 10%. T*TP was the most significant interaction contribution to model variation for DM whereas SY*TP was the most significant interaction contribution to model variation for nitrates. Treatment was the most significant main effect contributing to variation in model 2 for the following variables: yield, NDF, CP, DE, ME, RFV, TDN, Ca, and Mg. Timepoint was the most significant main effect for DM whereas site-year was the most significant main effect for nitrates (Table 4).

3.4.2 Yield

For the final harvest data only (model 1), corn was the highest yielding treatment ($P < 0.001$) ranging from 12 594 to 40 491 kg ha^{-1} except for Roblin 2014 where oats and barley had greater yields than corn; 8267 kg ha^{-1} and 6964 kg ha^{-1}, respectively. Fall rye was consistently within the lowest yielding annuals at final harvest ranging from 1951 to 5232 kg ha^{-1} across site-years (Table 2).

There was a significant SY*T interaction in model 2 which accounts for 20% of the variation (Table 4). Yield across all timepoints was highest for corn at Arborg, Roblin, and Carman in 2015, however, at Arborg 2015 oat yield was not significantly different than corn yield. Oats and barley had the highest yield across all timepoints for Roblin 2014 (Table 5, Figure 1). Treatment had the greatest effect on variation in the model at 38% (Table 4).

3.4.3 Dry matter content

At the final harvest, barley, oats, and/or foxtail millet had the highest DM (model 1). At Roblin 2015, oats and barley had the highest DM than any other site-year; 804 g kg^{-1} and 847 g kg^{-1}, respectively. Whereas at the other sites oats ranged from 615 g kg^{-1} to 764 g kg^{-1} and barley from 539 g kg^{-1} to 784 g kg^{-1}, excluding Arborg 2014 where solely oats was highest. Foxtail millet was not different ($P < 0.05$) than oats and barley at Roblin 2014, Arborg 2015, and Carman 2015 where DM ranged from 600 g kg^{-1} to 658 g kg^{-1} (Table 1).

There was a significant T*TP interaction in model 2 which accounts for 11% of the variation in the model (Table 2). Barley had the highest DM at each timepoint averaged across all site-years; oats DM was not different than barley for the final harvest (Table 6). Timepoint had the greatest effect on variation in the model at 44% (Table 4).

3.4.4. Neutral detergent fibre

At final harvest, foxtail millet had the highest NDF at Roblin in 2014 and 2015; 694 g kg^{-1} and 647 g kg^{-1}, respectively. At Arborg, foxtail millet and oats had the highest NDF in both years, with barley and fall rye similar in 2014. Oats and westerwold ryegrass had the highest NDF at Carman 2015 (Table 1).

There was a significant SY*T*TP interaction in model 2 (Table 4). Foxtail millet had the highest NDF of 611 g kg^{-1}, which was higher than any other treatment across all timepoints and site-years (Table 7, Figure 2). Treatment accounted for 45% of the total variation in the model (Table 4).

3.4.5 Digestible energy, metabolizable energy, and total digestible nutrients

For model 1, there were no differences between the three highest DE values at Roblin 2014: oats, fall rye, and barley. At Arborg 2014, fall rye, westerwold ryegrass, corn, and soybean had the highest DE, whereas corn and fall rye had the highest DE in at Arborg and Carman 2015. At Roblin 2015, barley and corn had the highest DE values. Highest ME and TDN values (Table 1) were the same as DE, except for TDN at Arborg 2015 where corn has the highest TDN of 691 g kg^{-1}. ME and TDN values for corn across site-years ranged from 2.24 Mcal kg^{-1} to 2.68 Mcal kg^{-1} and 613 g kg^{-1} to 733 g kg^{-1}, respectively (Table 1).

The results from model 2 were the same for DE, ME, and TDN. There was a significant SY*T*TP interaction which accounts for 15% of the variation in the model 2 (Table 4). Corn had the highest TDN of 676 g kg^{-1} compared to any other treatment across all timepoints and site-years (Table 7, Figure 2). Treatment accounted for 30% of the total variation in the model for these three variables (Table 4).

3.4.6 Crude Protein

At final harvest, fall rye had the highest CP at all site-years ranging from 154 g kg^{-1} to 234 g kg^{-1}; however, there was no significant difference between fall rye and soybean at final harvest Arborg 2014 (142 g kg^{-1}) and Roblin 2015 (147 g kg^{-1}). Westerwold ryegrass had the lowest CP in 2014 at both sites ranging from 60 to 68 g kg^{-1} and corn had the lowest CP across all sites in 2015 ranging from 66 to 84 g kg^{-1} (Table 1).

For model 2, all interactions contributed less than 6% to the variation in the model. For main effects, treatment had the greatest effect on variation in the model at 57% (Table 4). Either fall rye and/or soybean had the highest CP for all site-years (Table 5). Fall rye and soybean had the highest CP across all timepoints at Arborg 2014, Roblin 2015, and Arborg 2015. At these site-years, fall rye ranged from 169 g kg^{-1} to 230 g kg^{-1} and soybean ranged from 157 g kg^{-1} to 219 g kg^{-1}. At Roblin 2014, soybean, next to fall rye, had the highest CP and at Carman 2015, fall rye had the highest CP at 199 g kg^{-1} and 230 g kg^{-1}, respectively (Table 5).

3.4.7 Relative feed value

For model 1, barley and soybean had the highest RFV of 128 and 148 at Roblin and Arborg, respectively, in 2014. Note that there were no final harvest values for soybean in Roblin 2014. In 2015, corn had the highest RFV at all three sites ranging from 122 to 157 but was not statistically different from soybean at Roblin and fall rye, barley and soybean at Arborg (Table 1).

There was a significant SY*T*TP interaction for RFV which accounts for 14% of the variation in the model (Table 4). Soybean had the highest RFV of 153 across all timepoints and site-years (Table 7, Figure 2). Treatment accounted for 35% of the total variation in model 1 (Table 4).

3.4.8 Nitrates

At final harvest, there were no or few significant differences between treatments for nitrates at Arborg 2014, Roblin 2015, and Carman 2015. At Roblin 2014, oats, fall rye, and foxtail millet had the highest nitrate concentrations. At Arborg 2015, nitrates for oats, fall rye, barley westerwold ryegrass, and foxtail millet were the highest and not significantly different from each other. Most nitrate values were below maximum allowable levels (5 g kg^{-1} NO_3) except for oats (5.4 g kg^{-1} NO_3), fall rye (5.5 g kg^{-1} NO_3), westerwold ryegrass (5.3 g kg^{-1} NO_3), and foxtail millet (5.9 g kg^{-1} NO_3) at Arborg 2015 as well as fall rye (5.4 g kg^{-1} NO_3) at Carman 2015. Barley (4.9

g kg^{-1} NO_3) was not significantly different from the values above at Arborg 2015, however, barley fell below the maximum allowable levels whereas the other treatments did not (Table 1).

There was a significant SY*TP interaction in model 2 which accounts for 11% of the variation in the model (Table 4). Nitrates were highest during the 1st week of August averaged across all treatments at all site-years except for Roblin 2014 where nitrates were not different between timepoints (Table 8). Site-year had the greatest main effect on variation in the model at 30% (Table 4).

3.4.9 Minerals

P and K for the first three cuts are presented in tables as appendices to this chapter (Table A1) as they were not included in model 2 analysis.

3.4.9.1 Calcium

For model 1, fall rye (4.58 g kg^{-1}) had the highest Ca at Roblin 2014. Soybean Ca ranged from 10.78 g kg^{-1} to 17.45 g kg^{-1} and had the highest Ca at all other site-years; fall rye of 10.35 g kg^{-1} Ca was not different than soybean at Arborg 2015 (Table 10).

For model 2, all interactions contributed less than 6% to the variation in the model. For main effects, treatment had the greatest effect on variation in the model at 84% (Table 4).

3.4.9.2 Magnesium

At final harvest, foxtail millet had the highest Mg of 2.28 g kg^{-1} at Roblin 2014. Soybean at had the highest Mg at all other site-years ranging from 4.43 g kg^{-1} to 10.02 g kg^{-1}, however, fall rye was not different than soybean at Arborg 2015 (Table 10).

There was a significant SY*T interaction in model 2 which accounts for 12% of the variation in the model (Table 4). Soybean had the highest Mg at each site-year averaged across all timepoints (Table 5). Treatment had the greatest main effect on the model accounting for 56% of the variation (Table 4).

3.4.9.3 Phosphorus

At final harvest, fall rye had the highest P, ranging from 3.55 g kg^{-1} to 4.43 g kg^{-1}, for all site-years although there was no difference between fall rye and soybean at Arborg 2014 (Table 10).

3.4.9.4 Potassium

Fall rye had the highest K across all site-years, ranging from 17.35 g kg^{-1} to 28.65 g kg^{-1}. At Roblin 2015 and Arborg 2015, westerwold ryegrass K levels were not different from fall rye. There were no differences between K for fall rye, soybean, westerwold ryegrass, and foxtail millet at Arborg 2014 and no differences between fall rye and soybean at Carman 2015 (Table 10).

3.4.9.5 Tetany ratio

At final harvest, tetany ratios for all treatments at all site-years were below recommended values of 2.2 mEq kg^{-1}, except for oats at Roblin 2014, at 2.49 mEq kg^{-1} (Table 11).

3.4.10 Plant height

Corn was significantly taller than any other treatment at final harvest for all site-years (Table 1). Therefore, plant height was not analyzed for interactions in model 2.

At final harvest, oat lodging ranged from 65 – 90% and barley lodging ranged from 50 to 100 % at the three sites where lodging was noted (Table 9).

3.4.11 Day 70 plant counts

There were numerical differences between treatments for the day 70 plant count at all site-years (Table 12). However, statistical analyses were not performed on day 70 plant counts owing to differences in counting/classification amongst staff as to whether it was a plant or a shoot of a plant.

In 2014, westerwold ryegrass, barley, and oats had the highest plant counts as well as foxtail millet at Roblin. At Roblin, day 70 plant counts were 66, 61, and 64 plants m^{-2} for westerwold ryegrass, barley and oats, respectively. At Arborg, day 70 plant counts were 133, 126, and 103 plants m^{-2} for westerwold ryegrass, barley and oat, respectively.

In 2015 at Roblin, foxtail millet, fall rye, barley, westerwold ryegrass, and oat had the highest plant counts. At Arborg, westerwold ryegrass, foxtail millet, and barley had the highest plant counts. At Carman, westerwold ryegrass, foxtail millet, and oat had the highest plant counts. Westerwold ryegrass and foxtail millet were the highest plant counts overall, ranging from 72 – 101 plants m^{-2} and 65 – 82 plants m^{-2}, respectively (Table 12).

3.4.12 Stage of Maturity

Statistical analyses were not performed on stage of maturity values as they were alpha-numeric and different scales were used for different species that could not be compared statistically (Table 13). At Roblin 2014 final harvest, oats, barley, and foxtail millet were not at full maturity (Zadoks et al. 1974); oats were at the medium milk stage (Zadoks 76), barley had formed hard dough (Zadoks 88), and foxtail millet was at the beginning stage of inflorescence (the unfolding of a flower or seed head, Zadoks 51). Fall rye was less mature than westerwold ryegrass (Moore et al. 1991) as it was still in the vegetative-leaf development stage (stage 1.45), whilst westerwold ryegrass was in the reproductive development stage (stage 2.93). Corn (Hanway and Ritchie 1984) was still at its blister stage (R2) or beginning of cob development.

At Arborg 2014 final harvest (October 16), oats were at full maturity (92), the barley was at the hard dough stage (89), and the foxtail millet was still in the anthesis stage (66). The fall rye was at the same SOM as at Roblin 2014 and the westerwold ryegrass was slightly less mature (2.86) than at Roblin 2014. Corn at Arborg was also in the blister stage (R2) and soybean was at a beginning pod stage (R3).

In 2015 at all three sites, oats and barley reached full maturity (92) by the final harvest. Foxtail millet also reached full maturity by the final harvest at all sites except Arborg, where it remained at soft dough (83). Fall rye remained vegetative (1.2) into the fall at all sites, although a small number of immature seed heads were observed. At final harvest, the westerwold ryegrass at all sites was at an early to mid-reproductive stage (2.7 – 3.2). Corn maturity was more advanced in 2015 than 2014. In mid-October 2015, corn at Roblin and Arborg was at the dent stage (R5) and corn at Carman had reached physiological maturity (R6). Soybean was in a reproductive state at harvest but plots at Roblin were less mature than the other sites. Soybean at Roblin was at a full pod (R4), whereas soybean at Arborg and Carman were at beginning maturity (R7) and full maturity (R8), respectively (Table 14).

3.5 DISCUSSION

There is limited literature regarding stockpile grazing of annual forages in western Canada. This study provides information about the yield, nutritive potential and physical height of seven annual grass and cereal species to be used for late fall/early winter stockpile grazing for the calf-cow sector of the beef industry in Manitoba. Stockpile grazing forages and corn is practiced by approximately 36% of producers in Western Canada who utilize extended grazing strategies (Sheppard et al. 2015). In addition to assessing the variables at potential time of grazing in late fall/early winter, profiles were generated for each forage from late summer to assess changes over time in the growing season and to evaluate if yield and nutritional quality would persist in the fall.

Stockpile grazing is an effective way to extend the grazing season and provide a low-cost food source after conventional forage growth has ceased (McCartney et al. 2004a; McCartney 2016). A Canadian beef farm survey reported that about 30% of the surveyed farms chose not to winter graze because of either concern about wastage, animal welfare, decreased animal performance, and/or too much snow (Shepard et al. 2015). However, of the 60% that did practice winter grazing, 58% of those producers reported improved cattle heath and body condition (Shepard et al. 2015). This suggests that winter grazing systems not only have an economic advantage in regard to reduced feed costs but show improvement in cattle performance despite weather conditions (Shepard et al. 2015).

3.5.1 Establishment

At all five site-years, foxtail millet, fall rye, westerwold ryegrass, barley and/or oats had the highest day 70 plant counts ranging from 61 – 133 plants m^{-2} (Table 12). All the annual forage treatments had successful establishment, however, soybean at Roblin 2014, although established, was deemed a failure by T3. This was likely due to weed pressure and potential grazing from deer. Corn had lower day 70 plant counts ranging from 11 – 25 plants m^{-2}, however, this did not affect yield because corn plants were significantly larger and had greater biomass per plants than the other forage treatments.

3.5.2 Yield

The yield data on stockpiled annuals allows for determination of carrying capacity and the length of time a herd can graze on that given stockpile. Yield, CP, NDF, DM, and TDN values of some of the seven annual treatments in mid-October were compared to Seed Manitoba (2015, 2016) reports for the 2014 and 2015 growing season (reported on DM basis); variety values are averaged across site-years except for corn where data is only available for Elm Creek, MB. Seed Manitoba (2015) reported that hybrid Fusion RR corn had yields of approximately 18 039 kg ha^{-1} (DM) based on the 2014 growing season (May to September). In 2015, the same corn had yields of approximately 15 740 kg ha^{-1} (DM). Based on mid-October values from this stockpile grazing trial, corn exceeds Elm Creek forage yields in 2015 but not in 2014 (Table 3). Differences in environment and soil type could account for the higher productivity in 2014 in Elm Creek versus Arborg and Roblin. Elm Creek is approximately 20 km north of Carman and therefore, is geographically and climatically comparable to Carman. Yields from Seed Manitoba during the 2015 growing season in Elm Creek are comparable to yields at Carman; however, Carman trials performed better than Roblin and Arborg trials, thus if Carman trials would have been seeded in 2014 there would have likely been higher in productivity. This was likely due to differences in environment from 2014 to 2015. Fall rye yield average of 3389 kg ha^{-1} in this stockpile grazing trial were two-fold lower than Seed Manitoba (2015, 2016) average over 2014 and 2015, which was 7470 kg ha^{-1}. The low yield in fall rye stockpile forage was likely due to lack of heading which is likely due to early seeding in the spring in the current study. Fall rye remained vegetative until the fall except for a few heads throughout the plots. In Southern Alberta, it is recommended that fall rye be seeded in mid-August for fall grazing and if seeded too early yield, plant height, and heading will be reduced (McLelland and Brook 1999). Jefferson and Lardner (2012) report that Hazlet fall rye can be used for grazing in the first year and grain production in the second year. In the fall of 2009, Hazlet fall rye produced a yield of 2153 kg ha^{-1} (Jefferson and Lardner 2012). Yield for soybean was higher than the Seed Manitoba (2015, 2016) average of 3201 kg ha^{-1}. However, since the desired product for Seed Manitoba is oil the plants were likely planted further apart as the seed would be the desired commodity. Thus, yield would be greater per hectare, however, there would be less seeds in the harvest (7788 kg ha^{-1}). There was no information specific to Mammoth soybean variety thus the yield of 3201 kg ha^{-1} from Seed Manitoba (2015, 2016) is an average of numerous varieties of Roundup Ready Soybean. Stockpile barley yields of 6883 kg ha^{-1} in this study exceeded Seed Manitoba (2015, 2016) averages for Maverick barley in 2014 and 2015. Haymaker oats yield was comparable to MB averages in 2014 and 2015. Golden German foxtail millet had a yield comparable to the provincial average of 6373 kg ha^{-1} (Seed Manitoba 2015, 2016). By mid-October 2014, the forage did not achieve the provincial average having yields of 2800 kg ha^{-1} at Roblin and 2303 kg ha^{-1} at Arborg. However, in 2015 foxtail millet yield exceeded the provincial average (Seed Manitoba 2015, 2016).

Significant interactions in this study contributes to knowledge of selected annual species and may provide insight into nutrient and yield expectations for beef farmers. There was a strong SY*T interaction for yield which suggests that soil type (based on variable locations in this study), weather, and plant species are major contributors to yield potential. Accumulated rainfall, GDD, and average daily temperatures were variable amongst sites and years contributing to significant differences in yield within specific crops (Table A2, Figure A2, Figure A3, and Figure A4). In the summer of 2014, there was mean daily rainfall of about 3 to 4.5 mm in June and August whereas July experienced low daily mean rainfall (0.5 to 1 mm). In 2015, Roblin and Arborg had a peak in mean daily precipitation of about 4 to 5 mm in July and moderate rainfall in June and August. Carman had fairly consistent mean daily precipitation from May to July (2.5 to 3.5 mm) and a drop in rainfall of 1.5 mm or less there after. Mean monthly minimum and maximum temperatures were slightly higher in 2015 than in 2014 which could account for higher productively in 2015 (Figure A2, Figure A3, Figure A4). From May 1 to October 4, 2014, Roblin and Arborg had 1230 GDD (90% of normal) and 1370 GDD (99% of normal), respectively, whereas during this time period in 2015, Roblin, Arborg, and Carman had 1521 GDD (105% of normal), 1670 GDD (113% of normal), and 1772 (105% of normal) GDD (Table A2).

3.5.3 Nutritive value

Nutritional requirements will depend on the weight and physiological state of the cow, i.e. early to late pregnancy, lactating (NRC 2016). Producers often estimate DMI by assuming that a cow will eat 2 to 2.5 % of its body weight; however, if cattle are grazing during the early winter, additional energy requirements must be factored into DMI estimates (NRC 2016; Hutton et al. 2004). Cows grazing during the winter may require up to 20% extra energy to offset energy costs associated with foraging, walking, and thermoregulation (McCartney et al. 2004a). In stockpile grazing systems, cattle need to be confined to an area of the stockpile; otherwise they will selectively graze and waste forage (Hutton et al. 2004). Feeding loses for stored feeds range from 5 – 50%, taking into account wastage during harvesting, storage, and feeding (Hutton et al. 2004).

Crude protein, NDF, DM, and TDN values of some of the seven annual treatments in mid-October compared to Seed Manitoba (2015, 2016) reports for the 2014 and 2015 growing season (reported on DM basis); variety values are averaged across site-years except for corn where data is only available for Elm Creek, MB. Seed Manitoba (2015) reported that hybrid Fusion RR corn had 312 g kg^{-1} DM, 464 g kg^{-1} NDF and had a TDN of 708 g kg^{-1} based on the 2014 growing season from May to September. In 2015, the same corn had 298 g kg^{-1} DM, 477 g kg^{-1} NDF and had a TDN of 699 g kg^{-1}. In the current study, DM (275 g kg^{-1}) and NDF (527 g kg^{-1}) were higher than Elm Creek values (Seed Manitoba 2015, 2016); however, TDN of corn in this trial was comparable to corn in Elm Creek (Table 8). Maverick barley had an average CP of 132 g kg^{-1} in 2014 and 2015 (Seed Manitoba 2015, 2016); however, barley CP in this trial was lower (94 g kg^{-1}). Forage foxtail millet RFV, CP, and TDN averages were comparable to Manitoba values (Seed Manitoba 2015, 2016).

There is no literature on soybean use in stockpile grazing systems. By mid-October, remaining leaves were dry, fragile, and most plants were at full senescence (leaves fallen off). Soybean NDF in mid October had reached 458 g kg^{-1} (averaged across all site-years), which was the lowest NDF across treatments, and DM increased from 274 g kg^{-1} to 474 g kg^{-1} from early October to mid-October. Pods only reached full maturity at two of the five site-years and during the two harvests in October soybean stems were woody and difficult to cut with trimmers and there was leaf shatter. Although leaf/pod loss was not measured in the current study this may be particularly influential in terms of their suitability for grazing after frost and under snow conditions where the remaining biomass may be highly fibrous, potentially unpalatable stems.

There was a general trend over time that yields increased, NDF increased, and nutritive value decreased. Fall rye, westerwold ryegrass, and corn were the only treatments that demonstrated an increased or stable nutritive value later into the late fall/early winter. However, fall rye had significantly lower yield than the other two. Corn also had an increase of RFV into October. Westerwold ryegrass' high nutritive value in October was achieved through cutting the stand at 10 cm in late-July or early-August at each site-year. These summer cuts would be used by a producer for hay which could be used into the winter months. Yield during these harvests would be less than the late fall/early winter harvest, however, the nutritive value and nitrates would be higher. This cutting allowed the stand to remain vegetative for longer and although it reached a maturity of early to late heading, the stand remained green into October at all site-years.

The T*TP interaction for DM demonstrated that as the plants matured DM increased. NDF followed a similar trend to DM which was evident with a significant SY*T*TP interaction. Fiber content increased into the fall as nutritive value decreased with foxtail millet having the highest NDF for all species tested. Energy (DE, ME, and TDN) and RFV variables had high SY*T*TP interactions. Differences between site-years, timepoints, and treatments were highly variable, but corn performed best across all independent variables. Corn had increased energy into the fall and had higher values in 2015 than 2014 likely due to climatic variation. The variable RFV is an index value taking DM and DMI of an animal into consideration. For the other species, RFV decreased into the fall, however, corn RFV generally increased into the fall as starch continued to accumulate in the cobs adding to its potential for fall grazing. Nitrates had a significant SY*TP interaction meaning that location and timepoint during the growing season were the greatest contributor to variation amongst species. Nitrates are typically highest when plants are immature. Nitrates were only exceeded NRC (2016) recommendations in early August at which time cows would not be feeding on the stockpile. By the beginning of September, nitrate levels in general had dropped below harmful levels.

3.5.4 Plant height and stage of maturity

Snow depth and snow characteristics are also important factors to consider when grazing into the winter (Hamilton 2006). Cattle can graze in up to 60 cm of soft snow; however, if a crust caused by wind or thawing forms on the surface of the snow, the feed may become inaccessible (Hutton et al. 2004; Hamilton 2006). Accessibility due to plant height would not be an issue if stockpiling corn but could be an issue if stockpiling cereal grains or annual grasses. Lodging, particularly for barley and oats, could play a negative role in accessibility as well making it more difficult for cows to access forage. Lodging, when it occurred, of oats and barley ranged from 50 to 100%. It is important for farmers to monitor snow conditions and ensure that cattle have access to the stockpile or forage intake will be reduced (Hutton et al. 2004; Hamilton 2006).

For forage production systems including swath grazing, it is recommended to harvest barley at an early- to mid-dough stage, oat at the milk to early dough stage, and millet at early heading (Hutton et al. 2004; Seed Manitoba 2015, 2016). By mid-October 2014, barley was at a hard dough stage at Roblin and Arborg. At Roblin, oats were at a late milk stage whereas at Arborg oats was fully mature (ripe, hard seeds). At Roblin, foxtail millet was still in the inflorescence stage whereas at Arborg it was at anthesis. At mid-October harvest 2015, barley, oats, and foxtail millet were at full maturity, except for foxtail millet at Arborg where it was still in the early dough stage. At final harvest 2014, the only species that was at optimal maturity for grazing was oats at Roblin. At final harvest 2015, all of the grain forages were over mature for forage utilization. This variation in maturity is likely due to differences in temperature between years (Figure A2, Figure A3, Figure A4). In 2014, the GDD at the two sites were 1 – 10% lower than normal and in 2015, the GDD at the three sites were 5 – 13% higher than normal. This could explain the variation of the other treatments across site-years as well. The Government of Manitoba reports that it takes

60 – 90 days for barley to mature, 85 – 88 days for oats to mature, and 95 – 110 days for foxtail millet to mature (MA 2016). In this study, plots were seeded in late May or early June and would have theoretically been used for stockpiling in mid-October allowing 121 – 146 days for maturity. These cereal grains could have been seeded later in the season so that they were not fully mature at desired time of stockpile grazing. If preferred stockpile forage time is mid-October, oats and barley could be seeded in early August and foxtail millet could be seeded in mid-July. However, environmental conditions may not be ideal for growth under Manitoba climate i.e. adequate rainfall and warm temperatures. A study from the University of Wisconsin suggests that fall grown oats is a good way to extend the grazing season for replacement dairy heifers (Coblentz et al. 2014). They seeded two varieties of oats (Forage Plus and Ogle) on August 11, 2011. Beef heifers grazing on the stockpile oats had greater total weight gains and ADG than heifers in confinement fed a TMR (Coblentz et al. 2014). Since cows have lower nutrient requirements than heifers, similar or better results could have been observed for a solely cow treatment (NRC 2016). McCartney et al. (2008) suggests that oats can be seeded at any time from spring to late summer to meet forage requirements in the late fall/early winter in Canada.

Another consideration when grazing cereal grains is the possibility of subacute rumen acidosis (Nagaraja and Titgemeyer 2006). If cattle are selectively grazing the grain and not consuming enough fibrous material, subacute rumen acidosis due to accumulation of volatile fatty acids in the rumen could occur (Nagaraja and Titgemeyer 2006), potentially with the consumption of the oats and barley in the current study as they were at full maturity, when starches at their highest.

3.5.5 Meeting cattle requirements

As the aim of the current study is to provide information on stockpiled annuals and their potential utilization for beef cattle in Canada in the late fall/early winter, the physiological state of cattle (i.e. pregnant, cow or heifer), climate, and accessibility (i.e. snow depth) need to be considered. In the prairie provinces, cows typically calve in February and March therefore fetal growth would occur during the late fall and early winter at which time cows would be stockpile grazing (Sheppard et al. 2015). Cattle performance during winter grazing can only be estimated from nutritive and yield data shown in this study and is based on known requirements for maintenance, pregnancy, and growth. Corn TDN and CP values from the 2015 growing season would meet the nutritional requirements of a dry beef cow (up to 648 kg) in the middle trimester of pregnancy (NRC 2016; AARD 2011). Calcium would have to be supplemented into the diet but phosphorus levels would meet nutritional requirements (NRC 2016). Mid gestating cows at a maximum body weight of 648 kg and expected calf birth weight of 39 kg require a DMI of 19.4 kg/day based on an intake of 3% body weight accounting for wastage and winter climate (AARD 2011). The average yield of the three sites in October 2015 (31 591 kg ha^{-1} DM) would, in theory, be able to support approximately 60 mid gestating cows (648 kg) for 27 days on one hectare of land (AARD 2011).

The fall rye and westerwold ryegrass TDN and CP values from each site-year would meet the nutritional requirements of a dry beef cow (up to 648 kg) in the middle trimester of pregnancy (AARD 2011). Calcium and phosphorus levels were adequate to meet nutritional requirements of mid gestation cows (NRC 2016). In comparison to corn, under the same parameters, the average yield of all site-years for fall rye of 3389 kg ha^{-1} DM and westerwold ryegrass of 4050 kg ha^{-1} DM would, in theory, be able to support the same number of middle gestating cows on one hectare of land for three and three and a half days, respectively (AARD 2011). Although the potential stocking density for westerwold ryegrass is much less than corn, it could be grazed in the late summer and the regrowth would be comparable to the fall values in this study. Westerwold ryegrass would allow two grazing periods per year which makes this annual crop a good potential late fall/early winter stockpile grazing candidate next to corn.

Another concern with stockpile grazing forages is nitrate toxicity. NRC (2016) recommends that nitrates in forages do not exceed 5 g kg^{-1} NO_3. Annual forages tend to have higher nitrates levels than perennial forages and often increase under environmental stress with extreme heat, hail, frost, and drought causing nitrate levels to accumulate in forages (Hunt 2003; Hutton et al. 2004). Nitrates get converted to ammonia in the rumen, processed by the kidneys, and is excreted via urine, but if nitrate levels exceed 5 g kg^{-1} NO_3 then the conversion process in the body is unable to adequately convert the excess (Hunt 2003). Elevated levels of nitrates in forages can lead to changes in haemoglobin molecules leading to inefficient transport of oxygen in the blood thus making respiration difficult for the animal (Hunt 2003). In the current study, nitrates (g kg^{-1} NO_3) were particularly high from TP1 to TP3 at Arborg 2015 for most treatments, including fall rye, and for fall rye at Carman 2015. This was likely due to extreme heat and hail in during the 2015 field season. There were no nitrate values above 5 g kg^{-1} NO_3 at TP4.

There have been previous studies on extending the grazing season with the use of ryegrass and fall rye (Kallenbach et al. 2003; Aasen et al. 2004). Aasen et al. (2004) examined monocrop barley, oats, and field pea and mixtures with Italian ryegrass and fall rye for potential usage in swath grazing for late pregnancy and lactating cows in western Canada. Yields between monocrops of oats and barley and mixtures with fall rye and ryegrass were similar (Aasen et al. 2004). Most treatments provided minimum nutrient requirements into the late fall and early winter; however, only mixtures or monocrops involving field pea and/or fall rye and ryegrass would meet nutrient requirements into the spring. Other treatments exhibited above average weathering (Aasen et al. 2004). Another study looked at differences between two different cultivars of ryegrass and their potential use for stockpile winter forage in Missouri (Kallenbach et al. 2003). Fall rye was planted in late summer and exhibited rapid growth in the fall reaching yields from 825 kg ha^{-1} to 2356 kg ha^{-1} (Kallenbach et al. 2003). They found that stocker calves had gains of 0.5 to 1.5 kg $head^{-1}$ day^{-1} and that this high-quality forage could sustain all classes of beef and dairy cattle during the winter (Kallenbach et al. 2003). Yield of fall rye in the current study was higher than a study conducted in a warmer climate in the USA which suggests great potential for stockpile grazing animal trials in the future in Canada, however, the current study was seeded about a month prior.

Yield estimates for corn had the most variability amongst all the treatments in our study. This was likely due to two factors: different climates and changes in row spacing from 2014 to 2015 (Figure A2, Figure A3, Figure A4). In 2015, row spacing increased and plots sizes were doubled. In Manitoba, it takes 110 to 120 days for corn to mature (MA 2016). The elapsed time of corn stockpile plots fell within these parameters and corn was close to or at full maturity at final harvest 2015. However, in 2014 corn only reached the blister stage by October at which point cobs are still immature. Fusion corn used in this trial had a CHU rating of 2200 (Seed Manitoba 2015, 2016). The only site-year where this was not satisfied was Arborg 2015 (1940 accumulated CHU), which had the lowest yielding corn treatment in 2015 but was also seeded the latest. Corn in this trial demonstrated potential for late fall/early winter stockpile grazing; however, corn was slightly deficient in CP at Arborg 2014 and Carman 2015 and in Ca at Arborg 2015 and Carman 2015. Ball et al. (2008) also suggest that corn has great potential for stockpile grazing because of its high energy and yield potential. A study conducted in Lacombe and Brooks, AB compared different corn hybrids to conventional cultivars in a forage trial for potential winter stockpile grazing (Baron et al. 2003). Referencing average nutritive values to NRC, they found that all corn varieties would meet the maintenance requirements of mid gestation cows if consuming 6.0 to 7.5 kg d^{-1} DM (Baron et al. 2003). Crude protein concentrations in the current study were slightly lower than what Baron et al. (2003) found in their corn varieties. According to Lardner and Glen (2015), cows feeding on standing corn can consume 13 to 18 kg DM per day. Advantages of grazing standing corn includes greater biomass yield compared to small cereal grains, adequate energy and CP for cows in the fall and winter, and reduced risk of acidosis; however, later gestating cows may require protein supplementation (Lardner and Glen 2015).

The current study suggests that corn, fall rye, and westerwold ryegrass could provide adequate nutrition for dry cows; however, the yield for corn was up to six times greater than the other annuals tested and would be able to feed more cattle for longer. If producers aim to stockpile oats or barley in the late fall, they should seed in the late summer for optimal yield and nutritive value (MA 2016). Fall rye demonstrated high protein levels although yields of this crop were low. McLelland and Brook (1999) report that the optimal time to seed fall rye for grain production in southern and central Alberta is in September for optimal winter survival and summer productivity. More research is needed to test cattle performance when stockpile grazing on cereal grains and annual grasses in late fall/early winter in Manitoba and a cost analysis to further understand the economic advantage of stockpile grazing these annual species.

TABLES AND FIGURES

Table 1. Model 1: Chemical analyses (g kg DM^{-1} unless otherwise stated) and plant height of seven annual forages for the five site-years at final harvest (mid October).

Variable	Treatment	2014				2015					
		Roblin	SE	Arborg	SE	Roblin	SE	Arborg	SE	Carman	SE
DM (g kg^{-1})	Oat	644^{a}	17.1	764^{a}	17.0	804^{a}	40.8	615^{a}	51.4	754^{a}	31.5
	Fall rye	438^{b}	17.1	471^{c}	17.0	429^{bc}	40.8	344^{bc}	51.4	356^{c}	31.5
	Barley	647^{a}	17.1	677^{b}	17.0	847^{a}	40.8	539^{ab}	51.4	784^{a}	31.5
	Westerwold ryegrass	442^{b}	17.1	310^{d}	17.0	294^{c}	40.8	261^{c}	51.4	300^{c}	31.5
	Foxtail millet	609^{a}	17.1	456^{c}	17.0	543^{b}	40.8	600^{a}	51.4	658^{ab}	31.5
	Corn	291^{c}	17.1	340^{d}	17.0	462^{bc}	40.8	389^{abc}	51.4	552^{b}	31.5
	Soybean	n/a	n/a	459^{c}	17.0	459^{bc}	40.8	473^{abc}	51.4	341^{c}	31.5
NDF	Oat	531^{c}	8.8	608^{ab}	16.1	515^{cd}	9.9	628^{ab}	10.9	634^{a}	10.2
	Fall rye	544^{c}	8.8	567^{abc}	16.1	577^{b}	9.9	544^{c}	10.9	523^{cd}	10.2
	Barley	484^{d}	8.8	621^{ab}	16.1	473de	9.9	519^{c}	10.9	564^{bc}	10.2
	Westerwold ryegrass	541^{c}	8.8	519^{c}	16.1	534^{bc}	9.9	595^{b}	10.9	599^{ab}	10.2
	Foxtail millet	694^{a}	8.8	636^{a}	16.1	647^{a}	9.9	670^{a}	10.9	545^{cd}	10.2
	Corn	642^{b}	8.8	559^{bc}	16.1	508^{cde}	9.9	517^{c}	10.9	417^{e}	10.2
	Soybean	n/a	8.8	405^{d}	16.1	466^{e}	9.9	500^{c}	10.9	500^{d}	10.2
CP	Oat	72^{cd}	3.4	80^{b}	6.4	96^{b}	7.5	106^{cd}	0.34	102^{c}	7.3
	Fall rye	154^{a}	3.4	159^{a}	6.4	175^{a}	7.5	216^{a}	0.34	234^{a}	7.3
	Barley	86^{bc}	3.4	68^{b}	6.4	100^{b}	7.5	112^{c}	0.34	97^{cd}	7.3
	Westerwold ryegrass	68^{d}	3.4	60^{b}	6.4	103^{b}	7.5	117^{c}	0.34	89^{cd}	7.3
	Foxtail millet	86^{b}	3.4	79^{b}	6.4	76^{b}	7.5	93de	0.34	79^{cd}	7.3
	Corn	77^{bcd}	3.4	68^{b}	6.4	75^{b}	7.5	84^{e}	0.34	66^{d}	7.3
	Soybean	n/a	n/a	142^{a}	6.4	147^{a}	7.5	192^{b}	0.34	173^{b}	7.3
DE (Mcal kg^{-1})	Oat	2.88^{ab}	0.04	2.59^{bc}	0.07	2.91^{b}	0.04	2.40^{ef}	0.04	2.33^{c}	0.05
	Fall rye	2.92^{a}	0.04	2.89^{ab}	0.07	2.89^{b}	0.04	2.87^{ab}	0.04	3.01^{a}	0.05
	Barley	3.00^{a}	0.04	2.44^{c}	0.07	3.09^{a}	0.04	2.74^{bc}	0.04	2.59^{b}	0.05
	Westerwold ryegrass	2.74^{bc}	0.04	2.77^{ab}	0.07	2.87^{b}	0.04	2.51^{de}	0.04	2.42^{bc}	0.05
	Foxtail millet	2.33^{d}	0.04	2.61^{bc}	0.07	2.52^{c}	0.04	2.29^{f}	0.04	2.59^{b}	0.05
	Corn	2.70^{c}	0.04	2.95^{a}	0.07	3.12^{a}	0.04	3.05^{a}	0.04	3.23^{a}	0.05
	Soybean	n/a	n/a	2.83^{ab}	0.07	2.80^{b}	0.04	2.63^{cd}	0.04	2.51^{bc}	0.05

Variable	Treatment	2014				2015					
		Roblin	SE	Arborg	SE	Roblin	SE	Arborg	SE	Carman	SE
ME	Oat	2.39^{ab}	0.03	2.15^{bc}	0.06	2.41^{b}	0.03	2.00^{ef}	0.03	1.94^{c}	0.04
(Mcal kg^{-1})	Fall rye	2.42^{a}	0.03	2.40^{ab}	0.06	2.40^{b}	0.03	2.38^{ab}	0.03	2.50^{a}	0.04
	Barley	2.49^{a}	0.03	2.03^{c}	0.06	2.56^{a}	0.03	2.28^{bc}	0.03	2.15^{b}	0.04
	Westerwold ryegrass	2.27^{bc}	0.03	2.30^{ab}	0.06	2.38^{b}	0.03	2.09^{de}	0.03	2.01^{bc}	0.04
	Foxtail millet	1.93^{d}	0.03	2.17^{bc}	0.06	2.09^{c}	0.03	1.90^{f}	0.03	2.15^{b}	0.04
	Corn	2.24^{c}	0.03	2.45^{a}	0.06	2.59^{a}	0.03	2.53^{a}	0.03	2.68^{a}	0.04
	Soybean	n/a	n/a	2.35^{ab}	0.06	2.33^{b}	0.03	2.18^{cd}	0.03	2.08^{bc}	0.04
TDN	Oat	653^{ab}	8.3	586^{bc}	16.0	659^{b}	9.1	545^{ef}	9.3	529^{c}	11.6
	Fall rye	660^{a}	8.3	655^{ab}	16.0	656^{b}	9.1	651^{ab}	9.3	682^{a}	11.6
	Barley	681^{a}	8.3	554^{c}	16.0	699^{a}	9.1	622^{bc}	9.3	588^{b}	11.6
	Westerwold ryegrass	620^{bc}	8.3	629^{ab}	16.0	650^{b}	9.1	570de	9.3	549^{bc}	11.6
	Foxtail millet	527^{d}	8.3	593^{bc}	16.0	571^{c}	9.1	519^{f}	9.3	587^{b}	11.6
	Corn	613^{c}	8.3	668^{a}	16.0	708^{a}	9.1	691^{a}	9.3	733^{a}	11.6
	Soybean	n/a	n/a	642^{ab}	16.0	635^{b}	9.1	597^{cd}	9.3	568^{bc}	11.6
RFV	Oat	114^{b}	2.58	91^{bc}	5.24	118^{bc}	3.28	84^{bc}	2.74	82^{e}	3.27
	Fall rye	111^{b}	2.58	107^{bc}	5.24	105^{c}	3.28	111^{a}	2.74	119^{b}	3.27
	Barley	128^{a}	2.58	87^{c}	5.24	134^{a}	3.28	112^{a}	2.74	99^{cd}	3.27
	Westerwold ryegrass	107^{b}	2.58	113^{b}	5.24	112^{bc}	3.28	91^{b}	2.74	89de	3.27
	Foxtail millet	75^{d}	2.58	88^{c}	5.24	84^{d}	3.28	76^{c}	2.74	103^{cd}	3.27
	Corn	89^{c}	2.58	109^{bc}	5.24	126^{ab}	3.28	122^{a}	2.74	157^{a}	3.27
	Soybean	n/a	n/a	148^{a}	5.24	127^{ab}	3.28	113^{a}	2.74	109^{bc}	3.27
Nitrates	Oat	0.53^{abc}	0.13	0.35^{a}	0.12	1.48^{ab}	0.45	5.38^{a}	0.44	4.75^{a}	0.72
(g kg^{-1} NO_3)	Fall rye	0.83^{a}	0.13	0.40^{a}	0.12	1.83^{ab}	0.45	5.50^{a}	0.44	5.35^{a}	0.72
	Barley	0.30^{bc}	0.13	0.40^{a}	0.12	1.45^{b}	0.45	4.93^{ab}	0.44	2.70^{ab}	0.72
	Westerwold ryegrass	0.30^{bc}	0.13	0.25^{a}	0.12	1.95^{ab}	0.45	5.25^{a}	0.44	2.83^{ab}	0.72
	Foxtail millet	0.75^{ab}	0.13	0.40^{a}	0.12	3.00^{a}	0.45	5.93^{a}	0.44	3.28^{ab}	0.72
	Corn	0.20^{c}	0.13	0.33^{a}	0.12	2.36^{ab}	0.45	3.10^{bc}	0.44	1.63^{b}	0.72
	Soybean	n/a	n/a	0.20^{a}	0.12	2.65^{ab}	0.45	2.88^{c}	0.44	3.40^{ab}	0.72

Variable	Treatment	2014				2015					
		Roblin		Arborg		Roblin		Arborg		Carman	
Height (cm)	Oat	112^{b}	4.42	100^{b}	2.90	55de	4.15	57^{d}	2.13	104^{cd}	3.78
	Fall rye	38^{d}	4.42	34^{e}	2.90	41^{e}	4.15	33^{e}	2.13	57^{e}	3.78
	Barley	108^{b}	4.42	83^{c}	2.90	59^{d}	4.15	48^{d}	2.13	99^{cd}	3.78
	Westerwold ryegrass	95^{bc}	4.42	88^{bc}	2.90	80^{c}	4.15	78^{c}	2.13	94^{d}	3.78
	Foxtail millet	81^{c}	4.42	69^{d}	2.90	112^{b}	4.15	91^{b}	2.13	111^{bc}	3.78
	Corn	157^{a}	4.42	186^{a}	2.90	218^{a}	4.15	176^{a}	2.13	266^{a}	3.78
	Soybean	n/a	n/a	47^{e}	2.90	83^{c}	4.15	72^{c}	2.13	124^{b}	3.78

Table 2. Yield (kg DM ha^{-1}) of seven annual forages in late summer/early fall.

Timepoint	Treatment	2014				2015					
		Roblin	SE	Arborg	SE	Roblin	SE	Arborg	SE	Carman	SE
1st week of August	Oat	4 705^{a}	290	9 220^{a}	403	8 560^{b}	623	5 704^{b}	666	4 060^{c}	705
	Fall rye	1 509^{d}	109	2 439^{c}	68	3 180^{d}	253	3 185^{d}	110	1 483^{d}	353
	Barley	5 134^{a}	365	7 163^{b}	290	9 185^{b}	310	6 420^{b}	372	3 697^{c}	542
	Westerwold ryegrass	1 736^{c}	141	2 888^{c}	129	101^{d}	618	4 044^{c}	178	1 634^{d}	274
	Foxtail millet	1 104^{cd}	213	364^{c}	286	5 531^{b}	908	5 506^{b}	376	3 087^{c}	624
	Corn	1 859^{b}	214	3 456^{a}	562	5 997^{a}	928	4 624^{a}	1 491	13 270^{a}	1 000
	Soybean	262^{e}	141	1 220^{c}	234	2 670^{c}	485	1 092^{cd}	284	3 197^{b}	509
1st week of September	Oat	7 509^{a}	290	10 668^{a}	403	12 270^{b}	623	9 701^{b}	666	9 099^{c}	705
	Fall rye	2 572^{d}	109	2 213^{c}	68	4 692^{d}	253	2 710^{d}	110	3 272^{d}	353
	Barley	7 994^{a}	365	7 519^{b}	290	12 349^{b}	310	9 008^{b}	372	7 156^{c}	542
	Westerwold ryegrass	2 317^{c}	141	1 539^{c}	129	2 560^{d}	618	2 388^{c}	178	2 557^{d}	274
	Foxtail millet	2 336^{cd}	213	1 535^{c}	286	12 766^{b}	908	6 019^{b}	376	5 862^{c}	624
	Corn	5 438^{b}	214	9 443^{a}	562	26 460^{a}	928	12 325^{a}	1 491	29 644^{a}	1 000
	Soybean	1 138^{e}	141	3 034^{c}	234	4 678^{c}	485	3 796^{cd}	284	8 337^{b}	509
1st week of October	Oat	9 564^{a}	290	6 987^{a}	403	13 579^{b}	623	9 785^{b}	666	5 457^{c}	705
	Fall rye	2 362^{d}	109	1 805^{c}	68	5 377^{d}	253	4 030^{d}	110	2 718^{d}	353
	Barley	7 264^{a}	365	4 599^{b}	290	10 755^{b}	310	8 057^{b}	372	6 272^{c}	542
	Westerwold ryegrass	3 904^{c}	141	2 519^{c}	129	4 227^{d}	618	5 236^{c}	178	2 658^{d}	274
	Foxtail millet	3 528^{cd}	213	3 454^{c}	286	12 451^{b}	908	12 239^{b}	376	8 377^{c}	624
	Corn	5 659^{b}	214	11 179^{a}	562	37 835^{a}	928	24 632^{a}	1 491	29 454^{a}	1 000
	Soybean	1 887^{e}	n/a	3 038^{c}	234	9 903^{c}	485	5 204^{cd}	284	13 112^{b}	509

Timepoint	Treatment	2014				2015					
		Roblin	SE	Arborg	SE	Roblin	SE	Arborg	SE	Carman	SE
3rd week of October	Oat	8 267^{a}	434	6 887^{b}	800	12 024^{bc}	1 515	8 638^{b}	1 922	5 469^{cd}	1 216
	Fall rye	2 961^{b}	434	1 951^{c}	800	5 232^{d}	1 515	4 263^{b}	1 922	2 536^{d}	1 216
	Barley	6 964^{a}	434	3 833^{bc}	800	10 179^{bcd}	1 515	7 907^{b}	1 922	5 532^{cd}	1 216
	Westerwold ryegrass	3 705^{b}	434	3 115^{c}	800	4 416^{d}	1 515	5 595^{b}	1 922	3 421^{cd}	1 216
	Foxtail millet	2 800^{b}	434	2 303^{c}	800	14 835^{b}	1 515	9 241^{b}	1 922	8 770^{bc}	1 216
	Corn	4 365^{b}	434	12 594^{a}	800	40 491^{a}	1 515	27 082^{a}	1 922	27 199^{a}	1 216
	Soybean	n/a	n/a	3 393^{bc}	800	8 360^{cd}	1 515	6 186^{b}	1 922	13 211^{b}	1 216
Mean across all timepoints	Oat	7 511^{a}	290	8 441^{a}	403	11 608^{b}	623	8 457^{b}	666	6 021^{c}	705
	Fall rye	2 351^{d}	109	2 102^{c}	68	4 620^{d}	253	3 547^{d}	110	2 502^{d}	353
	Barley	6 839^{a}	365	5 778^{b}	290	10 617^{b}	310	7 848^{b}	372	5 664^{c}	542
	Westerwold ryegrass	2 915^{c}	141	2 515^{c}	129	2 826^{d}	618	4 316^{c}	178	2 567^{d}	274
	Foxtail millet	2 442^{cd}	213	1 914^{c}	286	11 396^{b}	908	8 251^{b}	376	6 524^{c}	624
	Corn	4 330^{b}	214	9 168^{a}	562	20 667^{a}	928	17 166^{a}	1 491	24 892^{a}	1 000
	Soybean	1 072^{e}	141	2 671^{c}	234	6 403^{c}	485	4 069^{cd}	284	9 464^{b}	509

A type I error rate of 0.05 was used for determination of significant differences and Tukey's test was used to compare treatment means within each site-year across all timepoints (model 1) and means within each site-year on the 3rd week of October (final harvest) only (model 2). SE values and Tukey mean comparisons are based on model 1 averaged across all timepoints and remain the same for the first three timepoints and for the average values across all timepoints. SE values and Tukey mean comparisons for the 3rd week of October are based on model 2.

Table 3. Significance of dependent variables based on site-year, timepoint, and treatment and their interactions from model 2.

Variable	Site-year	Timepoint	Treatment	T*TP	S*TP	S*T	S*T*TP
Yield* (kg ha^{-1})	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$
DM (g kg^{-1})	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$
NDF (g kg^{-1})	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$
CP (g kg^{-1})	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$
DE (Mcal kg^{-1})	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$
ME (Mcal kg^{-1})	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$
TDN (g kg^{-1})	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$
RFV	0.0008	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$
Nitrates (g kg^{-1} NO_3)	$P < 0.0001$	$P < 0.0001$	0.0047	0.3359	$P < 0.0001$	0.0002	0.0353
Ca (g kg^{-1})	$P < 0.0001$	0.01653	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$
Mg (g kg^{-1})	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$

*Yield values for this model (3) were log10 transformed.
Data in table reflects analysis of annual forages; Haymaker oat; Hazlet fall rye; Maverick barley; Aubade westerwold ryegrass; Golden German foxtail millet; Fusion corn; and Mammoth soybean at five site-years: Roblin and Arborg (2014 and 2015) and Carman (2015). The four time points for each site-year were in August, September, early October and mid-October (final harvest).

Table 4. Percent of total sum of squares for main effects (site-year, treatment, timepoint) interactions for yield and nutritive value of seven annual forages.

Variable	Site-year (SY)	Timepoint (TP)	Treatment (T)	T*TP	SY*TP	SY*T	SY*T*TP
Yield (kg ha^{-1})	12	7	**38**	9	3	**20**	6
DM (g kg^{-1})	2	**44**	25	**11**	6	4	3
NDF (g kg^{-1})	2	3	**45**	9	4	17	**13**
CP (g kg^{-1})	9	15	**57**	3	1	5	3
DE (Mcal kg^{-1})	7	5	**30**	10	3	19	**15**
ME (Mcal kg^{-1})	7	5	**30**	10	3	19	**15**
TDN (g kg^{-1})	7	5	**30**	10	3	19	**15**
RFV	1	4	**35**	15	5	18	**14**
Nitrates (g kg^{-1} NO_3)	**30**	14	2	1	**11**	6	7
Ca (g kg^{-1})	2	<1	**84**	1	<1	4	5
Mg (g kg^{-1})	22	<1	**56**	<1	<1	**12**	3

Data in table reflects analysis of annual forages; Haymaker oat; Hazlet fall rye; Maverick barley; Aubade westerwold ryegrass; Golden German foxtail millet; Fusion corn; and Mammoth soybean at five site-years: Roblin and Arborg (2014 and 2015) and Carman (2015). The four time points for each site-year were in August, September, early October and mid-October (final harvest).
Interactions less than 10% were not discussed in the results. Interactions discussed in the results are in bold.

Table 5. Model 2: Mean yield and nutritive value (g kg DM $^{-1}$ unless otherwise stated) of seven annual forages within each site-year averaged across four timepoints.

Variable	Treatment	2014				2015					
		Roblin	SE	Arborg	SE	Roblin	SE	Arborg	SE	Carman	SE
Yield* (kg ha^{-1})	Oat	7 511^{a}	549	8 441^{a}	549	11 608^{b}	549	8 457^{b}	549	6 021^{c}	549
	Fall rye	2 351^{cd}	549	2 102^{c}	549	4 620^{c}	549	3 547^{c}	549	2 502^{d}	549
	Barley	6 839^{a}	549	5 778^{b}	549	10 617^{b}	549	7 848^{b}	549	5 664^{c}	549
	Westerwold ryegrass	2 915^{c}	549	2 515^{c}	549	2 826^{d}	549	4 316^{c}	549	2 567^{d}	549
	Foxtail millet	2 442^{d}	549	1 914^{d}	549	11 396^{b}	549	8 251^{b}	549	6 524^{c}	549
	Corn	4 330^{b}	549	9 168^{a}	549	27 696^{a}	549	17 166^{a}	570	24 892^{a}	549
	Soybean	1 072^{e}	850	2 671^{c}	549	6 403^{c}	549	4 069^{c}	549	9 464^{b}	549
DM	Oat	357^{b}	11.67	453^{a}	11.67	509^{b}	11.67	422^{a}	11.67	483^{b}	11.67
	Fall rye	259^{d}	11.67	289^{b}	11.67	288^{d}	11.67	299^{c}	11.67	293^{e}	11.67
	Barley	392^{a}	11.67	474^{a}	11.67	585^{a}	11.67	451^{a}	11.67	576^{a}	11.67
	Westerwold ryegrass	289^{cd}	11.67	238^{c}	11.67	223^{e}	11.67	219^{e}	11.67	251^{f}	11.67
	Foxtail millet	314^{c}	11.67	320^{b}	11.67	341^{c}	11.67	344^{b}	11.67	426^{c}	11.67
	Corn	203^{e}	11.67	229^{c}	11.67	297^{d}	11.67	258^{d}	12.09	388^{d}	11.67
	Soybean	307^{c}	17.93	293^{b}	11.67	287^{d}	11.67	292^{c}	11.67	238^{f}	11.67
NDF	Oat	528^{d}	6.20	595^{b}	6.20	519^{cd}	6.20	585^{b}	6.20	589^{a}	6.20
	Fall rye	520^{d}	6.20	552^{c}	6.20	559^{b}	6.20	526^{d}	6.20	531^{d}	6.20
	Barley	512^{d}	6.20	562^{c}	6.20	460^{e}	6.20	535^{d}	6.20	513^{e}	6.20
	Westerwold ryegrass	554^{c}	6.20	556^{c}	6.20	531^{c}	6.20	567^{c}	6.20	570^{b}	6.20
	Foxtail millet	660^{a}	6.20	616^{a}	6.20	616^{a}	6.20	613^{a}	6.20	551^{c}	6.20
	Corn	603^{b}	6.20	562^{c}	6.20	507^{d}	6.20	507^{e}	6.42	454^{f}	6.20
	Soybean	382^{e}	9.61	369^{d}	6.20	412^{f}	6.20	417^{f}	6.20	455^{f}	6.20
CP	Oat	84de	5.09	83^{c}	5.09	95^{d}	5.09	129^{c}	5.09	118^{c}	5.09
	Fall rye	160^{b}	5.09	169^{a}	5.09	179^{a}	5.09	230^{a}	5.09	230^{a}	5.09
	Barley	96^{cd}	5.09	82^{c}	5.09	98^{d}	5.09	127^{cd}	5.09	102^{d}	5.09
	Westerwold ryegrass	99^{c}	5.09	91^{bc}	5.09	141^{b}	5.09	148^{b}	5.09	111^{cd}	5.09
	Foxtail millet	82^{e}	5.09	101^{b}	5.09	112^{c}	5.09	114de	5.09	88^{e}	5.09
	Corn	80^{e}	5.09	87^{c}	5.09	95^{d}	5.09	112^{e}	5.19	72^{f}	5.09
	Soybean	198^{a}	6.97	157^{a}	5.09	186^{a}	5.09	219^{a}	5.09	195^{b}	5.09

Variable	Treatment	2014				2015					
		Roblin	SE	Arborg	SE	Roblin	SE	Arborg	SE	Carman	SE
DE (Mcal kg^{-1})	Oat	2.89^{b}	0.03	2.61^{f}	0.03	2.88^{bc}	0.03	2.55^{e}	0.03	2.50^{d}	0.03
	Fall rye	2.94^{ab}	0.03	2.86^{c}	0.03	2.83^{c}	0.03	2.91^{b}	0.03	2.84^{b}	0.03
	Barley	2.93^{ab}	0.03	2.70^{e}	0.03	3.08^{a}	0.03	2.74^{c}	0.03	2.79^{b}	0.03
	Westerwold ryegrass	2.73^{d}	0.03	2.61^{f}	0.03	2.86^{c}	0.03	2.62^{d}	0.03	2.55^{d}	0.03
	Foxtail millet	2.54^{e}	0.03	2.77^{d}	0.03	2.55^{d}	0.03	2.43^{f}	0.03	2.64^{c}	0.03
	Corn	2.82^{c}	0.03	2.93^{b}	0.03	3.07^{a}	0.03	2.99^{a}	0.03	3.08^{a}	0.03
	Soybean	2.98^{a}	0.04	3.01^{a}	0.03	2.94^{b}	0.03	2.88^{b}	0.03	2.63^{c}	0.03
ME (Mcal kg^{-1})	Oat	2.40^{b}	0.02	2.17^{f}	0.02	2.39^{bc}	0.02	2.11^{e}	0.02	2.08^{d}	0.02
	Fall rye	2.44^{ab}	0.02	2.38^{c}	0.02	2.35^{c}	0.02	2.41^{b}	0.02	2.36^{b}	0.02
	Barley	2.44^{ab}	0.02	2.24^{e}	0.02	2.56^{a}	0.02	2.28^{c}	0.02	2.31^{b}	0.02
	Westerwold ryegrass	2.26^{d}	0.02	2.16^{f}	0.02	2.38^{c}	0.02	2.18^{d}	0.02	2.11^{d}	0.02
	Foxtail millet	2.11^{e}	0.02	2.30^{d}	0.02	2.12^{d}	0.02	2.02^{f}	0.02	2.19^{c}	0.02
	Corn	2.34^{c}	0.02	2.44^{b}	0.02	2.55^{a}	0.02	2.48^{a}	0.02	2.56^{a}	0.02
	Soybean	2.48^{a}	0.03	2.50^{a}	0.02	2.44^{b}	0.02	2.39^{b}	0.02	2.19^{c}	0.02
TDN	Oat	655^{b}	5.94	592^{f}	5.94	653^{bc}	5.94	578^{e}	5.94	568^{d}	5.94
	Fall rye	667^{ab}	5.94	649^{c}	5.94	642^{c}	5.94	660^{b}	5.94	644^{b}	5.94
	Barley	665^{ab}	5.94	612^{e}	5.94	698^{a}	5.94	622^{c}	5.94	632^{b}	5.94
	Westerwold ryegrass	618^{d}	5.94	592^{f}	5.94	649^{c}	5.94	595^{d}	5.94	577^{d}	5.94
	Foxtail millet	577^{e}	5.94	627^{d}	5.94	578^{d}	5.94	552^{f}	5.94	599^{c}	5.94
	Corn	640^{c}	5.94	666^{b}	5.94	696^{a}	5.94	679^{a}	6.11	699^{a}	5.94
	Soybean	676^{a}	8.89	682^{a}	5.94	665^{b}	5.94	652^{b}	5.94	597^{c}	5.94
RFV	Oat	115^{c}	2.33	94^{f}	2.33	117^{d}	2.33	95^{d}	2.33	93^{e}	2.33
	Fall rye	120^{bc}	2.33	111^{b}	2.33	107^{e}	2.33	116^{c}	2.33	113^{c}	2.33
	Barley	123^{b}	2.33	103^{cd}	2.33	138^{b}	2.33	110^{c}	2.33	115^{c}	2.33
	Westerwold ryegrass	105^{d}	2.33	101de	2.33	113^{d}	2.33	99^{d}	2.33	97^{e}	2.33
	Foxtail millet	84^{f}	2.33	95^{ef}	2.33	89^{f}	2.33	87^{e}	2.33	104^{d}	2.33
	Corn	99^{e}	2.33	109^{bc}	2.33	125^{c}	2.33	124^{b}	2.40	144^{a}	2.33
	Soybean	168^{a}	3.49	175^{a}	2.33	150^{a}	2.33	148^{a}	2.33	125^{b}	2.33

Variable	Treatment	2014				2015					
		Roblin	SE	Arborg	SE	Roblin	SE	Arborg	SE	Carman	SE
Nitrates ($g\ kg^{-1}\ NO_3$)	Oat	0.36[a]	1.00	1.11[a]	1.00	3.16[ab]	1.00	13.42[a]	1.00	6.70[ab]	1.00
	Fall rye	0.68[a]	1.00	1.02[a]	1.00	3.42[ab]	1.00	12.27[ab]	1.00	7.73[a]	1.00
	Barley	0.58[a]	1.00	0.55[a]	1.00	2.22[b]	1.00	9.71[bc]	1.00	3.69[cd]	1.00
	Westerwold ryegrass	1.46[a]	1.00	1.21[a]	1.00	5.73[a]	1.00	8.87[c]	1.00	5.47[abc]	1.00
	Foxtail millet	0.47[a]	1.00	1.60[a]	1.00	5.86[a]	1.00	8.51[cd]	1.00	3.67[cd]	1.00
	Corn	0.28[a]	1.00	1.56[a]	1.00	4.97[a]	1.00	6.04[de]	1.03	2.61[d]	1.00
	Soybean	0.53[a]	1.48	0.79[a]	1.00	4.73[ab]	1.00	5.49[e]	1.00	4.81[bcd]	1.00
Ca	Oat	1.97[e]	0.26	2.08[d]	0.26	2.38[c]	0.26	3.38[d]	0.26	3.77[de]	0.26
	Fall rye	4.41[b]	0.26	5.34[b]	0.26	5.30[b]	0.26	7.09[b]	0.26	6.61[b]	0.26
	Barley	2.09[e]	0.26	2.34[d]	0.26	2.37[c]	0.26	3.60[d]	0.26	4.41[cd]	0.26
	Westerwold ryegrass	3.39[c]	0.26	3.64[c]	0.26	5.73[b]	0.26	5.39[c]	0.26	4.88[c]	0.26
	Foxtail millet	2.89[cd]	0.26	2.40[d]	0.26	5.23[b]	0.26	3.96[d]	0.26	3.32[e]	0.26
	Corn	2.23[de]	0.26	2.26[d]	0.26	2.50[c]	0.26	2.37[e]	0.26	2.24[f]	0.26
	Soybean	15.64[a]	0.37	16.13[a]	0.26	17.63[a]	0.26	15.42[a]	0.26	13.08[a]	0.26
Mg	Oat	1.08[d]	0.16	1.98[e]	0.16	1.48[d]	0.16	2.63[f]	0.16	1.90[c]	0.16
	Fall rye	2.01[b]	0.16	3.97[b]	0.16	2.38[c]	0.16	4.73[c]	0.16	2.83[b]	0.16
	Barley	1.24[cd]	0.16	2.21[e]	0.16	1.49[d]	0.16	2.88[ef]	0.16	1.76[c]	0.16
	Westerwold ryegrass	1.45[c]	0.16	2.84[d]	0.16	2.57[c]	0.16	3.64[d]	0.16	1.91[c]	0.16
	Foxtail millet	2.01[b]	0.16	3.59[c]	0.17	4.45[b]	0.16	5.29[b]	0.16	2.70[b]	0.16
	Corn	1.94[b]	0.16	3.76[bc]	0.16	2.37[c]	0.16	3.05[e]	0.16	1.87[c]	0.16
	Soybean	4.44[a]	0.21	9.96[a]	0.16	6.41[a]	0.16	8.71[a]	0.16	4.70[a]	0.16

*Yield Tukey results are based on log10 transformed data; however, non-transformed data and SE are presented.

Table 6. Model 2: Mean yield and nutritive value (g kg DM $^{-1}$ unless otherwise stated) for seven annual forages within each timepoint for each treatment averaged across all site-years.

Variable	Treatment	TP1	SE	TP2	SE	TP3	SE	TP4	SE
Yield* (kg DM ha^{-1})	Oat	6 450[a]	473	9 849[b]	473	9 074[b]	473	8 257[b]	473
	Fall rye	2 359[bc]	473	3 092[de]	473	3 259[d]	473	3 389[d]	473
	Barley	6 320[a]	473	8 805[b]	473	7 389[c]	473	6 883[c]	473
	Westerwold ryegrass	2 080[bc]	473	2 272[e]	473	3 709[d]	473	4 050[d]	473
	Foxtail millet	3 118[b]	473	5 703[c]	473	8 010[bc]	473	7 590[bc]	473
	Corn	5 841[a]	473	16 662[a]	473	21 752[a]	489	22 346[a]	473
	Soybean	1 688[c]	473	4 197[d]	473	6 641[c]	597	6 418[c]	597
DM	Oat	189[b]	9.76	324[b]	9.76	551[b]	9.76	716[a]	9.76
	Fall rye	177[b]	9.76	300[b]	9.76	257[e]	9.76	407[d]	9.76
	Barley	236[a]	9.76	431[a]	9.76	616[a]	9.76	699[a]	9.76
	Westerwold ryegrass	197[b]	9.76	199[e]	9.76	259[e]	9.76	321[e]	9.76
	Foxtail millet	191[b]	9.76	247[c]	9.76	386[c]	9.76	573[b]	9.76
	Corn	145[c]	9.76	228[cd]	9.76	320[d]	10.08	407[d]	9.76
	Soybean	183[b]	9.76	204[de]	9.76	274[e]	12.34	474[c]	12.34
NDF	Oat	577[a]	5.22	539[c]	5.22	553[b]	5.22	583[b]	5.22
	Fall rye	481[c]	5.22	563[b]	5.22	556[b]	5.22	551[c]	5.22
	Barley	546[b]	5.22	488[d]	5.22	500[c]	5.22	532[d]	5.22
	Westerwold ryegrass	541[b]	5.22	570[b]	5.22	553[b]	5.22	558[c]	5.22
	Foxtail millet	587[a]	5.22	624[a]	5.22	597[a]	5.22	638[a]	5.22
	Corn	541[b]	5.22	536[c]	5.22	500[c]	5.39	529[d]	5.22
	Soybean	342[d]	5.39	413[e]	5.22	414[d]	6.57	458[e]	6.57
CP	Oat	129[de]	3.44	96[c]	3.44	91[c]	3.44	91[cd]	3.44
	Fall rye	215[b]	3.44	179[a]	3.44	193[a]	3.44	188[a]	3.44
	Barley	121[e]	3.44	97[c]	3.44	93[c]	3.44	93[c]	3.44
	Westerwold ryegrass	168[c]	3.44	125[b]	3.44	92[c]	3.44	88[cd]	3.44
	Foxtail millet	136[d]	3.44	99[c]	3.44	81[d]	3.44	83[de]	3.44
	Corn	129[de]	3.44	79[d]	3.44	74[d]	3.54	74[e]	3.44
	Soybean	234[a]	3.44	184[a]	3.44	169[b]	4.26	177[b]	4.26

Variable	Treatment	TP1	SE	TP2	SE	TP3	SE	TP4	SE
DE	Oat	2.69[f]	0.02	2.77[c]	0.02	2.66[d]	0.02	2.62[e]	0.02
(Mcal kg^{-1})	Fall rye	3.04[b]	0.02	2.77[c]	0.02	2.77[c]	0.02	2.91[b]	0.02
	Barley	2.82[d]	0.02	2.96[a]	0.02	2.84[b]	0.02	2.77[c]	0.02
	Westerwold ryegrass	2.75[e]	0.02	2.63[d]	0.02	2.65[d]	0.02	2.66[de]	0.02
	Foxtail millet	2.75[e]	0.02	2.55[e]	0.02	2.58[e]	0.02	2.47[f]	0.02
	Corn	2.92[c]	0.02	2.96[a]	0.02	3.03[a]	0.02	3.01[a]	0.02
	Soybean	3.14[a]	0.02	2.86[b]	0.02	2.84[bc]	0.03	2.71[d]	0.03
ME	Oat	2.23[f]	0.02	2.30[c]	0.02	2.21[d]	0.02	2.18[e]	0.02
(Mcal kg^{-1})	Fall rye	2.53[b]	0.02	2.30[c]	0.02	2.30[c]	0.02	2.42[b]	0.02
	Barley	2.34[d]	0.02	2.46[a]	0.02	2.35[b]	0.02	2.30[c]	0.02
	Westerwold ryegrass	2.28[e]	0.02	2.19[d]	0.02	2.20[d]	0.02	2.21[de]	0.02
	Foxtail millet	2.28[e]	0.02	2.12[e]	0.02	2.14[e]	0.02	2.05[f]	0.02
	Corn	2.42[c]	0.02	2.46[a]	0.02	2.51[a]	0.02	2.50[a]	0.02
	Soybean	2.61[a]	0.02	2.37[b]	0.02	2.35[bc]	0.02	2.25[d]	0.02
TDN	Oat	609[f]	4.62	629[c]	4.62	604[d]	4.62	595[e]	4.62
	Fall rye	691[b]	4.62	629[c]	4.62	629[c]	4.62	661[b]	4.62
	Barley	640[d]	4.62	671[a]	4.62	643[b]	4.62	629[c]	4.62
	Westerwold ryegrass	623[e]	4.62	597[d]	4.62	601[d]	4.62	604[de]	4.62
	Foxtail millet	624[e]	4.62	578[e]	4.62	585[e]	4.62	559[f]	4.62
	Corn	661[c]	4.62	672[a]	4.62	687[a]	4.76	683[a]	4.62
	Soybean	713[a]	4.76	648[b]	4.62	643[bc]	5.80	615[d]	5.80
RFV	Oat	100[e]	1.80	109[d]	1.80	104[d]	1.80	98[d]	1.80
	Fall rye	131[b]	1.80	104[e]	1.80	106[d]	1.80	110[c]	1.80
	Barley	111[cd]	1.80	126[b]	1.80	122[c]	1.80	112[c]	1.80
	Westerwold ryegrass	108[d]	1.80	99[f]	1.80	103[d]	1.80	102[d]	1.80
	Foxtail millet	99[e]	1.80	88[g]	1.80	95[e]	1.80	85[e]	1.80
	Corn	113[c]	1.80	116[c]	1.80	130[b]	1.85	121[b]	1.80
	Soybean	195[a]	1.85	147[a]	1.80	144[a]	2.26	126[a]	2.26

Variable	Treatment	TP1	SE	TP2	SE	TP3	SE	TP4	SE
Nitrates ($g\ kg^{-1}\ NO_3$)	Oat	9.66[a]	0.77	4.23[ab]	0.77	3.42[ab]	0.77	2.50[a]	0.77
	Fall rye	8.42[ab]	0.77	4.84[a]	0.77	4.05[a]	0.77	2.78[a]	0.77
	Barley	6.18[c]	0.77	2.74[ab]	0.77	2.54[ab]	0.77	1.96[a]	0.77
	Westerwold ryegrass	9.54[a]	0.77	4.22[ab]	0.77	2.31[ab]	0.77	2.12[a]	0.77
	Foxtail millet	6.46[bc]	0.85	4.09[ab]	0.77	2.87[ab]	0.77	2.67[a]	0.77
	Corn	6.96[bc]	0.77	2.41[b]	0.77	1.48[b]	0.80	1.52[a]	0.77
	Soybean	5.40[c]	0.77	3.30[ab]	0.77	2.37[ab]	0.98	2.01[a]	0.98
Ca	Oat	2.85[e]	0.18	2.57[e]	0.18	2.63[e]	0.18	2.82[e]	0.18
	Fall rye	4.80[b]	0.18	5.71[b]	0.18	6.22[b]	0.18	6.28[b]	0.18
	Barley	3.40[d]	0.18	2.77[e]	0.18	2.75[e]	0.18	2.94[e]	0.18
	Westerwold ryegrass	4.86[b]	0.18	4.87[c]	0.18	4.40[c]	0.18	4.30[c]	0.18
	Foxtail millet	3.96[c]	0.20	3.33[d]	0.18	3.28[d]	0.18	3.67[d]	0.18
	Corn	3.09[de]	0.18	2.70[e]	0.18	1.88[f]	0.19	1.62[f]	0.18
	Soybean	14.57[a]	0.18	16.23[a]	0.18	16.36[a]	0.23	15.18[a]	0.23
Mg	Oat	2.01[d]	0.10	1.80[e]	0.10	1.71[d]	0.10	1.74[e]	0.10
	Fall rye	3.11[c]	0.10	3.10[d]	0.10	3.28[b]	0.10	3.28[b]	0.10
	Barley	2.25[d]	0.10	1.76[e]	0.10	1.80[d]	0.10	1.87[de]	0.10
	Westerwold ryegrass	2.89[c]	0.10	2.65[d]	0.10	2.28[c]	0.10	2.11[cd]	0.10
	Foxtail millet	3.87[b]	0.11	3.84[b]	0.10	3.44[b]	0.10	3.30[b]	0.10
	Corn	3.10[c]	0.10	2.69[d]	0.10	2.44[c]	0.10	2.17[c]	0.10
	Soybean	6.73[a]	0.10	7.08[a]	0.10	7.00[a]	0.12	6.57[a]	0.12

*Yield Tukey results are based on log10 transformed data; however, non-transformed data and SE are presented.
TP1 = 1st week of August; TP2 = 1st week of September; TP3 = 1st week of October; TP4 = 3rd week of October.

Table 7. Means yield and nutritive values (g kg DM $^{-1}$ unless otherwise stated) for across five site-years and four timepoints.

Treatment	Yield (kg DM ha^{-1})	DM	NDF	CP	TDN	RFV
Oat	8 408	445	563	102	609	103
Fall rye	3 024	286	538	194	652	113
Barley	7 349	496	516	101	646	118
Westerwold ryegrass	3 028	244	556	118	606	103
Foxtail millet	6 105	349	611	99	587	92
Corn	15 245	275	527	89	676	120
Soybean	4 736	284	407	191	655	153

The four time points for each site-year were in August, September, early October and mid-October (final harvest).

Table 8. Model 2: Mean yield and nutritive value (g kg^{-1} DM unless otherwise stated) of seven annual forages within each site-year at four timepoints (TP) averaged across all treatments.

Variable	TP	2014				2015					
		Roblin	SE	Arborg	SE	Roblin	SE	Arborg	SE	Carman	SE
Yield*	1	2 330^{b}	429.8	3 821^{b}	429.8	5 032^{c}	429.8	4 368^{c}	429.8	4 347^{b}	429.8
(kg DM ha^{-1})	2	4 186^{a}	429.8	5 136^{a}	429.8	10 825^{b}	429.8	6 564^{b}	429.8	9 418^{a}	429.8
	3	4 890^{a}	502.6	4 797^{ab}	429.8	13 447^{a}	429.8	9 883^{a}	438.5	9 721^{a}	429.8
	4	4 286^{a}	502.6	4 868^{ab}	429.8	13 628^{a}	429.8	9 845^{a}	429.8	9 448^{a}	429.8
DM	1	205^{c}	8.42	218^{d}	8.42	190^{d}	8.42	149^{c}	8.42	178^{d}	8.42
	2	258^{b}	8.42	246^{c}	8.42	314^{c}	8.42	237^{b}	8.42	326^{c}	8.42
	3	220^{c}	10.00	351^{b}	8.42	394^{b}	8.42	460^{a}	8.61	477^{b}	8.42
	4	530^{a}	10.00	497^{a}	8.42	549^{a}	8.42	460^{a}	8.42	535^{a}	8.42
NDF	1	504^{c}	5.04	508^{c}	4.95	513^{bc}	4.95	523^{c}	4.95	535^{ab}	4.95
	2	539^{b}	4.95	550^{b}	4.95	514^{b}	4.95	537^{b}	4.95	527^{b}	4.95
	3	555^{a}	5.72	562^{ab}	4.95	501^{c}	4.95	515^{c}	5.04	491^{c}	4.95
	4	551^{ab}	5.72	559^{a}	4.95	531^{a}	4.95	568^{a}	4.95	540^{a}	4.95
CP	1	143^{a}	3.44	144^{a}	3.44	166^{a}	3.44	199^{a}	3.44	156^{a}	3.44
	2	97^{c}	3.44	109^{b}	3.44	130^{b}	3.44	154^{b}	3.44	123^{b}	3.44
	3	107^{b}	3.88	93^{c}	3.44	111^{c}	3.44	132^{c}	3.44	124^{b}	3.44
	4	110^{b}	3.88	94^{c}	3.44	110^{c}	3.44	131^{c}	3.44	120^{b}	3.44
DE	1	2.98^{a}	0.02	2.94^{a}	0.02	2.92^{a}	0.02	2.80^{a}	0.02	2.73^{ab}	0.02
(Mcal kg^{-1})	2	2.78^{b}	0.02	2.78^{b}	0.02	2.91^{a}	0.02	2.75^{b}	0.02	2.71^{bc}	0.02
	3	2.81^{b}	0.02	2.73^{c}	0.02	2.83^{b}	0.02	2.73^{b}	0.02	2.77^{a}	0.02
	4	2.76^{b}	0.02	2.69^{c}	0.02	2.88^{a}	0.02	2.64^{c}	0.02	2.67^{c}	0.02
ME	1	2.47^{a}	0.02	2.44^{a}	0.02	2.42^{a}	0.02	2.32^{a}	0.02	2.26^{ab}	0.02
(Mcal kg^{-1})	2	2.31^{b}	0.02	2.31^{b}	0.02	2.42^{a}	0.02	2.29^{ab}	0.02	2.25^{bc}	0.02
	3	2.33^{b}	0.02	2.23c	0.02	2.35^{b}	0.02	2.27^{b}	0.02	2.30^{a}	0.02
	4	2.29^{b}	0.02	2.26c	0.02	2.39^{a}	0.02	2.19^{c}	0.02	2.21^{c}	0.02

Variable	TP	2014				2015					
		Roblin	SE	Arborg	SE	Roblin	SE	Arborg	SE	Carman	SE
TDN	1	675^{a}	4.58	667^{a}	4.50	662^{a}	4.50	635^{a}	4.50	618^{ab}	4.50
	2	631^{b}	4.50	630^{b}	4.50	660^{a}	4.50	625^{b}	4.50	615^{bc}	4.50
	3	638^{b}	5.15	609^{c}	4.50	642^{b}	4.50	620^{b}	4.50	628^{a}	4.50
	4	626^{b}	5.15	618^{c}	4.50	654^{a}	4.50	599^{c}	4.58	605^{c}	4.50
RFV	1	132^{a}	1.72	131^{a}	1.69	121^{a}	1.69	118^{a}	1.69	110^{b}	1.69
	2	114^{b}	1.69	109^{b}	1.69	121^{a}	1.69	110^{b}	1.69	111^{b}	1.69
	3	110^{bc}	1.95	105^{c}	1.69	122^{a}	1.69	115^{a}	1.72	123^{a}	1.69
	4	109^{c}	1.95	106^{bc}	1.69	115^{b}	1.69	101^{c}	1.69	108^{b}	1.69
Nitrates	1	1.40^{a}	0.68	3.13^{a}	0.72	7.35^{a}	0.68	18.53^{a}	0.68	7.17^{a}	0.68
(g kg^{-1} NO_3)	2	0.29^{a}	0.68	0.79^{b}	0.68	4.87^{b}	0.68	7.25^{b}	0.68	5.25^{b}	0.68
	3	0.25^{a}	0.80	0.23^{b}	0.68	2.87^{c}	0.68	6.26^{bc}	0.69	3.98^{bc}	0.68
	4	0.55^{a}	0.80	0.33^{b}	0.68	2.10^{c}	0.68	4.71^{c}	0.68	3.42^{c}	0.68
Ca	1	3.58^{c}	0.17	4.84^{a}	0.17	6.23^{a}	0.17	6.39^{a}	0.17	5.77^{a}	0.17
	2	4.62^{b}	0.17	4.96^{a}	0.17	6.12^{a}	0.17	5.60^{b}	0.17	5.96^{a}	0.17
	3	5.26^{a}	0.19	5.05^{a}	0.17	5.69^{b}	0.17	5.51^{b}	0.17	5.26^{b}	0.17
	4	5.18^{a}	0.19	4.69^{a}	0.17	5.46^{b}	0.17	6.05^{a}	0.17	4.89^{b}	0.17
Mg	1	1.86^{a}	0.13	4.38^{a}	0.13	3.35^{a}	0.13	4.76^{a}	0.13	2.75^{a}	0.13
	2	1.91^{a}	0.13	4.17^{a}	0.13	3.18^{a}	0.13	4.42^{a}	0.13	2.68^{a}	0.13
	3	2.17^{a}	0.14	3.79^{a}	0.13	2.98^{a}	0.13	4.41^{a}	0.13	2.33^{b}	0.13
	4	2.16^{a}	0.14	3.83^{a}	0.13	2.57^{a}	0.13	4.11^{a}	0.13	2.35^{b}	0.13

*Yield Tukey results are based on log10 transformed data; however, non-transformed data and SE are presented.

Data in table reflects analysis of annual forages; Haymaker oat; Hazlet fall rye; Maverick barley; Aubade westerwold ryegrass; Golden German foxtail millet; Fusion corn; and Mammoth soybean at five site-years: The four time points for each site-year were in August, September, early October and mid-October (final harvest). TP1 = 1st week of August; TP2 = 1st week of September; TP3 = 1st week of October; TP4 = 3rd week of October.

Table 9. Mean percentage of area lodged in barley and oat plots for Roblin, Arborg, and Carman in 2015.

Sites	Date	Oat	Barley
Roblin	TP1	0%	0%
	TP2	0%	0%
	TP3	30%	10%
	TP4	90%	80%
Arborg	TP1	0%	0%
	TP2	30%	15%
	TP3	30%	80%
	TP4	65%	100%
Carman	TP1	15%	10%
	TP2	50%	10%
	TP3	50%	50%
	TP4	80%	50%

TP1 = 1st week of August; TP2 = 1st week of September; TP3 = 1st week of October; TP4 = 3rd week of October.

Table 10. Mineral analyses (g kg DM $^{-1}$ unless otherwise stated) for seven annual forages across five site-years at final harvest (model 1).

		2014 Harvest		2015 Harvest		
Mineral	Treatment	Roblin	Arborg	Roblin	Arborg	Carman
Ca	Oat	1.78[c]	2.15[cd]	2.15[c]	4.15[bc]	3.85[cd]
	Fall rye	4.58[a]	5.43[b]	4.80[b]	10.35[a]	6.23[b]
	Barley	1.75[c]	2.53[cd]	2.33[c]	3.88[bc]	4.23[cd]
	Westerwold ryegrass	3.35[b]	3.18[c]	4.90[b]	5.28[b]	4.75[c]
	Foxtail millet	3.18[b]	2.43[cd]	4.93[b]	4.50[b]	3.30[d]
	Corn	2.18[c]	1.78[d]	1.70[c]	1.30[c]	1.13[e]
	Soybean	n/a	15.33[a]	17.45[a]	12.90[a]	10.78[a]
	SE	0.15	0.23	0.36	0.68	0.42
Mg	Oat	1.03[d]	1.88[d]	1.33[c]	2.65[d]	1.83[cd]
	Fall rye	2.05[b]	3.78[b]	2.05[c]	5.95[ab]	2.58[b]
	Barley	1.23[c]	2.18[d]	1.43[c]	2.60[d]	1.90[bcd]
	Westerwold ryegrass	1.30[c]	2.25[d]	1.98[c]	3.35[cd]	1.68[d]
	Foxtail millet	2.28[a]	3.48[bc]	3.38[b]	4.83[bc]	2.53[bc]
	Corn	2.03[b]	3.22[c]	1.98[c]	2.10[d]	1.50[d]
	Soybean	n/a	10.00[a]	5.88[a]	7.30[a]	4.43[a]
	SE	0.04	0.16	0.20	0.44	0.16
P	Oat	2.38[c]	1.80[bc]	2.45[bc]	2.18[cd]	2.33[bc]
	Fall rye	4.43[a]	3.85[a]	4.03[a]	3.55[a]	3.73[a]
	Barley	2.88[bc]	1.68[bc]	2.85[b]	2.55[bc]	2.85[b]
	Westerwold ryegrass	2.20[c]	2.30[b]	2.28[c]	1.65[e]	2.20[bc]
	Foxtail millet	3.30[b]	1.58[c]	1.30[d]	1.10[f]	2.00[c]
	Corn	3.03[bc]	1.60[c]	1.73[d]	1.88[de]	2.08[bc]
	Soybean	n/a	3.33[a]	2.38[c]	2.90[b]	2.83[b]
	SE	0.20	0.16	0.10	0.11	0.20
K	Oat	16.88[cd]	10.50[b]	6.40[cd]	11.28[cd]	14.53[c]
	Fall rye	26.73[a]	17.35[a]	20.55[a]	22.08[a]	28.65[a]
	Barley	8.10[e]	7.35[b]	5.50[d]	9.23[d]	7.38[d]
	Westerwold ryegrass	17.88[bc]	17.70[a]	21.40[a]	18.43[ab]	23.03[b]
	Foxtail millet	22.33[ab]	16.68[a]	15.70[b]	14.45[bc]	15.38[c]
	Corn	12.28[de]	8.45[b]	9.13[c]	8.05[d]	8.55[d]
	Soybean	n/a	17.98[a]	13.28[b]	10.05[cd]	23.48[ab]
	SE	1.15	1.06	0.88	1.12	1.23

Table 11. Tetany ratios for the five site-years at final harvest.

	Treatment	2014 Harvest		2015 Harvest		
		Roblin	Arborg	Roblin	Arborg	Carman
Tetany Ratio (mEq kg^{-1})	Oat	**2.49**	1.03	0.76	0.68	1.08
	Fall rye	1.72	0.76	1.29	0.56	1.40
	Barley	1.10	0.62	0.60	0.58	0.51
	Westerwold ryegrass	1.67	1.32	1.34	0.87	1.57
	Foxtail millet	1.65	1.05	0.77	0.59	1.06
	Corn	1.14	0.61	0.94	0.87	1.22
	Soybean	n/a	0.29	0.25	0.21	0.67

Tetany ratios were calculated using MA conversion methods. The ratios are expressed as K/(Ca+Mg) in milliequivalents (mEq) per kg of dry matter. Ratios exceeding MA recommendations (greater than 2.2) are bolded.

Table 12. Plant counts (day 70) for seven annual forages at five site-years.

Site-year	Treatment	Plants $m^{2\ -1}$	Plants ha^{-1}
Roblin 2014	Oat	64	640 000
	Fall rye	38	380 000
	Barley	61	610 000
	Westerwold ryegrass	66	660 000
	Foxtail millet	69	690 000
	Corn	11	110 000
	Soybean	15	150 000
Roblin 2015	Oat	65	650 000
	Fall rye	78	780 000
	Barley	77	770 000
	Westerwold ryegrass	72	720 000
	Foxtail millet	81	810 000
	Corn	17	170 000
	Soybean	31	310 000
Arborg 2014	Oat	103	1 030 000
	Fall rye	76	760 000
	Barley	126	1 260 000
	Westerwold ryegrass	133	1 330 000
	Foxtail millet	21	210 000
	Corn	13	130 000
	Soybean	29	290 000
Arborg 2015	Oat	65	650 000
	Fall rye	64	640 000
	Barley	79	790 000
	Westerwold ryegrass	101	1 010 000
	Foxtail millet	82	820 000
	Corn	14	140 000
	Soybean	38	380 000
Carman 2015	Oat	65	650 000
	Fall rye	16	160 000
	Barley	47	470 000
	Westerwold ryegrass	101	1 010 000
	Foxtail millet	65	650 000
	Corn	25	250 000
	Soybean	30	300 000

Table 13. Mean (numeric) and medium (alpha-numeric) species stage of maturity (SOM) assessments of seven annual forages at five site-years.

Site	Date	Treatment						
		Oat	Fall rye	Barley	Westerwold	Foxtail millet	Corn	Soybean
Roblin	15-Oct-2014	76	1.5	88	3	51	R2	n/a
	04-Aug-2015	67	1	68	3.5	39	V7.5	R1
	01-Sep-2015	90	1.4	90	3	47	R3	R1
	01-Oct-2015	90	1.1	92	3	71	R4	R4
	19-Oct-2015	92	1.2	92	3	92	R5	R4
Arborg	16-Oct-2014	92	1.5	89	3	66	R2	R3
	04-Aug-2015	48	1.2	55	3.3	32	V7	R1
	02-Sep-2015	68	1.3	85	3	47	R1.5	R1
	02-Oct-2015	88	1.4	92	3	75	R4	R4.5
	15-Oct-2015	92	1.2	92	3.1	83	R5	R8
Carman	06-Aug-2015	57	1.4	83	3.4	33	R3	R1
	03-Sep-2015	79	1.3	89	3.6	69	R5	R5
	02-Oct-2015	88	1.3	92	3.8	86	R6	R6
	14-Oct-2015	92	1.2	92	3.3	92	R6	R7

Stage of maturity (SOM) results for 2014 are only for the final harvest. In 2015, the protocol was revised, and stage of maturity was assessed at each quadrat sampling date. The following scales were used to assess SOM: Moore et al. (1991) for fall rye and westerwold ryegrass; Zadoks et al. (1974) for oat, barley, and foxtail millet; Pedersen, (2008) for soybean; Hanway and Ritchie (1984) for corn. Mean SOM was calculated for the numeric scales (Moore; Zadoks) and medium SOM was calculated for the alphanumeric scales (Pedersen; Hanway and Ritchie). Grasses at stage 2.5 and above were rounded to 3.0. Larger numeric or alphanumeric values represent a more mature stage of plant growth and/or development.

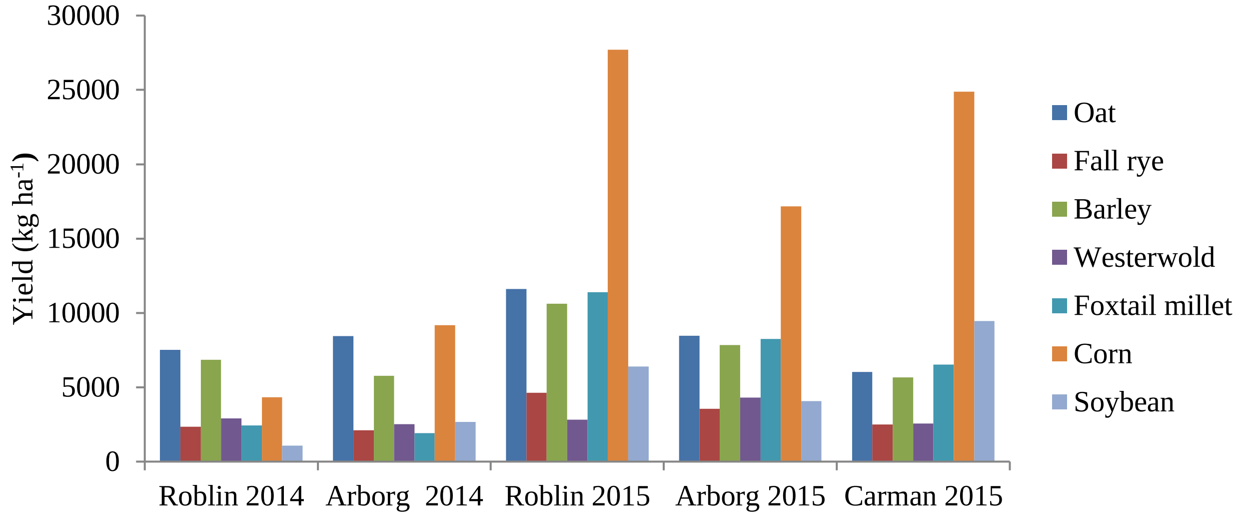

Figure 1. Yield of seven annual forages at five site-years averaged across four timepoints. Five site-years: Roblin 2014, Arborg 2014, Carman 2015, Arborg 2015, and Roblin 2015. TP1 = 1st week of August; TP2 = 1st week of September; TP3 = 1st week of October; TP4 = 3rd week of October.

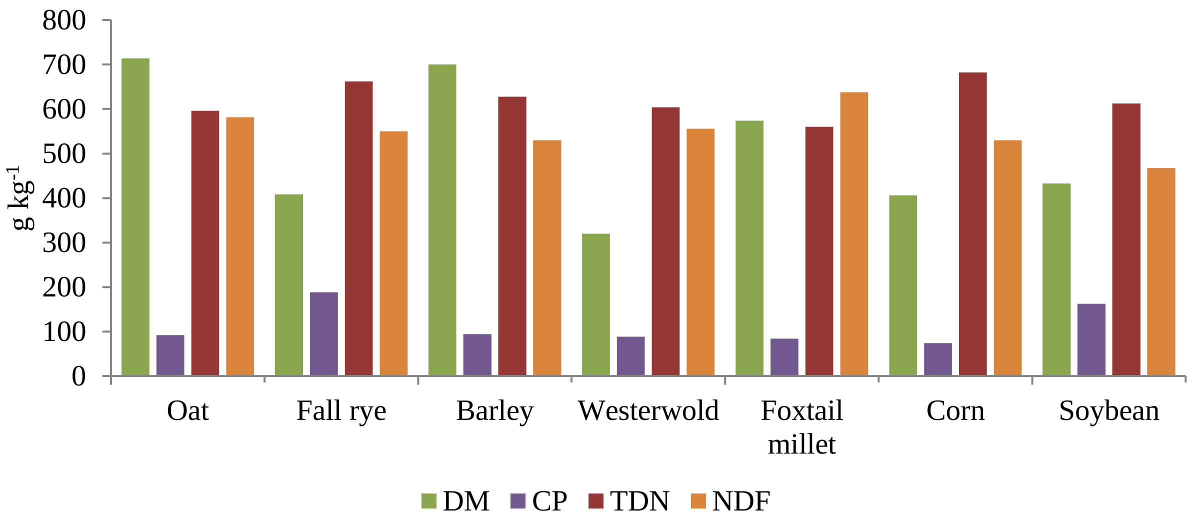

Figure 2. Means nutritive value for seven annual forages across all site-years and all timepoints. Five site-years: Roblin 2014, Arborg 2014, Carman 2015, Arborg 2015, and Roblin 2015. TP1 = 1st week of August; TP2 = 1st week of September; TP3 = 1st week of October; TP4 = 3rd week of October.

3.6 CONCLUSIONS

As per the hypothesis, there were significant differences in performance (i.e. yield, nutritive value, accessibility) between annual forage treatments. In this trial, corn, westerwold ryegrass, and fall rye were suitable candidates for further studies involving animal performance based on yield, nutritive value and plant height. Out of the seven annual species tested in this trial, corn demonstrated the best potential for large scale stockpile grazing in beef. Corn had the highest yield, height, TDN, DE, and ME across most site-years, as well as the highest RFV for all sites in 2015. Soybean, barley, oat, and foxtail millet were at or almost at full maturity at time of utilization of stockpile and, except for soybean, were high in NDF. Although westerwold ryegrass had significantly lower yield than corn, it could be used to stockpile graze if the accumulation period was longer to increase yield, however, nutritive value would need to be reassessed. Soybean had few to no leaves and foxtail millet stems were hard and fibrous with few leaves. Oats and barley were lodged and would be difficult to access under snow. In conclusion, corn had the highest potential for stockpile grazing in western Canada. Corn has been used for stockpile grazing in Western Canada, however, more research is required to further understand cattle performance when grazing corn and the economic benefit of stockpile grazing corn over other varieties in the late fall/early winter.

4. MANUSCRIPT II: Evaluation of pure and mixed grass-legume perennial forages for fall/winter stockpile grazing of beef cattle

4.1 ABSTRACT

This study evaluated the yield and nutritive value of five grass and three legume species in pure stands and binary grass-legume mixtures for their potential usage for stockpile grazing of beef cattle. Small scale plots were seeded at two locations in Manitoba: PESAI, Arborg in June 2014 and at the Ian N. Morrison Research Farm, Carman in July 2014. There were 23 forage treatments, eight pure and 15 binary grass-legume mixtures, which were also examined for an early stockpile (ES) or a late stockpile (LS) management system in the second year of the stands. The perennial forages selected were: Killarney orchardgrass; Courtenay tall fescue; Fleet meadow brome; Armada meadow brome; Success hybrid brome; Algonquin alfalfa; Yellowhead alfalfa; and Oxley II cicer milkvetch. Early stockpiling involved a single cut in the growing season, targeted at 10% legume bloom in the summer, after which regrowth was allowed to accumulate until mid-October, the typical turn out date for fall/winter grazing in Western Canada. Late stockpiling involved two cuts during the growing season, targeting 10% legume bloom on both occasions and the regrowth accumulated as per ES. Forage samples for nutritive value were taken in June at Arborg and Carman for both the early stockpile system and late stockpile system and again in July and August for the late stockpile system at Carman and Arborg, respectively. Grasses tended to have the highest cumulative and final harvest yields ($P < 0.05$), however, their nutritive value was significantly lower ($P < 0.05$) than pure legumes or grass-legume mixtures; legumes had the lowest yields. Final harvest yields were higher on the ES system; however, nutritive value was higher on the LS system. Courtenay + Oxley II (C+O) had a significantly higher cumulative yield and was significantly higher for the final harvest except for Arborg LS. Courtenay + Oxley II met the nutrient requirements (CP, TDN, Ca, Mg) of mid gestation beef cows at all sites and stockpile treatments except for the late stockpile system at Arborg where crude protein (CP) was 7 g kg^{-1} below the levels required for mid gestating cows and Mg was slightly above the maximum tolerance (AARD 2011; NRC 2016). For Arborg, all grass-legume mixtures had significantly higher final yields for ES except for K+O. There were no differences between any treatments for Arborg LS. For Carman, all Courtenay-legume mixtures had significantly higher final yields for ES with C+O having the greatest yield of 10 274 kg ha^{-1} which also had the greatest significant yield for the LS system of 6508 kg ha^{-1}. The average difference in cumulative yield for C+O between sites was approximately 1000 kg ha^{-1}. The fall yield of Carman ES and LS systems for C+O were 10 274 kg ha^{-1} and 6508 kg ha^{-1} which would have a carrying capacity of 30 cows for 18 days and 11 days, respectively, for beef cows in mid gestation based on DMI of 3% BW. Stockpile perennial grass-legume mixtures, especially C+O, demonstrated potential for extending the grazing season for beef cows in Manitoba based on high yield and high nutritive value.

Keywords: beef, grasses, legumes, nutritive value, perennial forages, stockpile grazing, yield

4.2 INTRODUCTION

Extended grazing of perennial and annual forages is becoming more prevalent in Western Canada for extending the grazing season as it offers producers economic benefits over confined feeding (Sheppard et al. 2015). Stockpile grazing is one of several extended grazing options available to producers to mitigate the cost of overwintering cattle in confinement, however, unlike other methods which utilize annual forages (e.g. corn grazing, swath grazing), stockpile grazing of perennial forages offers the opportunity to take an early season hay or grazing (Jungnitsch et al. 2011; Sheppard et al. 2015). With extended grazing, manure is deposited directly onto the land therefore costs associated with manure removal and fertilizer are eliminated (Aasen et al. 2004; Jungnitsch et al. 2011).

Stockpile grazing refers to grazing of forage growth accumulated from earlier in the growing season in the fall/winter and the use of perennial grasses and legumes in extended grazing systems is becoming a more frequent practice in the prairie provinces in western Canada. A survey conducted by Sheppard et al. (2015) included 1009 beef producers across Canada and reported that 466 producers practiced extended grazing and of those producers, 317 resided in Western Canada. Approximately 30% of the producers in western Canada that utilized extended grazing systems practiced stockpile grazing (Sheppard et al. 2015). Factors including the amount of snow accumulation, wasted feed, and animal health/welfare have limited more widespread uptake of extended grazing (Sheppard et al. 2015). Cool-season forages tend to maintain their nutritive value later in the growing season and therefore are preferred in stockpile grazing systems (Villalobos 2015). Bromegrasses, orchardgrass, tall fescue, and alfalfa are perennial species that have been successfully used as monocrops and/or grass-legume mixtures for stockpile grazing beef cattle (Baron et al. 2005; Karn et al. 2005; Drapeau et al. 2007; Thompson 2013). Alfalfa-grass mixtures had greater DM yields than grass monocultures or binary mixtures with cicer milkvetch during a seven-year study conducted in Swift Current, SK (Biligetu et al. 2014). This study focused on late-season stockpiles in September with no summer biomass removal and thus CP concentrations were relatively low (Biligetu et al. 2014).

Our project evaluated the nutritive value of 23 perennial pure grass, pure legume, and grass-legume binary mixture treatments for their potential usage for stockpile grazing of beef cows in the Canadian prairies. As the objective is low cost pasture-based, non-confined feeding, the identification of forages that can retain their nutritive value and produce high yields in the late fall/early winter are desirable. The hypothesis of this study was that there were significant differences in performance between treatments and that one or more treatments would demonstrate potential based on nutrient requirements of mid gestation beef cows for stockpile grazing for the beef industry in Manitoba. Specifically, this study aimed to compare eight perennial forage species in pure or mixed stands on an early stockpile (ES) or late stockpile (LS) system and evaluate their suitability for grazing mid gestation cows in the late fall/early winter by assessing yield, nutritive value and standing height.

4.3 MATERIALS & METHODS

4.3.1 Experimental Treatments

A range of cool season grass and legume perennial forages were selected based on potential winter hardiness, drought tolerance, seed availability, and cost for successful establishment and growth in the Canadian prairies. The following perennial forage cultivars were used alone and in grass-legume combination for evaluation: Killarney orchardgrass (*Dactylis glomerata*); Courtenay tall fescue (*Schedonorus arundinaceum*); Success hybrid brome (*Bromus riparius* × *B. inermis*), cv.'s Fleet and Armada meadow brome (*Bromus riparius*); cv.'s Algonquin and Yellowhead alfalfa (*Medicago sativa*); and Oxley II cicer milkvetch (*Astragalus cicer*). For mixed plots, the grass: legume ratio was 50:50 seeding ratio. This study was a RCBD with split plots (early or late stockpile treatment) and subplots (forage treatments). Three (Arborg) and four (Carman) replicates were established with early stockpile (ES; one cut) and late stockpile (LS; two cut) management systems as main plots within each replicate. The effect of early or late stockpiling was assessed with cutting dates based on observed plant maturity; early heading for grasses and early bloom for legumes (10% bloom), and where field/weather conditions allowed. Subplots were mono- (grass or legume) or bi-cultures (grass/legume mixture) for a total of 23 treatments. Therefore, there were 46 plots in each replicate, with 23 randomized treatments within each stockpile treatment system.

4.3.2 Plot Establishment and Management

Initially, plots were established at Parkland Crop Diversification Foundation (PCDF), Roblin, MB (51°11'00.2"N 101°21'21.0"W) and Prairies East Sustainable Agriculture Initiative (PESAI), Arborg, MB (50°54'17.5"N 97°16'21.6"W). However, excess moisture and weed pressure resulted in plot failure at the Roblin site, thus an additional site at the Ian N. Morrison Research Farm, Carman, MB (49°29'42.7"N 98°02'26.7"W). Thus, the Roblin site was abandoned and omitted from this study.

4.3.2.1 Plot seeding:

The land used for the forage evaluation trial at the two sites was fallow in 2013 except for half of one replicate at Arborg. This area had been in canola production the previous year (2013). The perennials were seeded on June 5 and July 11, 2014 at Arborg and Carman, respectively, with the later seeded date at Carman necessary following plot failure at an originally planned site at Roblin. Plots were 1.8 m x 7 m (12.6 m^2) and 2.1 m x 8 m (16.2 m^2) at Arborg and Carman, respectively. Seeding depth was 1.5 cm with 20 cm row spacing for a total of eight rows $plot^{-1}$. Pure perennial stands were seeded at the following rates: orchardgrass at 10 kg ha^{-1}, tall fescue at 9 kg ha^{-1}, hybrid brome at 10 kg ha^{-1}, meadow brome at 12 kg ha^{-1}, alfalfa at 8 kg ha^{-1}, and cicer milkvetch at 14 kg ha^{-1}. Mixed perennial stands were seeded at 50% of pure stand rates for each component of the mixture, e.g. Killarney orchardgrass and Algonquin alfalfa at 5 and 5 kg ha^{-1}, respectively. At Arborg, a Wintersteiger 8-row, double disk press drill with cone seeder used for seeding. At Carman, an RTech J-10D plot seeder with 10 double disk openers with individual row packers was used. Weed control was carried out by mowing of plot area one to two times per site in the year of establishment.

4.3.2.2 Fertility:

Soil samples were taken prior to seeding in 2014 and again in spring 2015 at each site to assess the soil nutrient status and plant nutrient requirements for mixtures and pure perennial plots. Based on soil tests for N, P, K and S, fertilizer was applied by pre-plant broadcasting in the spring of 2014 and in early May 2015 to meet the nutrient requirements of the forage with the highest requirement for each site based on recommendations for Manitoba (https://www.gov.mb.ca/agriculture/crops/soil-fertility/soil-fertility-guide/pubs/soil_ fertility_guide.pdf). Note, pure legume and grass-legume forage mixtures did not receive N application post-establishment but did receive other required soil nutrients. In the post-establishment year, soil samples were taken in spring and fertility broadcast applied according to the protocol in establishment year.

4.3.3 Forage Measurements

4.3.3.1 Emergence:

Plants were counted at seven, 14, 21, and 70 days post seeding to measure establishment. Quadrats (0.25 m^2) were used to determine emergence counts and for each plot; three quadrats were randomly placed within the plot and the two rows of plants within the quadrat (50 cm long) were counted to provide a representative average for each plot and each stand. In mixture plots, legume and grass emergence was counted independently.

4.3.3.2 Yield/nutritive value:

Early stockpile (ES; one cut) and late stockpile (LS; two cut) treatments were both cut in June at 10% bloom for legumes and early heading for grasses to represent a typical hay harvest. The LS treatment was cut a second time using the same approximate maturity for the legumes to represent a second hay harvest. Before each harvest, three measurements of plant height were made for each seeded species in each plot. Both early and late stockpiling plots were cut on June 15 to June 17, 2015 at Carman and June 26 to 30, 2015 at Arborg. All plots were harvested at a 10 cm cutting height with an Alfalfa-Omega plot master with forage harvester (R-Tech Industries Ltd, Homewood, Manitoba). The forage harvester was equipped with a Model 300 Digital Weight Indicator by Reliable Scale Corporation to permit weighing of fresh cut forage. Once the mass for a plot was recorded, the forage was dumped from the weigh basket and two random samples were collected by hand into Delnet bags (Delstar Technologies, Delaware, USA). The wet mass of each sample and average delnet bag(s) mass was recorded and samples were then subsequently dried at 60°C in a forced-air oven for a minimum of 48 hrs and subsequently ground in a Wiley mill to a 1 mm particle size in preparation for chemical analysis. The second sample was used to assess stage of maturity (SOM) and/or botanical composition. These samples were stored in freezers to assess SOM and botanical composition (for grass-legume mixtures only) at a later date, as harvest time required all available time and staff. Samples across replicates were pooled within forage treatment for the first two sample dates (June and late July/early August) for chemical analysis.

These initial sample dates were pooled as the cost to process each treatment at each site was not in the budget and that the main focus was the final yield.

Forage yield was determined at each harvest date and that the regrowth of ES and LS systems were determined in the fall. Forage yields were obtained from all plots in late fall to estimate the amount of stockpiled biomass available. Fall cutting dates were October 13 & 14, at Carman and October 16, 2015 at Arborg. All plots were cut with the forage harvester (Alfalfa-Omega plot master with forage harvester from R-Tech Industries Ltd, Homewood, Manitoba) to a length of half the plots so that potential spring stockpiled grazing could be observed on the uncut portion, although not discussed in this manuscript. Forage treatments were randomized within blocks (ES or LS) to determine area (front or back) of the plot to be cut (split-block design). From the clipped portion of the plot, a random sample was obtained for DM content and chemical analysis. Botanical composition (grass: legume ratio) was not assessed at the final harvest.

4.3.3.3 Stage of maturity and botanical composition:

Plant stage of maturity (SOM) was determined using the Kalu and Fick (1981) scale for legumes and Moore et al. (1995) scale for grasses and an average SOM calculated. For mixed stands, grass and legume portions were separated and each weighed separately to determine the percentage of each species in the stand or botanical composition. For mixed stands, all stems in 150 g of each species were staged to calculate an average SOM for legume and grass.

Botanical composition was determined for grass-legume mixtures only. This was completed in unison with SOM. The sample was divided into its respective grass and legume components and then the wet mass for each was recorded. The percentages of the grass and legume components were then calculated from the total wet mass to represent the proportion of each species in the forage treatment thus the botanical composition. Pure forage treatments were assumed to be 100% grass or 100% legume.

4.3.3.4 Plant height:

Height of stand (three measurements $plot^{-1}$) was also measured for each plot at each of the three sampling dates. For analysis of height, an average of all recorded heights was taken to provide a representative height.

4.3.4 Chemical Analyses

All samples were submitted for wet chemistry analysis to Central Testing Laboratory Ltd. (Winnipeg, MB). A wet chemistry analyses was conducted to determine the following values: acid detergent fibre (ADF), neutral detergent fibre (NDF), crude protein (CP), relative feed value (RFV), digestible energy (DE), metabolizable energy (ME), total digestible nutrients (TDN), and minerals (potassium (K), phosphorus (P), magnesium (Mg), calcium (Ca). Review of the methods used for ADF and NDF are available in section 08-26-06 of the ANKOM (2006). The following official methods of analysis can be found in AOAC (2005): CP AOAC 990.03, nitrate in forages 986.31 and mineral is a modification of AOAC 968.08, 935.13A. More details on nutritional analysis methods can be found in Appendix A.

4.3.5 Statistical Analysis

Perennial forage measurements were taken in 2015 only as 2014 was establishment year.

Model 1: For the mid-summer harvests sampled in June and again in late July/early August, samples for forage treatments were pooled/composited within early and late stockpiling treatments for quality analysis for both sites, therefore a complete statistical analysis could not be carried out as there were no replicated measures. Data were analyzed using the PROC CORR procedure of SAS 9.4 (SAS Inst. Inc., Cary, NC). Pearson correlations were used to test correlations between sites at each stockpile (1a) and between stockpile treatments at each site (1b). There were 23 observations for each site for the correlation model; 23 pooled treatments for each half of each replicate. For the purposes of multi-site year analysis two models (1a & 1b) were used. Dependent variables were: yield, DM, CP, DE, ME, TDN, RFV, nitrates, NDF, height, Ca, Mg, P and K. The model (1a) used was:

$$r = \frac{ss^2_{ab}}{ss_{a\,a}\, ss_{b\,b}}$$

where ss is the sum of squares, a is the response variable (e.g. yield, DM, TDN) at the early stockpile (early and late stockpile cut in June), and b is the response variable for the late stockpile (late stockpile cut in late July/early August). This model was used for both Arborg and Carman. Correlation coefficients (r) for the same response variables between cuts at each site were recorded. The model (1b) used was:

$$r = \frac{ss^2_{xy}}{ss_{x\,x}\, ss_{y\,y}}$$

where ss is the sum of squares, x is the response variable at Arborg, and y is the response variable at Carman. This model was run for both the early stockpile and the late stockpile systems for the two summer harvests. Correlation coefficients (r) for the same response variables between sites at each stockpile system were recorded.

Data for October harvests were analyzed using the PROC MIXED procedure of SAS 9.4 (SAS Inst. Inc., Cary, NC). There was one year of data for each of the two sites, Arborg and Carman. At each site there were 23 forage treatments (FOR) in each of two stockpile treatments (SP) compared in a randomized complete block design with three replicate blocks at Arborg and four replicate blocks at Carman (i.e. 56 plots per block). Initial statistical analysis revealed highly significant site by FOR interactions therefore Arborg and Carman sites were analyzed separately. The model (2) was:

$$Y_{ij} = \mu + FOR_i + SP_j + (FOR \times SP)_{ij} + R_k + e_{ijk}$$

where Y_{ij} is the response variable (e.g. yield), μ is mean for the variable, FOR_i is the forage treatment effect (fixed), SP_j (stockpile) was the effect of forage management (early (ES) or late (LS) stockpiling treatment) considered fixed, $(FOR \times SP)_{ij}$ was the treatment-stockpile interaction (fixed), R_k is the effect of replicate and e_{ij} was the random error associated with the observation. A contrast analysis was carried out to explain differences in mixtures versus pure stands of the species included in the mixture. A total of 15 contrasts (one for each grass-legume mixture) and estimates were analyzed to determine if the pure stands that comprise the mixture performed better or worse than the mixture for each dependent variable. The botanical composition values used in this model were acquired from the second cut harvest date and not the final October harvest for each site as this was the most up to date botanical composition data available (Table 14). Botanical composition values for October were not recorded.

Dependent variables for the October harvest model (2) were: yield, DM, CP, DE, ME, TDN, RFV, nitrates, NDF, height, Ca, Mg, P and K. The hypotheses for model (2) were: H_0:

there is no significant difference between FOR or SP; H_A: there is a significant difference between one or more FOR and between the two SP. For each model, differences between FOR means were determined using Tukey's multiple range test and were considered significant when $p < 0.05$.

4.4 RESULTS

4.4.1 Main effects (Forage, Stockpile) and FOR × SP interaction

There were significant correlations ($P < 0.05$) between ES harvest in June and the LS harvest in late July/early August at Arborg for the variables yield, DM, NDF, RFV, Ca, Mg, and K and ES and LS harvests at Carman for the variables DM, NDF, nitrates, RFV, Ca, Mg, and height (Table 15). Significant correlations ($P < 0.05$) between Arborg and Carman at ES harvest were found for all variables except for K and for LS harvest for all variables except for DM (Table 16).

There were significant differences between FOR and SP for each dependant variable ($P = 0.002$) in October at Arborg except for nitrates and K. There were also significant FOR×SP interactions for most dependant variables except for yield, nitrates, Mg, and P (Table 17). For Carman, there were significant differences between FOR and SP ($P < 0.001$) except for nitrates for SP. There were also significant FOR×SP interactions for most dependant variables except for yield, DM, nitrates, P, and K (Table 17). Contrast analyses were performed using model 2 to compare between pure grass and pure legume forage treatments and grass-legume mixture forage treatments performance for each dependent variable; for example, K+AL versus Killarney and Algonquin or 'K+AL vs K, AL'.

For the remainder of the results section, data presented represents analysis using model 2. Results of contrast analyses are discussed under each variable heading below.

4.4.2 Physical variables

4.4.2.1 Final and cumulative DM yield

Forage treatment (FOR) and SP were significant factors; however, no significant FOR×SP interactions for Arborg or Carman were observed (Table 17). At Arborg, Courtenay had the highest yield at ES of 5362 kg ha^{-1} (Table 18), however, only K+O was significantly lower. There were no significant differences between FOR for LS at Arborg (Table 18). All ES FOR had greater yields than the corresponding LS treatments (Table 18).

At Carman, Courtenay, C+AL, C+Y, and C+O had the highest significant yields ($P < 0.05$) for ES ranging from 8376 to 10 274 kg ha^{-1} with C+O having the greatest yield (Table 18). For LS, C+O had a significantly higher yield ($P < 0.05$) than any other FOR at 6508 kg ha^{-1} (Table 18). All ES FOR had greater yields than the corresponding LS treatments (Table 18).

At Arborg, Courtenay had the highest mean cumulative yield of 10 165 kg ha^{-1} (Table 19). There were four significant cumulative yield contrasts. For 'K+O vs K, O', 'C+O vs C, O', and 'AR+O vs AR, O', the pure forages produced higher cumulative yields than the forage mixture. However, 'S+O vs S, O' was also significant but the forage mixture had a higher cumulative yield than the pure forage counterparts (Table 20).

At Carman, Courtenay had the highest cumulative yield for ES at 15 518 kg ha^{-1} but was not significantly different from most of the other forage treatments (Table 19). For LS, Fleet had the highest cumulative yield of 14 761 kg ha^{-1} (Table 19). Courtenay, Fleet, Armada, and C+O had highest significant ($P < 0.05$) mean cumulative yields at 14 330 kg ha^{-1}, 14 602 kg ha^{-1}, 14 537 kg ha^{-1}, and 14 451 kg ha^{-1}, respectively (Table 19). There were four significant cumulative yield contrasts. For 'F+AL vs F, AL' and 'AR+AL vs AR, AL', the forage mixtures produced higher cumulative yields than their pure forage counterparts. For 'K+Y vs K, Y' and 'K+O vs K, O', the pure forages had higher cumulative yields than the forage mixture (Table 21).

4.4.2.2 Standing plant height

There was a significant FOR×SP interaction for both sites (Table 17). For Arborg ES, Oxley II had the highest height at 32 cm but there was no significant difference between Oxley II and the majority of the FOR ($P < 0.05$); the shortest being that of Yellowhead at 22 cm. For Arborg LS, C+AL was the tallest at 34 cm with only Success, Fleet, Armada, and Yellowhead significantly shorter than the other FOR ranging from 27 to 28 cm (Table 22). There were three significant contrasts where the forage mixtures in 'K+Y vs K, Y', 'K+O vs K, O' and 'F+Y vs F, Y' had a greater height than the pure forages by 2.2 to 2.8 cm (Table 20).

At Carman ES, C+Y had the highest height of 32 cm but was not significantly different from Killarney, Courtenay, Success, Oxley II, K+O, C+AL, C+O, S+O, F+O, and AR+O. The shortest forage treatments for Carman ES were Algonquin and Yellowhead at 23 cm. For Carman LS, Oxley II had the greatest height of 37 cm but was not significantly different from C+O or S+O ($P < 0.05$). The shortest FOR was Algonquin at 29 cm (Table 22). The forage mixture in the contrasts 'AR+AL vs AR, AL' had a higher height ($P < 0.01$) by 1.8 cm compared to the pure forages (Table 21).

4.4.2.3. Stage of Maturity – Final cut

Forage treatment stage of maturity was assessed at final harvest in October for both stockpile treatments. No statistics were performed on this data as it was alpha-numeric and qualitative. Senescence refers to amount of leaf shatter/drop and/or aging of leaves.

4.4.2.3.1 Grasses

For Arborg ES, Killarney, Courtenay and Armada were vegetative and had 50% senescence. Success and Fleet were in early to late reproductive stages and had 40% senescence. For the grasses in the grass-legume mixtures Killarney, Courtenay, and Success were vegetative to early reproductive whereas the meadow bromegrasses Fleet and Armada remained vegetative (Table 23). For Arborg LS, all pure grass FOR were vegetative and senescence ranged from 30 to 50%. All grasses in the mixtures were vegetative and senescence ranged from 10 to 40% (Table 23).

For Carman ES, Killarney, Courtenay, Fleet, and Armada were vegetative whereas Success was late reproductive; senescence ranged from 20 to 50%. All grasses in the mixtures were vegetative except for Success which was in late reproduction. Grass senescence ranged from 10 to 40% (Table 24). For Carman LS, all pure grass FOR were vegetative, except for Success which was in late reproduction. Pure grass senescence ranged from 15 to 50%. Killarney, Fleet, and Armada in the mixtures were vegetative to late vegetative and senescence ranged from 5 to 40%, whereas Courtenay and Success were early to late reproductive and senescence ranged from 5 to 20% (Table 24).

4.4.2.3.2 Legumes

For Arborg ES, legumes were in late reproduction and both alfalfa varieties were at 60% senescence whereas Oxley II still had intact leaves (0% senescence). The legumes in the grass-legume mixtures were in a late reproductive state. Algonquin and Yellowhead had 50 to 60% senescence whereas Oxley II had 0 to 10% senescence (Table 23). For Arborg LS, all pure legume FOR were vegetative to early reproductive and had 10% senescence. The majority of the legumes in the grass-legume mixtures were in a vegetative state except for S+AL, S+Y, S+O, and F+AL which were in early to late reproduction. Legume senescence ranged from 0 to 20% (Table 23).

For Carman ES, legumes were in late reproduction and the alfalfas had 50 to 70% senescence whereas Oxley II only had 5% senescence. All of the legumes in the grass-legume mixtures were in a late reproductive state. Algonquin and Yellowhead had 40 to 60% senescence whereas Oxley II showed no senescence (Table 24). For Carman LS, the pure alfalfas were late vegetative and senescence was 30% whereas Oxley II was late reproductive and no senescence was observed. There was variation in maturity between legumes in grass-legume mixtures ranging from late vegetative to late reproductive. Alfalfa senescence ranged from 5 to 20% whereas no senescence was observed for Oxley II (Table 24).

4.4.3 Chemical analyses

4.4.3.1 Dry matter content

There was a significant FOR×SP interaction for Arborg, however no interaction was observed at Carman with significant main effects at this site (Table 17). For ES at Arborg, Yellowhead (553 g kg^{-1}) and S+AL (557 g kg^{-1}) had the highest DM but were not significantly different from Killarney, Success, Fleet, Armada, Algonquin, K+AL, K+Y, C+AL, C+Y, S+Y, F+AL, F+Y, F+O, AR+AL, AR+Y, and AR+O. For LS, Success had the highest DM of 520 g kg^{-1} but was not significantly different from Killarney, Fleet, Armada, Yellowhead, K+Y, C+O, F+Y, F+O, and AR+Y (Table 25). There were no significant differences in DM between mixed and pure forage treatments except for 'AR+O vs AR, O' where the pure forages were higher in DM by 70 g kg^{-1} than the forage mixtures at a significance of P = 0.003 (Table 20).

At Carman, Algonquin had the highest DM and for ES (546 g kg^{-1}) but was not different from Success, Fleet, Armada, Yellowhead, S+AL, S+Y, F+AL, F+Y, AR+AL, and AR+Y. Success hybrid brome (388 g kg^{-1}) had the highest DM for LS but was not significantly different from Fleet, Armada, Algonquin, Yellowhead, S+AL, F+AL, F+Y, AR+AL, and AR+Y (Table 25). There were several significant differences between forage mixtures and their corresponding pure FOR. For 'K+AL vs K, AL', 'C+AL vs C, AL', 'S+AL vs S, AL', 'S+O vs S, O', 'F+AL vs F, AL', 'F+O vs F, O', 'AR+AL vs AR, AL', and 'AR+O vs AR, O', pure FOR had higher DM compared to the forage mixture ranging from 40 to 90 g kg^{-1} higher (Table 21).

4.4.3.2 Crude protein

There were significant FOR×SP interactions for both sites (Table 17). For Arborg ES, pure grass FOR had significantly lower CP values than legume and mixed FOR. For Arborg LS, Algonquin, Yellowhead, Oxley II, K+AL, C+AL, S+AL, S+Y, S+O, F+AL, and AR+AL had the significantly highest CP values ranging from 132 to 195 g kg^{-1} (Table 26). For the contrast analysis, 'K+O vs K, O', and 'AR+O vs AR, O' exhibited higher CP for the forage mixtures than the pure forages ranging from 26.1 to 61.9 g kg^{-1} at the final cut. Whereas 'S+O vs S, O', 'F+AL vs F, AL', and 'AR+AL vs AR, AL' exhibited higher CP for the pure forages than the forage mixtures by 25.9 to 40 g kg^{-1} (Table 20).

For Carman ES, there were few significant differences between forage treatments except that all the straight grass FOR, K+Y, S+Y, and F+Y had significantly lower CP values than legume and other mixed FOR. For Carman LS, Oxley II, S+O, Success, Algonquin, Yellowhead, S+AL, and S+Y had significantly higher ($P < 0.05$) CP values than all other FOR ranging from 147 to 179 g kg^{-1} (Table 26). For the contrast analysis, 'C+O vs C, O', 'S+O vs S, O', and 'AR+O vs

AR, O' exhibited higher CP for the forage mixtures than the pure forages with differences ranging from 14.9 to 20.6 g kg^{-1}. At Carman, CP was similar or greater than in the LS system (Table 26). At Arborg, a similar trend was seen, however, mixtures including Oxley II had a lower CP value for the LS system (Table 26).

4.4.3.3 Digestible energy, metabolizable energy, and total digestible nutrients

There were significant FOR×SP interactions for DE, ME, and TDN at both sites (Table 28). For both sites, the same FOR and contrasts were significant for DE, ME and TDN (Table 27, Table 28, Table 29, Table 30, and Table 31). For Arborg ES, K+O had the highest TDN of 632 g kg^{-1} ($P < 0.05$) but was not significantly different in the Tukey test from Courtenay, Oxley II, K+O, C+Y, C+O, and S+O. For Arborg LS, C+AL and S+O had the numerically highest TDN of 658 and 659 g kg^{-1} but were not statistically different from other FOR except for Success, Fleet, and Armada which had significantly lower TDN values (Table 31). For the contrast analysis, 'K+O vs K, O' and 'F+Y vs F, Y' the forage mixtures had significantly higher TDN ($P = 0.01$; $P = 0.025$) than their corresponding pure forages ranging from differences of 45 to 57 g kg^{-1} TDN (Table 28).

For Carman ES, C+Y had the highest TDN of 602 g kg^{-1} ($P < 0.05$) but was not significantly different from Killarney, Courtenay, Success, Oxley II, K+O, C+AL, C+O, S+O, F+O, and AR+O (Table 31). For Carman LS, Oxley II, C+O, S+Y, and S+O had the highest significant TDN ranging from 648 to 704 g kg^{-1}. For the contrast analysis, 'F+AL vs F, AL' and 'AR+AL vs AR, AL' the forage mixtures had significantly higher ($P = 0.034$, $P = 0.006$) TDN than the corresponding pure forages ranging from 27 to 35 g kg^{-1} greater (Table 29).

4.4.3.4 Relative feed value

There were significant FOR×SP interactions for both sites (Table 17). At Arborg ES, C+O had significantly higher RFV than most FOR but was not different from Oxley II, K+O, and S+O. At Arborg for LS, there were few significant differences between treatments with Killarney, Success, Fleet, Armada, C+Y, C+O, F+O, and AR+Y having significantly lower RFV than the rest of the FOR (Table 32). For the contrast analysis, 'K+O vs K, O' and 'AR+O vs AR, O' forage mixtures had significantly higher RFV than the pure forages ranging from a difference of 23 to 24 (Table 28).

At Carman, Oxley II had the highest significant mean RFV and for both SP ranging from 122 to 195 (Table 32). For ES, K+O, C+O, and S+O also had significantly high RFV ranging from 102 to 122 (Table 32). For the contrast analysis, 'S+O vs S, O' the forage mixture had significantly higher RFV than the pure forages by 14 units (Table 29).

4.4.3.5 Neutral detergent fibre

There was a significant FOR×SP interaction for NDF at both sites (Table 17). At Arborg, Success had the highest mean NDF ranging from 639 to 640 g kg^{-1} and for both SP (Table 33). For ES, Success had the highest NDF which significantly differed only from Oxley II, K+O, C+O, and S+O ($P < 0.05$) (Table 33). There were three contrasts where pure FOR had significantly higher NDF ($P = 0.004$) than their corresponding forage mixtures. The pure forages in the contrasts 'K+AL vs K, AL', 'K+O vs K, O', and 'AR+O vs AR, O' had higher NDF values by 11 to 69 g kg^{-1} higher than their mixtures (Table 20).

At Carman, Fleet had the highest mean NDF ranging from 597 to 674 g kg^{-1}, which was observed across both SP. For ES, there were no significant differences between Fleet, the other pure grass FOR, Algonquin, Yellowhead, and the following mixtures: K+AL, K+Y, S+AL, S+Y, F+AL, F+Y, AR+AL, and AR+Y. For LS there were no significant differences between Fleet, all the other straight grass FOR, K+AL, K+Y, C+Y, F+AL, F+Y, AR+Y, and AR+O (Table 33). There were three FOR contrasts where pure forages had higher NDF than their corresponding mixtures. The pure forages in 'K+O vs K, O', 'S+O vs S, O', and 'AR+O vs AR, O' had NDF values ranging from 39 to 72 g kg^{-1} higher than the forage mixtures at a significance of $P = 0.002$ (Table 21).

4.4.3.6 Nitrates

There were no significant main effect or interactions for nitrates at Arborg, however, a significant FOR effect was found for Carman (Table 17). At Carman, C+O was the highest nitrate concentration at 3.7 g kg^{-1} NO_3 while Yellowhead at 1.3 g kg^{-1} NO_3, K+AL and K+Y (both at 1.4 g kg^{-1} NO_3) were significantly lower (Table 34). Nitrates at Arborg ranged from 0.9 to 1.3 g kg^{-1} NO_3 (Table 34). The contrast analysis, 'C+AL vs C, AL' revealed higher nitrate concentrations for the forage mixtures than the pure forages with a difference of 1.13 g kg^{-1} NO_3 (Table 29).

4.4.3.7 Minerals

4.4.3.7.1 Calcium

There was a significant FOR×SP interaction for both Arborg and Carman (Table 17). In general, Ca content in the forage decreased with LS at Arborg while at Carman it tended to increase with LS (Table 35).

For Arborg ES, the three pure legumes and the majority of the forage mixtures were similar for Ca content with Oxley II being highest at 17.6 g kg^{-1} and Courtenay being the lowest at 5.3 g kg^{-1}. For Arborg LS, the three pure legumes and the majority of the forage mixtures were statistically similar for Ca content with Oxley II being highest at 14.1 g kg^{-1} (Table 35). There were five contrasts where the pure forages had higher Ca than their corresponding forage mixtures. The following contrasts 'K+AL vs K, AL', 'K+O vs K, O', 'C+AL vs C, AL', 'F+O vs F, O' and 'AR+O vs AR, O' had higher Ca ranging from 0.21 to 0.59 g kg^{-1} than their pure forage counterparts. The contrast 'C+Y vs C, Y' were also significantly different, however, the pure forages had higher Ca by 0.19 g kg^{-1} than the forage mixture (Table 36).

For Carman ES, Oxley II had the highest Ca content of 11.8 g kg^{-1} but was not significantly different from Algonquin, S+O, F+AL, and AR+O. For Carman LS, Oxley II had the highest Ca content of 15.0 g kg^{-1} but was not significantly different from Algonquin, Yellowhead, or S+O which ranged from 11.9 to 13 g kg^{-1}. Across both sites and SP, the pure grass FOR had the lowest Ca (Table 35), however, there were two significant contrasts. The forage mixture in the contrast 'S+O vs S, O' had significantly higher Ca by 0.29 g kg^{-1} than the corresponding pure forages. The pure forages in the contrast 'AR+AL vs AR, AL' had significantly higher Ca by 0.15 g kg^{-1} than the corresponding forage mixture (Table 37).

4.4.3.7.2 Magnesium

There was a significant FOR×SP interaction for Carman but not for Arborg (Table 17).

At Arborg, Oxley II and S+O had the highest mean Mg content but were not different from Courtenay, all Courtenay-legume mixtures, Yellowhead, all Killarney-legume mixtures, and AR+O ranging from 3.9 to 5.3 g kg^{-1} (Table 38). There were four significant contrasts. The forage mixtures in the following contrasts 'K+Y vs K, Y', 'K+O vs K, O', 'C+AL vs C, AL', and 'AR+O vs AR, O' had higher Mg ranging from 0.8 to 1.6 g kg^{-1} than their corresponding pure forage counterparts (Table 36).

For Carman ES, C+O, C+Y, and K+O had the highest Mg content ranging from 3.4 to 3.6 g kg^{-1} but were not significantly different from Killarney, Courtenay, Oxley II, K+Y, C+AL, S+O, F+O, and AR+O ($P < 0.05$). For Carman LS, Oxley II had the highest Mg content of 3.5 g kg^{-1} but was not different from the majority of the FOR (Table 38). Arborg demonstrated higher levels of Mg than Carman (Table 38). There were three contrasts where forage mixtures had significantly higher Mg than their corresponding pure forages. The forage mixtures in 'K+O vs K, O', 'S+O vs S, O', and 'AR+O vs AR, O' had higher Mg, ranging from 0.4 to 0.6 g kg^{-1}, than the pure forages (Table 37).

4.4.3.7.3 Phosphorus

The FOR×SP interactions at both sites were not significant, however, FOR and SP main effects were significant for both sites (Table 17). For Arborg, Oxley II, all Killarney-legume mixtures, and S+O had the highest significant mean P content ($P < 0.05$) ranging from 2.0 to 2.5 g kg^{-1} (Table 39). Most of the contrasts for P were significant where forage mixtures were significantly higher in P than pure forages ($P < 0.05$) except for 'C+AL vs C, AL', 'S+O vs S, O', and 'F+O vs F, O'. For significant contrasts, differences ranged from 0.1 to 0.7 g kg^{-1} (Table 36).

For Carman, mean P content ranged from 2.2 to 2.8 g kg^{-1} with Courtenay, Algonquin, Yellowhead, Oxley II, S+AL, S+Y, and AR+AL being significantly lower ($P < 0.05$) in P content (Table 39). There were seven contrasts where forage mixtures had significantly higher P than their corresponding pure forages. The forage mixtures in the contrasts: 'K+AL vs K, AL', 'K+Y vs K, Y', 'C+AL vs C, AL', 'S+AL vs S, AL', 'F+AL vs F, AL', 'F+Y vs F, Y' and 'AR+AL vs AR, AL' had higher P ranging from 0.3 to 0.5 g kg^{-1} than the pure forages (Table 37).

4.4.3.7.4 Potassium

There was a significant FOR×SP interaction for Arborg but not for Carman. There was a significant difference between ES and LS at Carman (Table 17).

At Arborg for the ES treatment, the majority of FOR were not different from one another in K content ranging from 14.9 to 23.0 g kg^{-1}, however, Algonquin, Yellowhead, S+AL, S+Y, and F+AL had significantly lower K values. For Arborg LS, Killarney, Courtenay, Algonquin, Oxley II, all Killarney-legume mixtures, C+AL, S+AL, S+O, F+AL, AR+AL, and AR+O had the highest significant K content ranging from 16.9 to 26.4 g kg^{-1}. For both SP, Oxley II had the highest K content (Table 40). There was one significant contrast where the forage mixture in 'F+Y vs F, Y' had higher K than the pure forages by 3.7 g kg^{-1} (Table 36).

At Carman, Killarney, Courtenay, Oxley II, all Killarney-legume mixtures, C+AL, S+AL, S+O, F+AL, AR+AL, and AR+O had the highest mean K content ($P < 0.05$) ranging from 27.4 to 35.0 g kg^{-1} with Courtenay having the highest K content. Courtenay and/or C+O had the highest K values (Table 40). There were two significant contrasts where the forage mixtures in 'K+AL vs K, AL' and 'S+O vs S, O' had higher K than the pure forages by 3.7 and 5.3 g kg^{-1}, respectively (Table 37).

4.4.3.7.5 Tetany ratio

No statistics were performed on tetany ratio data as differences between FOR was not of concern but rather any FOR that exceeded recommended values (2.2 mEq kg^{-1}). At Arborg final harvest on October 16, tetany ratios for all treatments for were below recommended values (2.2 mEq kg^{-1}). However, at second cut of the LS treatment on August 5, Killarney had a tetany ratio above the recommended value of 2.27 mEq kg^{-1} (Table A3). Tetany ratios ranged from 0.31 to 2.27 mEq kg^{-1} between June 26 and October 16, 2015 at Arborg (Table A3).

At Carman final harvest October 13 and 14, tetany ratios for all treatments were below recommended values (2.2 mEq kg^{-1}). However, the majority of the grasses and several of the grass-legume mixtures had tetany ratios exceeding recommended values at the first and second cuts during the summer (Table A4). Tetany ratios ranged from 0.56 to 5.14 mEq kg^{-1} between June 15 and October 14, 2015 at Carman (Table A4).

4.5 DISCUSSION

This study provides information about yield and nutritive potential of eight pure grass or legume stands, and their 15 binary grass-legume mixtures and the potential for late fall/early winter stockpile grazing by beef cattle under western Canadian conditions. The impact of early or late stockpiling of forage was also investigated. Profiles were generated for each pure and binary forage combination in each stockpile system to address knowledge gaps pertaining to yield and quality of forages for late season grazing.

4.5.1 Establishment

Carman had a higher number of plants m^{-2} at the plant counts than Arborg accounting for better establishment at Carman (Table A5). At Arborg pure grass counts ranged from 50 – 160 m^{-2}, legumes ranged from 19 – 25 m^{-2}, and mixtures ranged from 18 – 82 m^{-2} for the grass component and 7 – 23 m^{-2} for the legume component. At Carman pure grass counts ranged from 60 – 320 m-

^{2}, legumes ranged from 80 – 221 m^{-2}, and mixtures ranged from 33 – 205 m^{-2} for the grass component and 33 – 96 m^{-2} for the legume component (Table A5). Precipitation and time of seeding likely affected treatment success as heavy rain or seeding with potential frost could negatively affect establishment. Two sites, Roblin and Arborg, were seeded in early June of 2014. Roblin experienced substantial amounts of rain (over 60 mm in two days at the end of June) post seeding and coupled with weed competition resulted in plot failure (Figure A2; Figure A3; MA 2016). Carman was therefore seeded on July 11, 2014. Warm temperatures and seasonal rainfall provided excellent growing conditions, resulting in good establishment (Figure A4). Grasses had better establishment than legumes at Arborg and grass stands had the highest yields at final harvest likely due to the drier conditions than at Carman. Grasses perform better in dry conditions than legumes as their fibrous roots allow them to bind soil together and acquire moisture better than legumes with taproots (Baenziger 1975; Goplen et al. 1980; Acharya 2001; Coulman 2009; McCaughey 2009).

Legumes fix di-nitrogen from the soil via a symbiotic relationship with bacteria so when legumes are planted with grasses less nitrogen fertilizer is required by the stand if the legume is successfully inoculated. There is an economic benefit regarding nitrogen fertilizer (chemical or manure) as less intervention for soil nutrients will be required in legume-grass mixtures as legumes fix di-nitrogen and less or no fertilizer is required. Grass and legumes also have differential soil space utilization monopolizing on variable soil depths (Baenziger 1975; Goplen et al. 1980; Acharya 2001; Coulman 2009; McCaughey 2009). Alfalfa roots can penetrate deep into the soil (3 to 9 m) with Algonquin having a deep taproot and Yellowhead having branched roots (Baenziger 1975; Goplen et al. 1980). Oxley II cicer milkvetch is rhizomatous with a creeping, shallow root system in comparison (Acharya 2001). The grasses in the current study have fibrous root systems (Coulman 2009; McCaughey 2009). Di-nitrogen fixation, differential soil space utilization, trial establishment, and climate could explain the variation of pure stand versus mixture success at both sites and the opposite trend we see at each. Overall, forage mixtures had higher yields and greater nutritive value than pure stands.

4.5.2 Final and cumulative DM yield

C+O had the highest late fall/early winter yield at both sites and for both SP. At Carman, Courtenay, C+AL, and C+Y also had significantly higher yields for the ES system. In the current study, pure stands and binary mixtures of meadow bromes, tall fescue, orchardgrass, Success hybrid brome, alfalfas, and cicer milkvetch were tested for stockpile potential. For C+O, final yields were greater for the ES system than the LS system. Pure grass treatments had the highest cumulative yields and were generally higher in the ES system than the LS system. Grass-alfalfa mixtures have been found to produce greater yields than grass monocultures (Thompson 2013; Biligetu et al. 2014; Elgersma and Soegaard 2016). In the current study, N fertilizer was applied to grass monoculture treatments to meet minimum requirements of the most nutrient-hungry forage type (Nelson and Burns 2006; Biligetu et al. 2014) which could explain higher grass yields. At Arborg, Courtenay and Fleet had the highest cumulative yields whereas at Carman, Courtenay, Fleet and Armada had the highest cumulative yields. Many of the grass-legume treatments were not significantly different from the pure grass cumulative yields, however, Killarney-legume mixtures and Success-legume mixtures generally had lower cumulative yield than the other mixtures. Pure legume treatments typically had significantly lower cumulative yields than the pure grass or grass-legume mixture treatments as legumes, particularly alfalfa, are susceptible to leaf shatter and thus some biomass would be lost throughout harvesting (Hancock and Collins 2006;

Biligetu et al. 2014). Leaf senescence was also observed to be greater on the legume treatments than the grass or grass-legume treatments (Table 39, 40). The contrast analysis revealed that at Arborg, most of the pure forages had greater cumulative yields than their forage mixture counterpart, particularly the grasses. The opposite trend was observed at Carman where most of forage mixtures had greater cumulative yields than their corresponding pure forage counterparts. This may have been due to better establishment and climate at Carman and lower weed pressure. Arborg had gleysol clay soils with poor drainage so during rainfall the ground was saturated with moisture, but during periods with little rainfall the ground was cracked and dry. Carman had larger particle sized deltaic soil and lacustrine clay which are dominantly well drained, so soil moisture was more consistent.

Tests using Success hybrid bromegrass indicated that the hybrid yielded higher than the parent species of meadow and smooth bromegrass (Coulman 2006), however, in the current study the opposite was observed. For both sites and both stockpiling systems, Armada and Fleet (meadow bromegrass) typically had higher yields than Success. This may have been due to seed quality as a function of storage methods and/or seed shelf life. A germination test was carried out in late April 2015 and mold growth was observed on all Success replicates whereas all other seeds had little to no mold growth. In a two-week period, Success and Killarney had 34% germination whereas all other perennial cultivars had 52% germination or greater (Table A6). Although Killarney had 34% germination in April 2015, establishment was not seen to an issue for this grass. Seeding occurred in spring of 2014, so during that year from seeding to germination test, the seed integrity could have been negatively affected by storage methods and/or seed shelf life.

A study complimentary to the current project by Peng (2017), found that early stockpiled perennial forages had significantly higher yields than late stockpiled forages and that early stockpiled forages had lower nutritive value than late stockpiled forages. Pure stands and binary mixtures of Fleet meadow brome, Courtenay tall fescue, orchardgrass, Success hybrid brome, Algonquin alfalfa, and Oxley II cicer milkvetch were tested for stockpile potential in the Canadian Great Plains Region (Peng 2017). Early stockpiled Fleet meadow brome mixed with Algonquin alfalfa demonstrated the highest DM yield of 3600 kg ha^{-1} (Peng 2017). A study conducted in Normandin, Quebec from 1997 to 1999 tested varieties of tall fescue for yield potential and nutritive value (Drapeau et al. 2007). Courtenay tall fescue had the highest annual yield in first post-establishment year (10 030 kg ha^{-1}) with the stand yield decreasing over the following two years; 8880 kg ha^{-1} and 6660 kg ha^{-1}, respectively. In the current study, Courtenay yield at Carman is comparable to Drapeau et al. (2007) observations likely due to greater than average rainfall during establishment at Carman (Figure A4, Table A2) which met or exceeded historical precipitation during the summer months in Normandin, Quebec (The Weather Network 2017). Baron et al. (2005) suggests that meadow bromegrass consistently provides high yields from year to year in western Canada, however, the longer the period before grazing, the lower the nutritive value because as plants transition from a vegetative to a reproductive state nutrients are allocated to seeds instead of leaves. Incorporating alfalfa with meadow bromegrass, especially with additional N fertilizer, produced higher yields than pure bromegrass even when fertilized (Kopp et al. 2003). A four-year average yield in Brandon, MB under cattle grazing of unfertilized alfalfa-bromegrass and unfertilized pure bromegrass were 3120 kg ha^{-1} and 1940 kg ha^{-1}, respectively (Kopp et al. 2003). A three-year grazing trial of beef cows in Humboldt, SK examined forage usage and animal performance when grazing perennial stockpiled forage in paddocks versus round bale hay in a drylot (Kulathunga et al. 2016). Forage utilization for hay bales was an average of 94% over the three years and 58%, 78%, and 89% for year one, two, and three for stockpiled grazing; however, stockpiled grazing system costs were 14% lower and there was no difference in body weight and BCS for the cows between the two grazing treatments (Kulathunga et al. 2016). In the current study, forage treatments with the best stockpile grazing potential will be further assessed via cow grazing trials.

Elgersma and Soegaard (2016) found that pure grass had lower yields compared to mixtures at a fall harvest after frequent cutting in Denmark. Plots containing timothy, perennial ryegrass, and meadow fescue as the grass species and white clover, red clover, lucerne (alfalfa), and birdsfoot trefoil as the legume species were established. Although species and cut frequency (treatments were on a five-cut system from May to October) were different than the current study, all mixtures were binary. Thompson (2013) found that grass-alfalfa mixtures grown on irrigated land in the interior of British Columbia had 14% greater yields than grass monocultures. Varieties of orchardgrass and tall fescue grown with alfalfa reached yields of 12 390 kg ha^{-1} and 12 650 kg ha^{-1}, respectively (Thompson 2013). A seven-year study conducted in Swift Current, SK found that grass-legume mixtures with alfalfa produced greater DM yields than other mixtures not containing alfalfa in the late summer/early fall (Biligetu et al. 2014). Alfalfa grown as a monocrop, compared to cicer milkvetch, also produced greater DM yields (Biligetu et al. 2014). The trend observed in Biligetu et al. (2014) was similar to the trend observed in the current study at Arborg for both ES and LS stockpile treatments, however, the opposite trend was observed at the Carman site. Oxley II cicer milkvetch had greater DM yield than alfalfa and mixtures with Oxley II had greater yield than mixtures with alfalfa. In a stockpile grazing trial in Manitoba, Courtenay tall fescue had a 4-year average yield of 1628 kg ha^{-1} whereas in combination with Oxley II cicer milkvetch the mixture yielded of 2612 kg ha^{-1} (MA 2008). In the current study at the Carman site on either stockpile system (ES and LS), C+AL and C+Y yields ranged from 4414 kg ha^{-1} to 8888 kg ha^{-1} which compares to the results of Thompson (2013) and Courtenay and C+O fall yields exceeded those reported by MA (2008).

The ES final yields for C+O were higher than LS yields at both sites with a difference of about 7000 kg ha^{-1} between sites suggesting a strong site effect. However, cumulative yield of C+O on either stockpile system had a difference of about 1000 kg ha^{-1} with the ES system having greater cumulative yield. From a producer stand point, the LS system may increase the usage of the pasture with two baling harvests/grazing events as opposed to one (i.e. ES grazing system) resulting in greater land use for that particular field/paddock.

4.5.3 Nutritive value

Nutrient requirements for each class of cattle differ depending on a range of factors including physiological state (i.e. lactating, gestating, growing), breed (i.e. British or Continental), climate, and body weight (NRC 2016). The nutrient requirements of a beef cow in mid gestation (Table A7) that would be the typical physiological stage in late fall/early winter is 500 g kg^{-1} TDN, 77 g kg^{-1} CP, 1.7 g kg^{-1} Ca, and 1.4 g kg^{-1} P (AARD 2011). Energy (TDN) and CP content of a feed are viewed as two of the most important factors influencing the nutritional status and performance of cattle (Yoshihara et al. 2013).

In the current study, Courtenay-legume treatments on an ES system demonstrated the best potential for stockpile grazing beef cows taking both yield potential and nutritive value into consideration given their high CP and TDN relative to the other treatments under investigation. However, the Courtenay-legume mixtures on the LS system had higher nutritional value but the two early season harvests resulted in lower yield at final harvest than the ES system.

At Carman, forage mixtures had higher TDN and CP than pure forage treatments whereas pure grass or legume treatments generally had higher NDF than their corresponding forage mixtures. The same trends were observed at Arborg except that only about half of the contrasts followed the CP trend observed at Carman. Thus, overall forage mixtures had greater nutritional value than the pure grass or legume forages. Forage mixtures may have had greater nutritive value because the legume component contributed more protein than grass compared to pure grass treatments. Aasen et al. (2004) found that mixtures retain their nutritive value better than monocrops into the fall. After grasses and legumes start to head, the energy of the plant is shifted to reproductive structures as opposed to vegetative structures and there is increased lignification of the stem, which is indigestible to cattle, thus the nutritive value decreases (Baron et al. 2005; Mathis and Sawyer 2007).

The average final yield for C+O on the ES system and LS system was 6776 kg ha^{-1} and 4028 kg ha^{-1}, respectively. The average cumulative yield for C+O on the ES system and LS system was 10 744 kg ha^{-1} and 9737 kg ha^{-1}, respectively. According to Glunk and Lewis (2014), a dry cow can consume 1.8% body weight of low quality forage (dry winter forage; <52% TDN), 2.2% body weight of medium quality forage (dry pasture during fall; 52 – 59% TDN), and 2.5% body weight of high quality forage (early-late bloom legume and pre-boot stage grass). The C+O treatment would fall into the medium to high quality forage range based on TDN. A mid gestation cow at a body weight of 648 kg could thus consume 14.3 kg DM of medium quality forage and 16.2 kg DM of high quality forage per day. The C+O final yield of 3277 kg ha^{-1} (medium quality; 2.2% BW) for Arborg ES system would, in theory, support approximately 30 mid gestation cows (648 kg) for seven d on one hectare of land. The C+O final yield of 1548 kg ha^{-1} (medium quality; 2.2% BW) for Arborg LS system would be able to support approximately 30 early gestating cows

(648 kg) for three d on one ha. The C+O final yield of 10 247 kg ha^{-1} (medium quality; 2.2% BW) for Carman ES system would support approximately 30 early gestating cows (648 kg) for 23 d on one ha. Lastly, the C+O final yield of 6508 kg ha^{-1} (medium quality; 2.2% BW) for Carman LS system would support approximately 30 early gestating cows (648 kg) for 15 d on one ha. Gains and body condition could potentially be maintained better during the winter months on the LS system C+O, however, due to a significantly higher nutritive value (TDN, CP, lower NDF) than the ES system.

Nutritive value of perennial grasses declines into the fall as leaves age and frost occurs; CP decreases and NDF increases (Aasen et al. 2004; Mathis and Sawyer 2007). In a study in Quebec, Courtenay tall fescue had 139 g kg^{-1} CP, averaged across two production years in the fall (Drapeau et al. 2007). A study by Thompson (2013) in British Columbia, found that alfalfa-grass mixtures had higher CP and lower NDF than grass monocultures when harvested three times from June to October (values are an average of the three sampling dates). These authors reported orchardgrass had CP of 113 g kg^{-1} and tall fescue had CP of 107 g kg^{-1}, whereas in mixtures orchardgrass-alfalfa had CP of 147 g kg^{-1} and tall fescue-alfalfa had CP of 165 g kg^{-1}. Orchardgrass had NDF of 602 g kg^{-1} and tall fescue had NDF of 583 g kg^{-1} whereas in mixtures orchardgrass-alfalfa had NDF of 546 g kg^{-1} and tall fescue-alfalfa had NDF of 503 g kg^{-1}. The current study had later fall harvest dates, by about two weeks, and MB typically receives less precipitation than BC which may explain why Killarney and Courtenay CP values were less, however, NDF values were comparable.

Kopp et al. (2003) reported higher CP and NDF on a bi-rotational grazing pasture than a mono-rotational of alfalfa-bromegrass and/or pure bromegrass at Brandon, MB. Unfertilized alfalfa-bromegrass paddocks had 133 g kg^{-1} CP and 512 g kg^{-1} NDF on a mono-rotational grazing system and 141 g kg^{-1} CP and 536 g kg^{-1} NDF on a two-rotational grazing system (Kopp et al. 2003). The LS systems in the current study had higher CP values than the ES system and NDF values were higher for the ES system than the LS system. This trend can be observed in grass-legumes mixtures over several years and not just one grazing season. Over years, botanical composition of alfalfa-grass stands change and alfalfa persistence declines along with nutritive value compared to pure alfalfa stands (Smith et al. 1992).

Leaves of plants contain more nutrients than stems, however, alfalfa is prone to leaf shatter under frost/winter conditions which may be an influential factor in forage selections for extended grazing. Cicer milkvetch maintains nutritional quality and leaf integrity better than alfalfa into the fall and is persistent once established (Loeppky et al. 1996; Acharya 2001). Many of the grass-Oxley II mixtures in the current study had significantly high TDN and CP values compared to other treatments. Grass-Oxley II mixtures ranged from 531 to 636 g kg^{-1} for TDN and CP ranged from 92 to 159 g kg^{-1} for both sites and in both stockpile systems. Oxley II cicer milkvetch had 548 to 632 g kg^{-1} TDN at three different sites in the Canadian prairies in 2013 and 2014 which were similar in nutritive to other cicer milkvetch cultivars for stockpiled grazing (Jefferson and Coulman 2015). In the current study, Oxley II cicer milkvetch at the final harvest at Arborg had TDN values ranging from 620 to 625 g kg^{-1} with the ES system being slightly higher than the LS system. At Carman, the ES system had a lower TDN than the LS system; 592 g kg^{-1} and 704 g kg^{-1}, respectively.

Nitrate toxicity is not generally cause for concern in perennial stockpile grazing systems as perennials tend to have lower nitrate levels than annual forages and decrease as a perennial forage stand matures (Hunt 2003; Hutton et al. 2004). It is recommended by NRC (2016), that nitrates in forages should not exceed 5 g kg^{-1} NO_3. There were no nitrate values above 5 g kg^{-1}

NO_3 at the October sampling date representing the typical time of the initiation of stockpile grazing by cattle (Table 31). When elevated levels of nitrate are consumed by ruminant livestock, nitrate gets converted to nitrite and then ammonia in the rumen. In extreme cases, high concentrations of ammonia can surpass the animals' ability to absorb and excrete it effectively. When this happens, ammonia binds to hemoglobin in the bloodstream and oxygen deprivation occurs and ultimately death can result (Yaremcio 1991). Conditions that may cause elevated nitrate concentrations in forages include hail, frost, and sudden heat waves. If forages are grazed within a few days of environmental stress, there is an increased risk of nitrate accumulation (Hunt 2003).

Mineral content in all forage treatments met the nutritional requirements of a gestating beef cow throughout all three trimesters (Table A7). All forage treatments were below maximum tolerable concentrations for all minerals except for Mg for Yellowhead, Oxley II, K+Y, K+O, C+AL, C+O, S+O, and AR+O for Arborg LS. In general, legumes tend to have higher Mg concentrations than grasses (NRC 2016), thus generally having lower potential for deficiencies. Calcium and magnesium deficiencies can pose serious issues to cow health resulting in milk fever and grass tetany. Dry beef cows require 0.18% of Ca and 0.12% of Mg in their total diet whereas lactating cows require 0.58% and 0.20%, respectively (NRC 2016). Deficiencies are most problematic in the period surrounding parturition thus may be less of an issue in late fall/early winter than in spring given the average Canadian beef calving date occurs in March. However, Mg deficiency can result in grass tetany particularly on summer pasture although Mg supplementation may still be required on stockpiled forages (NRC 2016; Parish and Rhinehart 2008). Symptoms of grass tetany include muscle twitching of the head, reduced feed intake, muscle spasms, and if untreated could result in death (Parish and Rhinehart 2008). Grass-legume mixtures can help to reduce the risk of grass tetany as legumes typically contain greater levels of

Mg than grasses (Parish and Rhinehart 2008). However, low mineral concentrations can be managed through strategic supplementation of cattle on pasture through blocks and other forms of supplementation.

Low quality forage is characterized as preserved or mature forage (mature grass and legume) having less than 520 g kg^{-1} TDN, medium quality forage is characterized as pasture during fall (boot-stage grass; late bloom legume) having 520 to 590 g kg^{-1} TDN, and high-quality forage is characterized as early-bloom to mid-bloom legume forage and vegetative grass having more than 590 g kg^{-1} TDN (Glunk and Lewis 2014). On this basis, for the ES system at both sites, most forage treatments would be considered low to medium quality. However, Oxley II and S+O at Arborg and Courtenay, Oxley II, C+Y, and C+O at Carman would be considered high quality based on TDN. For the LS systems at both sites, forages would be characterized as medium to high quality based on forage quality ratings set out by Glunk and Lewis (2014).

4.5.4 Plant height and stage of maturity

Winter snow accumulation in western Canada can reduce the accessibility of standing forages and limit cattle utilization (Aasen et al. 2004; Hamilton 2006). Sufficient yields of stockpiled perennial forages are required for cattle to facilitate grazing through the snow (Baron et al. 2005). Cattle can graze in up to 60 cm of soft snow under optimal conditions, but accessibility issues arise in the presence of winds creating a hard ice crust on the snow surface thus producers must monitor snow conditions to ensure adequate forage intake (Hutton et al. 2004; Hamilton 2006). Additionally, consideration of the animal's energy expenditure to break through the crusted snow is important when considering their nutrient demands during winter months (NRC 2016; Hutton et al. 2004). In the current study, heights ranged from 22 to 34 cm, however, access to this forage would be dependent on winter weather conditions at time of grazing (Karn et al. 2005). Further research is required to assess accessibility of forage treatments evaluated in this study under Manitoba winter conditions.

Grasses ranged from vegetative to an early reproductive SOM with a maximum of 50% leaf senescence. Legumes were in a late reproductive stage with alfalfa having a high degree of leaf senescence. Oxley II cicer milkvetch had higher nutritive value and remained vegetative with having little to no leaf senescence (Table 39). Based on assessment of leaf senescence and SOM, grasses, legumes, and grass-legume mixtures maintained their forage quality into the fall better on the LS system than on the ES system given the lesser decline of TDN and CP (Table 39).

In the current study Courtenay-legume treatments on an ES system demonstrated the best potential for stockpile grazing beef cows when taking yield potential, nutritive value, mineral profile, and plant height/accessibility into consideration. Grass-legume treatments in this study had adequate yields and high nutritive value during fall, particularly mixtures containing milkvetch. Although bromegrass is often used in combination with alfalfa for stockpile grazing, tall fescue produced higher yields which would have the capacity to carry more animals and/or for a longer period of time. Also, tall fescue is moisture tolerant (Najda and Yoder 2005) and combined with the high yields exhibited offers potential for producers in areas where heavy, wetter soils prohibit growth of other grasses for grazing. The use of grass-legume mixtures for stockpiled forages also potentially reduces costs associated with nitrogen fertilizer which may be required for high yield of pure grass forages (MA 2008; Biligetu et al. 2014; current study). However, soil testing for residual nutrients including nitrogen would provide clear indication of existing soil nutrient resources and the suitability of additional fertilizer application. The C+O mixture demonstrated the best potential to carry through into a large-scale late fall/early winter stockpile grazing trial with cows based on its yield and nutritive analysis. The C+O treatment was the highest mixture treatment for final yield, amongst the highest for cumulative yield, and met the nutrient requirements of beef cattle at all sites and cuts except for Arborg LS where CP was 7 g kg^{-1} too low and Mg was slightly above the maximum tolerance level (AARD 2011; NRC 2016).

A study conducted at the Agriculture and Agri-Food Canada Research Centre in Brandon, MB found that pregnant cows in an extended grazing treatment, compared to a dry lot treatment, maintained body weight better in four out of the five production years (Legesse et al. 2011). These extended grazing treatments included grazing dormant perennial pastures and swathed annual crops (Legesse et al. 2011). These authors also found that cows on the drylot treatments experienced 1.8 times greater risk of being culled and had lower rates of calf survival attributed to lack of fitness including lameness and/or udder breakdown. In Iowa, dry beef cows were successfully winter stockpile grazed on a tall fescue-alfalfa mixture and had a greater BW and higher BCS than cows grazing stockpiled bromegrass or corn crop residue (Hitz and Russell 1998). In the current study, while the nutritive value for the LS system was significantly higher than for the ES system; either system would meet cow nutrient requirements, with the differences arising in terms of yield and subsequently carrying capacity. Courtenay + Oxley II was the most successful forage treatment in regard to late fall/early winter stockpile yield and nutritive value and subsequent carrying capacity, accessibility, whilst providing sufficient nutrients to a cow in mid gestation during the early winter.

TABLES AND FIGURES

Table 14. Botanical composition of late stockpile (LS) at Arborg and Carman, harvested August 5, 2015 and July 21, 2015, respectively. Botanical composition is presented on a DM basis.

	Arborg		Carman	
Forage treatment	LS Botanical Composition		LS Botanical Composition	
	Grass (%*)	Legume (%)	Grass (%)	Legume (%)
Killarney + Algonquin	62	38	37	65
Killarney + Yellowhead	32	68	80	20
Killarney + Oxley II	91	9	88	12
Courtenay + Algonquin	47	53	56	44
Courtenay + Yellowhead	40	60	85	15
Courtenay + Oxley II	80	20	83	17
Success + Algonquin	25	75	27	73
Success + Yellowhead	2	98	37	63
Success + Oxley II	4	96	66	34
Fleet + Algonquin	20	80	33	67
Fleet + Yellowhead	49	51	61	39
Fleet + Oxley II	85	15	71	29
Armada + Algonquin	20	80	26	74
Armada + Yellowhead	44	56	65	35
Armada + Oxley II	99	1	80	20

*The percentages (%) of the grass and legume components were calculated from the total wet mass of each sample to represent the proportion of each species in the forage treatment, thus the botanical composition. Pure forage treatments were assumed to be 100% grass or 100% legume.

Table 15. Pearson correlations between summer harvests (stockpile initiation dates) at each site for yield and quality variables for pure and mixed perennial forages. All values were in g kg^{-1} DM unless otherwise stated.

	Arborg		Carman	
Variable	CC	*P*	CC	*P*
Yield (kg DM ha^{-1})	0.74	<0.0001	0.00035	0.9987
DM (g kg^{-1})	0.59	0.0037	0.65	0.0007
CP	0.13	0.5506	0.41	0.0534
DE (Mcal/kg)	0.10	0.6421	0.40	0.0592
ME (Mcal/kg)	0.11	0.6396	0.39	0.0634
NDF	0.65	0.0011	0.83	<0.0001
Nitrates (g kg^{-1} NO_3)	0.13	0.5508	0.71	0.0002
RFV	0.50	0.0177	0.86	<0.0001
TDN	0.13	0.5725	0.37	0.0839
Ca	0.77	<0.0001	0.87	<0.0001
Mg	0.53	0.0107	0.79	<0.0001
P	0.31	0.1634	0.23	0.2857
K	0.45	0.0370	0.40	0.0597
Height (cm)	0.30	0.1743	0.68	0.0003

Early stockpile (ES) harvest and late stockpile (LS) harvest dependent variables were correlated across all forage treatments from the LS block pooled across replicates at Arborg and Carman.

Table 16. Pearson correlations between sites at each summer harvest (stockpile initiation dates) for yield and quality variables for pure and mixed perennial forages. All values were in g kg^{-1} DM unless otherwise stated.

	First cut (ES)		Second cut (LS)	
Variable	CC	*P*	CC	*P*
Yield (kg DM ha^{-1})	0.72	0.0002	0.49	0.0178
DM	0.79	<0.0001	0.35	0.1053
CP	0.53	0.0110	0.61	0.0018
DE (Mcal/kg)	0.71	0.0002	0.46	0.0275
ME (Mcal/kg)	0.71	0.0002	0.46	0.0277
NDF	0.89	<0.0001	0.81	<0.0001
Nitrates (g kg^{-1} NO_3)	0.89	<0.0001	0.53	0.0087
RFV	0.92	<0.0001	0.83	<0.0001
TDN	0.70	0.0003	0.44	0.0377
Ca	0.92	<0.0001	0.89	<0.0001
Mg	0.77	<0.0001	0.68	0.0004
P	0.80	<0.0001	0.71	0.0002
K	0.32	0.1413	0.55	0.0067
Height (cm)	0.92	<0.0001	0.50	0.0141

Correlation coefficients (CC) and their significance (p) for each dependent variable are above.

Table 17. Main effects (forage and stockpile treatments) and forage*stockpile treatment interaction on yield and nutritive value (g kg^{-1} DM unless otherwise stated) of stockpile perennial forages final harvest.

	Arborg			Carman		
Variable	Forage (FOR)	Stockpile (SP)	FOR*SP	Forage (FOR)	Stockpile (SP)	FOR*SP
Yield (kg DM ha^{-1})	0.0020*	<0.0001	0.1864	<0.0001	<0.0001	0.0571
DM	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.7799
CP	<0.0001	<0.0001	0.0007	<0.0001	<0.0001	<0.0001
DE (Mcal/kg)	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
ME (Mcal/kg)	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
NDF	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
RFV	<0.0001	<0.0001	0.0003	<0.0001	<0.0001	<0.0001
TDN	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Height (cm)	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Nitrates (g kg^{-1} NO_3)	0.3803	0.9082	0.3672	0.0007	0.9086	0.9724
Ca	<0.0001	<0.0001	0.0021	<0.0001	0.0012	<0.0001
Mg	<0.0001	<0.0001	0.3027	<0.0001	0.0014	0.0004
P	<0.0001	<0.0001	0.3424	<0.0001	<0.0001	0.1077
K	<0.0001	0.1874	0.0024	<0.0001	<0.0001	0.4208

*P-value <0.05 is significant

Table 18. Yield analysis for mixed and pure stand stockpile perennial forage treatments harvested in October at Arborg and Carman for perennial final harvest.

Variable	Forage treatment	Arborg		Carman	
		ES	LS	ES	LS
Yield (kg DM ha^{-1})	Killarney Orchardgrass	4 329[ab]	1 596	6 494[bcd]	2 332[efg]
	Courtenay Tall Fescue	5 362[a]	2 413	8 490[abc]	4 485[bc]
	Success Hybrid Brome	3 574[ab]	1 309	6 444[bcd]	1 766[g]
	Fleet Meadow Brome	3 185[ab]	3 051	5 980[bcde]	3 324[bcdefg]
	Armada Meadow Brome	4 555[ab]	1 492	5 520[bcde]	3 621[bcdef]
	Algonquin Alfalfa	3 136[ab]	1 285	3 097[e]	1 940[fg]
	Yellowhead Alfalfa	3 170[ab]	1 442	4 006[de]	1 881[g]
	Oxley II Cicer Milkvetch	2 075[ab]	1 002	5 959[bcde]	2 931[bcdefg]
	Killarney + Algonquin	3 278[ab]	1 271	5 736[bcde]	2 946[bcdefg]
	Killarney + Yellowhead	2 782[ab]	1 576	4 782[de]	2 273[efg]
	Killarney + Oxley II	1 870[b]	1 528	5 430[cde]	2 819[cdefg]
	Courtenay + Algonquin	5 100[ab]	1 709	8 888[ab]	4 629[b]
	Courtenay + Yellowhead	3 224[ab]	2 210	8 376[abc]	4 414[bcd]
	Courtenay + Oxley II	3 277[ab]	1 548	10 274[a]	6 508[a]
	Success + Algonquin	3 512[ab]	1 715	5 695[bcde]	1 760[g]
	Success + Yellowhead	2 972[ab]	1 748	5 256[de]	2 128[fg]
	Success + Oxley II	2 487[ab]	1 437	5 993[bcde]	2 952[bcdefg]
	Fleet + Algonquin	3 916[ab]	1 445	5 634[bcde]	2 876[bcdefg]
	Fleet + Yellowhead	4 270[ab]	1 799	5 385[cde]	2 906[bcdefg]
	Fleet + Oxley II	2 550[ab]	1 366	6 776[bcd]	3 962[bcde]
	Armada + Algonquin	4 033[ab]	1 640	4 619[de]	2 664[defg]
	Armada + Yellowhead	3 081[ab]	1 526	6 045[bcde]	2 765[cdefg]
	Armada + Oxley II	3 112[ab]	2 013	5 500[cde]	3 054[bcdefg]
Standard error between treatments		1 035	702 – 823	1 529	1 604 – 1 627

Treatment means within columns followed by the same letter are not significantly different using Tukey's multiple range test ($P = 0.05$).

Table 19. Cumulative yield analysis for mixed and pure stand stockpile perennial forage treatments harvested in October at Arborg and Carman for perennial final harvest.

Variable	Forage treatment	Arborg			Carman		
		Mean	ES	LS	Mean	ES	LS
Cumulative Yield (kg DM ha^{-1})	Killarney Orchardgrass	8 531^{ab}	8 413^{abc}	8 648^{ab}	12 708^{abc}	13 662^{abcde}	11 754^{abcdef}
	Courtenay Tall Fescue	10 165^{a}	11 602^{a}	8 727^{ab}	14 330^{a}	15 518^{a}	13 143^{abcd}
	Success Hybrid Brome	7 311^{abc}	7 431^{abc}	7 190^{abc}	11 289^{abcdef}	12 838^{abcdef}	10 097^{defgh}
	Fleet Meadow Brome	9 150^{ab}	8 574^{abc}	9 726^{a}	14 602^{a}	14 443^{abc}	14 761^{a}
	Armada Meadow Brome	9 313^{ab}	9 945^{ab}	8 681^{ab}	14 537^{a}	15 370^{ab}	13 703^{abc}
	Algonquin Alfalfa	6 898^{abc}	6 797^{abc}	7 000^{abc}	8 313^{ef}	7 390^{g}	9 235^{efgh}
	Yellowhead Alfalfa	6 703^{bc}	6 125^{bcd}	7 280^{abc}	9 024^{def}	9 967^{defg}	8 361^{gh}
	Oxley II Cicer Milkvetch	1 885^{d}	1 506^{e}	2 263^{d}	7 953^{f}	8 692^{fg}	7 214^{h}
	Killarney + Algonquin	7 205^{abc}	7 513^{abc}	6 897^{abc}	10 873^{abcdef}	11 106^{bcdefg}	10 640^{cdefg}
	Killarney + Yellowhead	6 137^{bc}	6 161^{bcd}	6 114^{abcd}	9 696^{cdef}	9 710^{efg}	9 682^{efgh}
	Killarney + Oxley II	4 292^{cd}	4 587^{cd}	3 997^{cd}	9 914^{cdef}	10 815^{cdefg}	9 013^{fgh}
	Courtenay + Algonquin	7 740^{ab}	8 670^{abc}	6 811^{abc}	13 251^{abc}	14 531^{abc}	11 970^{abcdef}
	Courtenay + Yellowhead	7 648^{abc}	7 292^{abc}	8 004^{abc}	13 799^{ab}	15 089^{abc}	12 509^{abcde}
	Courtenay + Oxley II	6 029^{bc}	6 570^{abcd}	5 488^{bcd}	14 451^{a}	14 917^{abc}	13 985^{ab}
	Success + Algonquin	7 875^{ab}	7 671^{abc}	8 078^{abc}	10 430^{bcdef}	11 458^{abcdefg}	9 402^{efgh}
	Success + Yellowhead	7 492^{abc}	7 417^{abc}	7 566^{abc}	10 211^{bcdef}	11 246^{abcdefg}	9 176^{fgh}
	Success + Oxley II	5 950^{bc}	5 924^{bcd}	5 976^{abcd}	10 332^{bcdef}	11 642^{abcdefg}	9 023^{fgh}
	Fleet + Algonquin	8 286^{ab}	8 794^{abc}	7 778^{abc}	12 571^{abcd}	13 349^{abcde}	11 793^{abcdef}
	Fleet + Yellowhead	8 363^{ab}	9 487^{abc}	7 240^{abc}	11 885^{abcde}	13 121^{abcde}	10 649^{cdefg}
	Fleet + Oxley II	6 592^{bc}	6 510^{bcd}	6 674^{abc}	13 794^{ab}	15 067^{abc}	12 522^{abcde}
	Armada + Algonquin	8 269^{ab}	8 929^{abc}	7 608^{abc}	12 034^{abcd}	11 654^{abcdef}	12 262^{abcdef}
	Armada + Yellowhead	7 236^{abc}	7 520^{abc}	6 953^{abc}	12 573^{abcd}	14 270^{abcd}	10 876^{bcdefg}
	Armada + Oxley II	6 477^{bc}	6 978^{abc}	5 975^{abcd}	12 346^{abcd}	12 857^{abcdef}	11 757^{abcdef}
Standard error between treatments		649	1 035	771	1 375 – 1 393	1 529	1 604 - 1 627

Treatment means within columns followed by the same letter are not significantly different using Tukey's multiple range test (P = 0.05).

Table 20. Contrast analysis for variables cumulative yield, DM, CP, NDF and height at Arborg, October 16, 2015 as affected by forage and stockpile treatment. Average botanical composition ratios (grass: legume) were used to compare mixed treatments against their pure counterparts.

	Cumulative yield (kg ha^{-1})		DM (g kg^{-1})		CP (g kg^{-1})		NDF (g kg^{-1})		Height (cm)	
Comparison	Estimate	*P*	Estimate	*P*	Estimate	*P*	Estimate	*P*	Estimate	*P*
K+AL vs K, AL	705	0.376	10	0.581	-18.4	0.105	69	0.004	-1.3	0.219
K+Y vs K, Y	1150	0.155	20	0.305	4.3	0.705	37	0.123	-2.2	0.041
K+O vs K, O	3641	<.0001	30	0.154	-26.1	0.036	94	0.0004	-2.8	0.014
C+AL vs C, AL	693	0.380	-10	0.620	10.1	0.367	23	0.327	-1.1	0.285
C+Y vs C, Y	440	0.579	30	0.179	20.0	0.078	-1	0.963	-1.8	0.078
C+O vs C, O	2480	0.004	-10	0.646	-12.9	0.275	-2	0.933	-0.4	0.735
S+AL vs S, AL	-873	0.288	10	0.586	18.9	0.106	8	0.746	-1.5	0.174
S+Y vs S, Y	-777	0.389	30	0.228	-1.4	0.912	19	0.473	-2.0	0.095
S+O vs S, O	-3849	<.0001	-20	0.407	25.9	0.042	-15	0.570	-0.6	0.622
F+AL vs F, AL	-937	0.262	30	0.151	40.0	0.001	8	0.732	-1.7	0.120
F+Y vs F, Y	-462	0.558	30	0.088	-4.5	0.689	27	0.24	-2.4	0.020
F+O vs F, O	1468	0.086	10	0.706	-16.6	0.171	25	0.316	0.2	0.851
AR+AL vs AR, AL	-887	0.289	20	0.301	32.0	0.008	6	0.793	-1.6	0.135
AR+Y vs AR, Y	615	0.437	20	0.414	-6.2	0.579	23	0.330	-1.4	0.188
AR+O vs AR, O	2762	0.003	70	0.003	-61.9	<0.0001	110	<.0001	-1.6	0.173
SE range	786 – 903		198 – 227		19.8 – 22.7		11.1 – 12.8		23.0 – 26.4	

Forage treatments: Killarney orchardgrass (K); Courtenay tall fescue (C); Success hybrid brome (S); cv.'s Fleet (F) and Armada meadow brome (AR); cv.'s Algonquin (AL) and Yellowhead alfalfa (Y); and Oxley II cicer milkvetch (O). A (+) represents a mixture whereas a (,) represents the two corresponding pure forages. Positive estimates indicate that the mixed treatment was greater compared to the pure treatment that comprised that mixture. Negative estimates indicate that the straight treatments were greater compared to the mixed treatment. Average botanical composition values used for this analysis were from August 5, 2015 because no botanical composition data were available for October. Samples and cutting took place at an early stockpile (ES) in June, 2015 and a late stockpile (LS) in late July/early August, 2015.

Table 21. Contrast analysis for variables cumulative yield, DM, CP, NDF and height of stockpiled perennial forages at Carman, October 13 – 14, 2015. Average botanical composition ratios (grass: legume) were used to compare mixed treatments against their pure counterparts.

	Cumulative Yield (kg ha^{-1})		DM (g kg^{-1})		CP (g kg^{-1})		NDF (g kg^{-1})		Height (cm)	
Comparison	Estimate	*P*	Estimate	*P*	Estimate	*P*	Estimate	*P*	Estimate	*P*
K+AL vs K, AL	-934	0.298	40	0.019	0.7	0.924	15	0.213	-1.1	0.094
K+Y vs K, Y	2275	0.016	20	0.301	-5.0	0.502	13	0.294	-0.2	0.773
K+O vs K, O	2223	0.023	40	0.052	-13.7	0.078	40	0.002	-1.3	0.089
C+AL vs C, AL	-1568	0.079	40	0.041	-10.0	0.182	23	0.066	-0.8	0.241
C+Y vs C, Y	-265	0.782	10	0.547	-7.6	0.323	11	0.380	-0.5	0.504
C+O vs C, O	-1205	0.205	-10	0.649	-14.9	0.050	10	0.428	-0.1	0.868
S+AL vs S, AL	-1314	0.152	40	0.014	-1.9	0.784	15	0.217	-0.9	0.177
S+Y vs S, Y	-349	0.692	20	0.274	-5.9	0.402	-6	0.634	-0.7	0.323
S+O vs S, O	-178	0.842	90	<.0001	-20.6	0.004	72	<.0001	-1.0	0.125
F+AL vs F, AL	-2183	0.017	60	0.002	-6.0	0.405	16	0.182	-1.2	0.077
F+Y vs F, Y	542	0.542	20	0.178	1.4	0.845	-1	0.909	-0.4	0.553
F+O vs F, O	-1121	0.220	40	0.022	-13.3	0.069	14	0.242	-0.2	0.782
AR+AL vs AR, AL	-2103	0.019	40	0.036	-0.8	0.913	9	0.436	-1.8	0.010
AR+Y vs AR, Y	34	0.969	30	0.076	-4.8	0.504	-4	0.710	-0.4	0.553
AR+O vs AR, O	874	0.337	60	0.002	-18.3	0.013	39	0.002	-1.0	0.164
SE range	879 – 966		17.8 – 19.6		7.0 – 7.7		11.7 – 12.9		0.67 – 0.73	

Forage treatments: Killarney orchardgrass (K); Courtenay tall fescue (C); Success hybrid brome (S); cv.'s Fleet (F) and Armada meadow brome (AR); cv.'s Algonquin (AL) and Yellowhead alfalfa (Y); and Oxley II cicer milkvetch (O). A (+) represents a mixture whereas a (,) represents the two corresponding pure forages. Positive estimates indicate that the mixed treatment was greater compared to the pure treatment that comprised that mixture. Negative estimates indicate that the straight treatments were greater compared to the mixed treatment. Average botanical composition values used for this analysis were from August 5, 2015 because no botanical composition data were available for October. Samples and cutting took place at an early stockpile (ES) in June, 2015 and a late stockpile (LS) in late July/early August, 2015.

Table 22. Height analysis for mixed and pure stand stockpile perennial forage treatments harvested in October at Arborg and Carman for perennial final harvest.

Variable	Forage treatment	Arborg		Carman	
		ES	LS	ES	LS
Height (cm)	Killarney Orchardgrass	27^{abcdef}	30^{abc}	$28^{abcdefg}$	32^{cdefgh}
	Courtenay Tall Fescue	30^{abcd}	32^{abc}	31^{ab}	34^{bcde}
	Success Hybrid Brome	26^{def}	27^{bc}	29^{abcdef}	33^{bcdef}
	Fleet Meadow Brome	26^{cdef}	27^{c}	$27^{cdefghi}$	30^{fgh}
	Armada Meadow Brome	27^{bcdef}	27^{bc}	$27^{cdefghi}$	31^{efgh}
	Algonquin Alfalfa	23^{ef}	32^{abc}	23^{i}	29^{h}
	Yellowhead Alfalfa	22^{f}	28^{bc}	23^{hi}	32^{cdefg}
	Oxley II Cicer Milkvetch	32^{a}	32^{abc}	31^{abc}	37^{a}
	Killarney + Algonquin	26^{cdef}	33^{ab}	$27^{cdefghi}$	30^{gh}
	Killarney + Yellowhead	27^{bcdef}	30^{abc}	$27^{bcdefgh}$	32^{cdefgh}
	Killarney + Oxley II	33^{a}	31^{abc}	30^{abcd}	33^{bcdefg}
	Courtenay + Algonquin	26^{cdef}	34^{a}	$28^{abcdefg}$	32^{cdefg}
	Courtenay + Yellowhead	28^{abcde}	30^{abc}	32^{a}	33^{bcdefg}
	Courtenay + Oxley II	32^{ab}	31^{abc}	31^{ab}	34^{abc}
	Success + Algonquin	25^{def}	32^{abc}	25^{ghi}	31^{cdefgh}
	Success + Yellowhead	24^{ef}	30^{abc}	25^{fghi}	34^{bcd}
	Success + Oxley II	31^{abc}	34^{a}	31^{abc}	36^{ab}
	Fleet + Algonquin	26^{def}	32^{abc}	25^{ghi}	31^{defgh}
	Fleet + Yellowhead	27^{bcdef}	30^{abc}	26^{defghi}	31^{defgh}
	Fleet + Oxley II	26^{cdef}	28^{abc}	$28^{abcdefg}$	32^{cdefg}
	Armada + Algonquin	25^{def}	33^{ab}	26^{efghi}	31^{defgh}
	Armada + Yellowhead	26^{def}	29^{abc}	$27^{bcdefgh}$	30^{fgh}
	Armada + Oxley II	26^{cdef}	31^{abc}	30^{abcde}	32^{cdefgh}
Standard error between treatments		1.32	1.14	0.88 – 1.07	0.54 – 0.60

The total model looks at differences between treatments regardless of cut and ES & LS model looks at differences between treatments within each stockpile at each site. Treatment means within columns followed by the same letter are not significantly different using Tukey's multiple range test (P = 0.05). Final harvest dates at Arborg and Carman were October 16, 2015 and October 13 – 14, 2015, respectively.

Table 23. Visual assessment of stage of maturity of stockpiled perennial forages located in Arborg at final harvest October 16, 2015.

	Early stockpile		Late stockpile	
Forage treatment	Grass SOM	Legume SOM	Grass SOM	Legume SOM
Killarney Orchardgrass	veg, 50% sen	n/a	veg, 50% sen	n/a
Courtenay Tall Fescue	veg, 50% sen	n/a	veg, 30% sen	n/a
Success Hybrid Brome	late repro, 40% sen	n/a	veg, 40% sen	n/a
Fleet Meadow Brome	early repro, 40% sen	n/a	veg, 50% sen	n/a
Armada Meadow Brome	veg, 50% sen	n/a	veg, 40% sen	n/a
Algonquin Alfalfa	n/a	late repro, 60% sen	n/a	early repro, 10% sen
Yellowhead Alfalfa	n/a	late repro, 60% sen	n/a	veg, 10% sen
Oxley II Cicer Milkvetch	n/a	late repro, 0% sen	n/a	veg, 10% sen
Killarney + Algonquin	veg, 30% sen	late repro, 60% sen	veg, 30% sen	veg, 10% sen
Killarney + Yellowhead	veg, 30% sen	late repro, 50% sen	veg, 40% sen	veg, 10% sen
Killarney + Oxley II	early repro, 50% sen	late repro, 0% sen	veg, 40% sen	veg, 0% sen
Courtenay + Algonquin	veg, 20% sen	late repro, 60% sen	veg, 30% sen	veg, 10% sen
Courtenay + Yellowhead	early repro, 30% sen	late repro, 50% sen	veg, 20% sen	veg, 10% sen
Courtenay + Oxley II	early repro, 40% sen	late repro, 0% sen	veg, 30% sen	veg, 0% sen
Success + Algonquin	early repro, 30% sen	late repro, 60% sen	veg, 10% sen	early repro, 10% sen
Success + Yellowhead	early repro, 30% sen	late repro, 50% sen	veg, 20% sen	early repro, 10% sen
Success + Oxley II	early repro, 30% sen	late repro, 0% sen	veg, 30% sen	late repro, 0% sen
Fleet + Algonquin	veg, 20% sen	late repro, 50% sen	veg, 10% sen	early repro, 10% sen
Fleet + Yellowhead	veg, 20% sen	late repro, 60% sen	veg, 20% sen	veg, 10% sen
Fleet + Oxley II	veg, 20% sen	late repro, 0% sen	veg, 20% sen	veg, 10% sen
Armada + Algonquin	veg, 20% sen	late repro, 50% sen	veg, 20% sen	veg, 20% sen
Armada + Yellowhead	veg, 30% sen	late repro, 50% sen	veg, 20% sen	veg, 20% sen
Armada + Oxley II	veg, 20% sen	late repro, 10% sen	veg, 30% sen	veg, 10% sen

For grasses (Moore et al., 1991), vegetative (veg) represents stages ranging from 1.0 to 2.4, early reproduction (early repro) represents stages ranging from 2.5 to 3.7 with less than 40% of the plot in the heading stage, and late reproductive (late repro) represents stages ranging from 3.5 to 3.9 with more than 40% of the plot in the heading stage. For legumes (Kalu and Fick, 1981), vegetative (veg) represents stages ranging from 0 to 4, early reproductive (early repro) represents stages ranging from 5 to 6 or the flowering stage, and late reproductive (late repro) represents stages ranging from 7 to 9 or the seed pod stage. Percent senescence (sen) was visually estimated.

Table 24. Visual assessment of stage of maturity of stockpiled perennial forages located in Carman at final harvest October 12, 2015.

	ES		LS	
Forage treatment	Grass SOM	Legume SOM	Grass SOM	Legume SOM
Killarney Orchardgrass	veg, 50% sen	n/a	veg, 50% sen	n/a
Courtenay Tall Fescue	veg, 20% sen	n/a	veg, 20% sen	n/a
Success Hybrid Brome	late repro, 40% sen	n/a	late repro, 30% sen	n/a
Fleet Meadow Brome	veg, 50% sen	n/a	veg, 15% sen	n/a
Armada Meadow Brome	veg, 40% sen	n/a	veg, 20% sen	n/a
Algonquin Alfalfa	n/a	late repro, 70% sen	n/a	late veg, 30% sen
Yellowhead Alfalfa	n/a	late repro, 50% sen	n/a	late veg, 30% sen
Oxley II Cicer Milkvetch	n/a	late repro, 5% sen	n/a	late repro, 0% sen
Killarney + Algonquin	veg, 40% sen	late repro, 50% sen	veg, 25% sen	late repro, 20% sen
Killarney + Yellowhead	veg, 40% sen	late repro, 50% sen	late veg, 35% sen	late veg, 20% sen
Killarney + Oxley II	veg, 40% sen	late repro, 0% sen	late veg, 40% sen	late veg, 0% sen
Courtenay + Algonquin	veg, 20% sen	late repro, 50% sen	late veg, 10% sen	late veg, 20% sen
Courtenay + Yellowhead	veg, 15% sen	late repro, 60% sen	early repro, 10% sen	late veg, 10% sen
Courtenay + Oxley II	veg, 10% sen	late repro, 0% sen	early repro, 10% sen	late veg, 0% sen
Success + Algonquin	late repro, 20% sen	late repro, 50% sen	early repro, 20% sen	early repro, 30% sen
Success + Yellowhead	late repro, 40% sen	late repro, 50% sen	late repro, 15% sen	late veg, 20% sen
Success + Oxley II	late repro, 30% sen	late repro, 0% sen	late repro, 20% sen	late repro, 0% sen
Fleet + Algonquin	veg, 20% sen	late repro, 40% sen	veg, 5% sen	late veg, 20% sen
Fleet + Yellowhead	veg, 20% sen	late repro, 50% sen	veg, 20% sen	early repro, 20% sen
Fleet + Oxley II	veg, 10% sen	late repro, 0% sen	veg, 10% sen	late repro, 0% sen
Armada + Algonquin	veg, 20% sen	late repro, 50% sen	veg, 10% sen	late veg, 20% sen
Armada + Yellowhead	veg, 20% sen	late repro, 50% sen	veg, 20% sen	early repro, 5% sen
Armada + Oxley II	veg, 10% sen	late repro, 0% sen	veg, 10% sen	late veg, 0% sen

For grasses (Moore et al., 1991), vegetative (veg) represents stages ranging from 1.0 to 2.4, early reproduction (early repro) represents stages ranging from 2.5 to 3.7 with less than 40% of the plot in the heading stage, and late reproductive (late repro) represents stages ranging from 3.5 to 3.9 with more than 40% of the plot in the heading stage. For legumes (Kalu and Fick, 1981), vegetative (veg) represents stages ranging from 0 to 4, early reproductive (early repro) represents stages ranging from 5 to 6 or the flowering stage, and late reproductive (late repro) represents stages ranging from 7 to 9 or the seed pod stage. Percent senescence (sen) was visually estimated.

Table 25. Dry matter (DM) analysis for mixed and pure stand stockpile perennial forage treatments harvested in October at Arborg and Carman for perennial final harvest.

Variable	Forage treatment	Arborg		Carman
		ES	LS	Mean
DM (g kg^{-1})	Killarney Orchardgrass	428^{abcd}	413^{abcde}	374^{cdefgh}
	Courtenay Tall Fescue	423^{bcd}	389^{bcde}	308^{h}
	Success Hybrid Brome	528^{ab}	520^{a}	439^{ab}
	Fleet Meadow Brome	493^{abc}	501^{ab}	435^{abc}
	Armada Meadow Brome	491^{abc}	490^{ab}	425^{abcd}
	Algonquin Alfalfa	552^{ab}	383^{bcde}	471^{a}
	Yellowhead Alfalfa	553^{a}	413^{abcde}	442^{ab}
	Oxley II Cicer Milkvetch	337^{d}	309^{e}	310^{h}
	Killarney + Algonquin	461^{abcd}	387^{bcde}	392^{bcdefg}
	Killarney + Yellowhead	455^{abcd}	430^{abcd}	371^{cdefgh}
	Killarney + Oxley II	371^{cd}	381^{bcde}	328^{fgh}
	Courtenay + Algonquin	499^{abc}	395^{bcde}	333^{efgh}
	Courtenay + Yellowhead	428^{abcd}	420^{abcde}	319^{gh}
	Courtenay + Oxley II	384^{cd}	415^{abcde}	319^{gh}
	Success + Algonquin	557^{a}	378^{bcde}	439^{abcd}
	Success + Yellowhead	513^{ab}	398^{bcde}	434^{abc}
	Success + Oxley II	371^{cd}	329de	315^{gh}
	Fleet + Algonquin	495^{abc}	388^{bcde}	402^{abcdef}
	Fleet + Yellowhead	490^{abc}	416^{abcde}	417^{abcde}
	Fleet + Oxley II	453^{abcd}	461^{abc}	355^{defgh}
	Armada + Algonquin	514^{ab}	383^{bcde}	421^{abcd}
	Armada + Yellowhead	500^{abc}	443^{abc}	403^{abcdef}
	Armada + Oxley II	465^{abcd}	373^{cde}	343^{efgh}
Standard error between treatments		24.5	22.0	17.5 – 19.1

The total model looks at differences between treatments regardless of cut and ES & LS model looks at differences between treatments within each stockpile at each site. Treatment means within columns followed by the same letter are not significantly different using Tukey's multiple range test (P = 0.05). Final harvest dates at Arborg and Carman were October 16, 2015 and October 13 – 14, 2015, respectively.

Table 26. Crude protein (CP) analysis for mixed and pure stand stockpile perennial forage treatments harvested in October at Arborg and Carman for perennial final harvest.

Variable	Forage treatment	Arborg		Carman	
		ES	LS	ES	LS
CP ($g\ kg\ DM^{-1}$)	Killarney Orchardgrass	57[cd]	78[defg]	95[cd]	103[h]
	Courtenay Tall Fescue	66[bcd]	70[fg]	81[d]	102[h]
	Success Hybrid Brome	77[bcd]	72[fg]	99[bcd]	157[abcde]
	Fleet Meadow Brome	60[cd]	59[g]	90[cd]	106[gh]
	Armada Meadow Brome	48[d]	58[g]	86[d]	104[h]
	Algonquin Alfalfa	153[a]	195[a]	117[abcd]	147[abcdef]
	Yellowhead Alfalfa	102[abcd]	141[abcd]	103[abcd]	154[abcde]
	Oxley II Cicer Milkvetch	149[a]	190[a]	141[a]	177[ab]
	Killarney + Algonquin	92[abcd]	161[ab]	107[abcd]	131[defgh]
	Killarney + Yellowhead	85[abcd]	114[bcdefg]	97[bcd]	123[efgh]
	Killarney + Oxley II	110[abcd]	96[cdefg]	111[abcd]	129[defgh]
	Courtenay + Algonquin	90[abcd]	138[abcde]	113[abcd]	127[defgh]
	Courtenay + Yellowhead	86[abcd]	74[efg]	102[abcd]	107[gh]
	Courtenay + Oxley II	132[ab]	70[fg]	115[abcd]	121[efgh]
	Success + Algonquin	113[abcd]	147[abc]	105[abcd]	160[abcd]
	Success + Yellowhead	104[abcd]	139[abcd]	99[bcd]	169[abc]
	Success + Oxley II	120[abc]	159[abc]	139[ab]	179[a]
	Fleet + Algonquin	90[abcd]	132[abcdef]	113[abcd]	141[bcdefg]
	Fleet + Yellowhead	83[abcd]	108[bcdefg]	97[bcd]	119[fgh]
	Fleet + Oxley II	106[abcd]	79[defg]	122[abcd]	136[cdefgh]
	Armada + Algonquin	102[abcd]	133[abcdef]	111[abcd]	135[cedfgh]
	Armada + Yellowhead	90[abcd]	105[bcdefg]	112[abcd]	111[fgh]
	Armada + Oxley II	113[abcd]	119[bcdefg]	131[abc]	121[fgh]
Standard error between treatments		14.8	12.4	8.0 – 8.7	7.7 – 8.3

The total model looks at differences between treatments regardless of cut and ES & LS model looks at differences between treatments within each stockpile at each site. Treatment means within columns followed by the same letter are not significantly different using Tukey's multiple range test (P = 0.05). Final harvest dates at Arborg and Carman were October 16, 2015 and October 13 – 14, 2015, respectively.

Table 27. Digestible energy (DE) analysis for mixed and pure stand stockpile perennial forage treatments harvested in October at Arborg and Carman for perennial final harvest. All values are reported on a DM basis.

Variable	Forage treatment	Arborg		Carman	
		ES	LS	ES	LS
DE (Mcal/kg)	Killarney Orchardgrass	2.32^{bcdefg}	2.58^{ab}	2.36^{abcdef}	2.66^{cdefgh}
	Courtenay Tall Fescue	2.51^{abcde}	2.75^{ab}	2.60^{ab}	2.82^{bcdef}
	Success Hybrid Brome	2.22^{defg}	2.31^{b}	2.50^{abcd}	2.84^{bcde}
	Fleet Meadow Brome	2.24^{defg}	2.29^{b}	2.26^{bcdefg}	2.55^{gh}
	Armada Meadow Brome	2.31^{bcdefg}	2.33^{b}	2.26^{bcdefg}	2.58^{fgh}
	Algonquin Alfalfa	1.99^{fg}	2.73^{ab}	1.91^{g}	2.44^{h}
	Yellowhead Alfalfa	1.92^{g}	2.43^{ab}	1.96^{g}	2.74^{cdefg}
	Oxley II Cicer Milkvetch	2.75^{ab}	2.73^{ab}	2.61^{ab}	3.11^{a}
	Killarney + Algonquin	2.25^{defg}	2.80^{ab}	2.26^{bcdefg}	2.54^{gh}
	Killarney + Yellowhead	2.29^{cdefg}	2.58^{ab}	2.27^{bcdefg}	2.68^{cdefgh}
	Killarney + Oxley II	2.79^{a}	2.67^{ab}	2.56^{abc}	2.74^{cdefg}
	Courtenay + Algonquin	2.28^{cdefg}	2.90^{a}	2.41^{abcdef}	2.71^{cdefg}
	Courtenay + Yellowhead	2.40^{abcdef}	2.59^{ab}	2.66^{a}	2.74^{cdefg}
	Courtenay + Oxley II	2.72^{abc}	2.66^{ab}	2.61^{ab}	2.87^{abc}
	Success + Algonquin	2.14^{efg}	2.73^{ab}	2.12^{fg}	2.67^{cdefgh}
	Success + Yellowhead	2.04^{fg}	2.56^{ab}	2.14^{efg}	2.86^{abcd}
	Success + Oxley II	2.66^{abcd}	2.91^{a}	2.57^{abc}	3.04^{ab}
	Fleet + Algonquin	2.21^{defg}	2.78^{ab}	2.12^{fg}	2.62^{defgh}
	Fleet + Yellowhead	2.29^{cdefg}	2.54^{ab}	2.21^{cdefg}	2.61^{defgh}
	Fleet + Oxley II	2.25^{defg}	2.43^{ab}	2.39^{abcdef}	2.70^{cdefg}
	Armada + Algonquin	2.16^{efg}	2.79^{ab}	2.19^{defg}	2.60^{efgh}
	Armada + Yellowhead	2.21^{defg}	2.45^{ab}	2.28^{bcdefg}	2.56^{gh}
	Armada + Oxley II	2.23^{defg}	2.64^{ab}	2.51^{abcde}	2.67^{cdefgh}
Standard error between treatments		0.1115	0.0976	0.0720 – 0.0885	0.0433 – 0.0484

The total model looks at differences between treatments regardless of cut and ES & LS model looks at differences between treatments within each stockpile at each site. Treatment means within columns followed by the same letter are not significantly different using Tukey's multiple range test (*P* = 0.05). Final harvest dates at Arborg and Carman were October 16, 2015 and October 13 – 14, 2015, respectively.

Table 28. Contrast analysis for variables ME, DE, TDN, RFV and nitrates of stockpiled perennial forages at Arborg, October 16, 2015. Average botanical composition ratios (grass: legume) were used to compare mixed treatments against their pure counterparts.

	ME (Mcal/kg)		DE (Mcal/kg)		TDN (g kg^{-1})		RFV		Nitrates (g kg^{-1} NO_3)	
Comparison	Estimate	*P*	Estimate	*P*	Estimate	*P*	Estimate	*P*	Estimate	*P*
K+AL vs K, AL	-0.09	0.211	-0.11	0.213	-25	0.219	-16	0.054	0.06	0.689
K+Y vs K, Y	-0.14	0.054	-0.17	0.055	-39	0.055	-12	0.179	-0.01	0.930
K+O vs K, O	-0.21	0.010	-0.25	0.010	-57	0.010	-24	0.013	0.16	0.331
C+AL vs C, AL	-0.08	0.240	-0.10	0.249	-23	0.251	-8	0.368	0.01	0.932
C+Y vs C, Y	-0.12	0.107	-0.14	0.111	-32	0.107	-3	0.764	-0.02	0.875
C+O vs C, O	-0.03	0.697	-0.04	0.687	-9	0.680	3	0.710	-0.20	0.210
S+AL vs S, AL	-0.08	0.274	-0.10	0.280	-22	0.288	-2	0.852	0.03	0.828
S+Y vs S, Y	-0.10	0.217	-0.12	0.216	-28	0.216	-7	0.453	-0.03	0.870
S+O vs S, O	-0.05	0.507	-0.06	0.548	-13	0.555	11	0.250	-0.29	0.083
F+AL vs F, AL	-0.13	0.100	-0.15	0.095	-35	0.096	-3	0.775	-0.13	0.394
F+Y vs F, Y	-0.16	0.027	-0.20	0.026	-45	0.025	-9	0.279	-0.38	0.013
F+O vs F, O	-0.002	0.975	-0.005	0.958	-2	0.939	-1	0.921	-0.16	0.327
AR+AL vs AR, AL	-0.10	0.190	-0.12	0.191	-27	0.191	-1	0.892	-0.27	0.087
AR+Y vs AR, Y	-0.08	0.290	-0.09	0.283	-22	0.272	-6	0.501	0.04	0.804
AR+O vs AR, O	-0.09	0.278	-0.11	0.261	-26	0.246	-23	0.020	0.02	0.922
SE range	0.072 – 0.082		0.087 – 0.099		19.6 – 22.5		8 – 10		0.15 – 0.17	

Forage treatments: Killarney orchardgrass (K); Courtenay tall fescue (C); Success hybrid brome (S); cv.'s Fleet (F) and Armada meadow brome (AR); cv.'s Algonquin (AL) and Yellowhead alfalfa (Y); and Oxley II cicer milkvetch (O). A (+) represents a mixture whereas a (,) represents the two corresponding pure forages. Positive estimates indicate that the mixed treatment was greater compared to the pure treatment that comprised that mixture. Negative estimates indicate that the straight treatments were greater compared to the mixed treatment. Average botanical composition values used for this analysis were from August 5, 2015 because no botanical composition data were available for October. Samples and cutting took place at an early stockpile (ES) in June, 2015 and a late stockpile (LS) in late July/early August, 2015.

Table 29. Contrast analysis for variables ME, DE, TDN, RFV and nitrates of stockpiled perennial forages at Carman, October 13 – 14, 2015. Average botanical composition ratios (grass: legume) were used to compare mixed treatments against their pure counterparts.

	ME (Mcal/kg)		DE (Mcal/kg)		TDN (g kg^{-1})		RFV		Nitrates (g kg^{-1} NO_3)	
Comparison	Estimate	*P*	Estimate	*P*	Estimate	*P*	Estimate	*P*	Estimate	*P*
K+AL vs K, AL	-0.08	0.071	-0.10	0.071	-23	0.073	-4	0.281	0.19	0.731
K+Y vs K, Y	-0.002	0.967	-0.001	0.981	-1	0.960	-1	0.722	0.13	0.812
K+O vs K, O	-0.08	0.103	-0.10	0.100	-22	0.104	-6	0.088	-0.27	0.644
C+AL vs C, AL	-0.07	0.135	-0.09	0.137	-20	0.139	-5	0.136	-1.13	0.048
C+Y vs C, Y	-0.03	0.512	-0.04	0.496	-9	0.485	-3	0.457	-0.33	0.573
C+O vs C, O	-0.0006	0.990	-0.001	0.981	-0.5	0.971	1	0.794	-0.80	0.162
S+AL vs S, AL	-0.07	0.138	-0.08	0.130	-19	0.128	-5	0.163	0.16	0.761
S+Y vs S, Y	-0.03	0.584	-0.03	0.550	-8	0.531	-0.3	0.939	-0.06	0.917
S+O vs S, O	-0.06	0.176	-0.08	0.173	-17	0.172	-14	<.0001	-0.67	0.193
F+AL vs F, AL	-0.10	0.038	-0.12	0.036	-27	0.034	-4	0.210	-0.04	0.947
F+Y vs F, Y	-0.02	0.664	-0.03	0.622	-6	0.628	1	0.708	0.33	0.537
F+O vs F, O	-0.01	0.839	-0.01	0.853	-3	0.825	4	0.218	-0.65	0.235
AR+AL vs AR, AL	-0.13	0.006	-0.16	0.006	-35	0.006	-5	0.164	-0.51	0.341
AR+Y vs AR, Y	-0.02	0.678	-0.03	0.649	-6	0.662	2	0.634	-0.74	0.171
AR+O vs AR, O	-0.06	0.177	-0.08	0.156	-18	0.157	-3	0.371	-0.45	0.411
SE range	0.046 – 0.050		0.055 – 0.060		12.4 – 13.5		3 – 4		0.53 – 0.58	

Forage treatments: Killarney orchardgrass (K); Courtenay tall fescue (C); Success hybrid brome (S); cv.'s Fleet (F) and Armada meadow brome (AR); cv.'s Algonquin (AL) and Yellowhead alfalfa (Y); and Oxley II cicer milkvetch (O). A (+) represents a mixture whereas a (,) represents the two corresponding pure forages. Positive estimates indicate that the mixed treatment was greater compared to the pure treatment that comprised that mixture. Negative estimates indicate that the straight treatments were greater compared to the mixed treatment. Average botanical composition values used for this analysis were from August 5, 2015 because no botanical composition data were available for October. Samples and cutting took place at an early stockpile (ES) in June, 2015 and a late stockpile (LS) in late July/early August, 2015.

Table 30. Metabolizable energy (ME) analysis for mixed and pure stand stockpile perennial forage treatments harvested in October at Arborg and Carman for perennial final harvest. All values are reported on a DM basis.

Variable	Forage treatment	Arborg		Carman	
		ES	LS	ES	LS
ME (Mcal/kg)	Killarney Orchardgrass	1.93^{bcdefg}	2.14^{ab}	1.96^{abcdef}	2.20^{cdefg}
	Courtenay Tall Fescue	2.08^{abcde}	2.28^{ab}	2.16^{ab}	2.34^{bcde}
	Success Hybrid Brome	1.84^{defg}	1.92^{b}	2.08^{abcd}	2.35^{bcde}
	Fleet Meadow Brome	1.86^{defg}	1.90^{b}	1.87^{bcdefg}	2.12^{fg}
	Armada Meadow Brome	1.92^{bcdefg}	1.93^{b}	1.88^{bcdefg}	2.14^{efg}
	Algonquin Alfalfa	1.65^{fg}	2.27^{ab}	1.58^{g}	2.03^{g}
	Yellowhead Alfalfa	1.59^{g}	2.02^{ab}	1.63^{g}	2.28^{cdef}
	Oxley II Cicer Milkvetch	2.28^{ab}	2.27^{ab}	2.17^{ab}	2.58^{a}
	Killarney + Algonquin	1.87^{defg}	2.33^{ab}	1.87^{bcdefg}	2.11^{fg}
	Killarney + Yellowhead	1.90^{cdefg}	2.14^{ab}	1.89^{bcdefg}	2.23^{cdefg}
	Killarney + Oxley II	2.31^{a}	2.22^{ab}	2.12^{abc}	2.27^{cdef}
	Courtenay + Algonquin	1.89^{cdefg}	2.41^{a}	2.00^{abcdef}	2.25^{cdef}
	Courtenay + Yellowhead	2.00^{abcdef}	2.15^{ab}	2.20^{a}	2.28^{cdef}
	Courtenay + Oxley II	2.25^{abc}	2.21^{ab}	2.16^{ab}	2.38^{abc}
	Success + Algonquin	1.78^{efg}	2.27^{ab}	1.75^{fg}	2.21^{cdefg}
	Success + Yellowhead	1.70^{fg}	2.12^{ab}	1.78^{efg}	2.37^{abcd}
	Success + Oxley II	2.21^{abcd}	2.42^{a}	2.14^{abc}	2.52^{ab}
	Fleet + Algonquin	1.84^{defg}	2.31^{ab}	1.76^{fg}	2.17^{cdefg}
	Fleet + Yellowhead	1.90^{cdefg}	2.11^{ab}	1.83^{cdefg}	2.17^{defg}
	Fleet + Oxley II	1.87^{defg}	2.02^{ab}	1.99^{abcdef}	2.25^{cdef}
	Armada + Algonquin	1.79^{efg}	2.32^{ab}	1.82^{defg}	2.16^{efg}
	Armada + Yellowhead	1.83^{efg}	2.04^{ab}	1.89^{bcdefg}	2.13^{fg}
	Armada + Oxley II	1.85^{defg}	2.19^{ab}	2.08^{abcde}	2.21^{cdefg}
Standard error between treatments		0.0923	0.0809	0.0598 – 0.0735	0.0358 – 0.0400

The total model looks at differences between treatments regardless of cut and ES & LS model looks at differences between treatments within each stockpile at each site. Treatment means within columns followed by the same letter are not significantly different using Tukey's multiple range test (P = 0.05). Final harvest dates at Arborg and Carman were October 16, 2015 and October 13 – 14, 2015, respectively.

Table 31. Total Digestible Nutrients (TDN) analysis for mixed and pure stand stockpile perennial forage treatments harvested in October at Arborg and Carman for perennial final harvest. All values are reported on a DM basis.

Variable	Forage treatment	Arborg		Carman	
		ES	LS	ES	LS
TDN ($g\ kg^{-1}$)	Killarney Orchardgrass	527^{bcdefg}	584^{ab}	535^{abcdef}	602^{cdefgh}
	Courtenay Tall Fescue	569^{abcde}	624^{ab}	591^{ab}	640^{bcdef}
	Success Hybrid Brome	503^{defg}	525^{b}	564^{abcd}	643^{bcde}
	Fleet Meadow Brome	508^{defg}	519^{b}	$512^{bcdefgh}$	578^{gh}
	Armada Meadow Brome	524^{bcdefg}	527^{b}	$513^{bcdefgh}$	584^{fgh}
	Algonquin Alfalfa	452^{fg}	621^{ab}	432^{h}	553^{h}
	Yellowhead Alfalfa	435^{g}	551^{ab}	444^{gh}	622^{cdefg}
	Oxley II Cicer Milkvetch	625^{ab}	620^{ab}	592^{ab}	704^{a}
	Killarney + Algonquin	510^{defg}	635^{ab}	$511^{bcdefgh}$	577^{gh}
	Killarney + Yellowhead	520^{cdefg}	584^{ab}	$516^{bcdefgh}$	608^{cdefgh}
	Killarney + Oxley II	632^{a}	605^{ab}	580^{abc}	621^{cdefg}
	Courtenay + Algonquin	517^{cdefg}	658^{a}	554^{abcdef}	615^{cdefg}
	Courtenay + Yellowhead	545^{abcdef}	588^{ab}	602^{a}	622^{cdefg}
	Courtenay + Oxley II	617^{abc}	603^{ab}	591^{ab}	652^{abc}
	Success + Algonquin	485^{efg}	620^{ab}	456^{fgh}	604^{cdefgh}
	Success + Yellowhead	464^{fg}	580^{ab}	486^{efgh}	648^{abcd}
	Success + Oxley II	603^{abcd}	659^{a}	583^{abc}	689^{ab}
	Fleet + Algonquin	502^{defg}	631^{ab}	481^{fgh}	593^{cdefgh}
	Fleet + Yellowhead	519^{cdefg}	576^{ab}	501^{cdefgh}	592^{defgh}
	Fleet + Oxley II	510^{defg}	552^{ab}	542^{abcdef}	613^{cdefg}
	Armada + Algonquin	490^{efg}	633^{ab}	496^{defgh}	589^{efgh}
	Armada + Yellowhead	502^{defg}	557^{ab}	517^{bcdefg}	580^{gh}
	Armada + Oxley II	506^{defg}	599^{ab}	570^{abcde}	605^{cdefgh}
Standard error between treatments		25.2	22.1	16.3 – 20.0	9.8 – 11.0

The total model looks at differences between treatments regardless of cut and ES & LS model looks at differences between treatments within each stockpile at each site. Treatment means within columns followed by the same letter are not significantly different using Tukey's multiple range test ($P = 0.05$). Final harvest dates at Arborg and Carman were October 16, 2015 and October 13 – 14, 2015, respectively.

Table 32. Relative Feed Value (RFV) analysis for mixed and pure stand stockpile perennial forage treatments harvested in October at Arborg and Carman for perennial final harvest. All values are reported on a DM basis.

Variable	Forage treatment	Arborg		Carman	
		ES	LS	ES	LS
RFV	Killarney Orchardgrass	82[bc]	95[bcd]	79[efg]	104[def]
	Courtenay Tall Fescue	93[bc]	105[abcd]	93[bcdef]	108[cdef]
	Success Hybrid Brome	78[c]	80[d]	85[cdefg]	107[cdef]
	Fleet Meadow Brome	80[bc]	81[d]	75[fg]	92[f]
	Armada Meadow Brome	81[bc]	82[d]	77[fg]	93[f]
	Algonquin Alfalfa	75[c]	141[abc]	70[g]	105[cdef]
	Yellowhead Alfalfa	72[c]	105[abcd]	73[fg]	123[c]
	Oxley II Cicer Milkvetch	153[a]	149[ab]	122[a]	195[a]
	Killarney + Algonquin	86[bc]	139[abc]	83[cdefg]	102[def]
	Killarney + Yellowhead	90[bc]	110[abcd]	82[defg]	107[cdef]
	Killarney + Oxley II	126[ab]	109[abcd]	103[abc]	109[cdef]
	Courtenay + Algonquin	85[bc]	138[abc]	91[bcdefg]	109[cdef]
	Courtenay + Yellowhead	92[bc]	98[bcd]	99[bcde]	108[cdef]
	Courtenay + Oxley II	113[abc]	99[bcd]	102[abcd]	118[cde]
	Success + Algonquin	81[bc]	124[abcd]	77[fg]	112[cdef]
	Success + Yellowhead	78[c]	113[abcd]	74[fg]	121[cd]
	Success + Oxley II	118[abc]	157[a]	110[ab]	153[b]
	Fleet + Algonquin	85[bc]	125[abcd]	78[fg]	103[def]
	Fleet + Yellowhead	84[bc]	104[abcd]	78[fg]	98[ef]
	Fleet + Oxley II	92[bc]	92[cd]	91[bcdef]	112[cdef]
	Armada + Algonquin	82[bc]	126[abcd]	78[fg]	105[cdef]
	Armada + Yellowhead	84[bc]	98[bcd]	80[efg]	96[f]
	Armada + Oxley II	90[bc]	120[abcd]	101[bcd]	105[def]
Standard error between treatments		9.16	10.58	3.88 – 4.80	3.46 – 3.84

The total model looks at differences between treatments regardless of cut and ES & LS model looks at differences between treatments within each stockpile at each site. Treatment means within columns followed by the same letter are not significantly different using Tukey's multiple range test (*P* = 0.05). Final harvest dates at Arborg and Carman were October 16, 2015 and October 13 – 14, 2015, respectively.

Table 33. Neutral detergent fibre (NDF) analysis for mixed and pure stand stockpile perennial forage treatments harvested in October at Arborg and Carman for perennial final harvest. All values are reported on a DM basis.

Variable	Forage treatment	Arborg		Carman	
		ES	LS	ES	LS
NDF	Killarney Orchardgrass	632^{ab}	591^{ab}	660^{ab}	544^{abcd}
(g kg^{-1})	Courtenay Tall Fescue	589^{abcd}	559^{abcd}	599^{abcdef}	546^{abcd}
	Success Hybrid Brome	640^{a}	639^{a}	645^{abc}	556^{abcd}
	Fleet Meadow Brome	626^{ab}	635^{a}	674^{a}	597^{a}
	Armada Meadow Brome	634^{ab}	633^{a}	662^{ab}	599^{a}
	Algonquin Alfalfa	615^{ab}	415de	653^{abc}	511^{cde}
	Yellowhead Alfalfa	626^{ab}	510^{abcde}	634^{abc}	473^{e}
	Oxley II Cicer Milkvetch	405^{e}	423^{cde}	463^{h}	327^{g}
	Killarney + Algonquin	588^{abcd}	423^{cde}	609^{abcdef}	540^{abcd}
	Killarney + Yellowhead	569^{abcd}	522^{abcde}	622^{abcde}	535^{bcd}
	Killarney + Oxley II	479de	520^{abcde}	539^{fgh}	534^{bcd}
	Courtenay + Algonquin	600^{abcd}	440^{bcde}	582^{bcdefg}	527^{bcde}
	Courtenay + Yellowhead	578^{abcd}	567^{abcd}	576^{cdefg}	541^{abcd}
	Courtenay + Oxley II	512^{bcde}	576^{abc}	551^{defg}	513^{cde}
	Success + Algonquin	604^{abcd}	472^{bcde}	645^{abc}	511^{cde}
	Success + Yellowhead	606^{abcd}	494^{abcde}	657^{ab}	494de
	Success + Oxley II	487^{cde}	389^{e}	507^{gh}	410^{f}
	Fleet + Algonquin	586^{abcd}	473^{bcde}	623^{abcd}	544^{abcd}
	Fleet + Yellowhead	610^{abc}	533^{abcde}	640^{abc}	569^{abc}
	Fleet + Oxley II	560^{abcd}	586^{ab}	587^{bcdef}	516^{bcde}
	Armada + Algonquin	597^{abcd}	468^{bcde}	639^{abc}	531^{bcde}
	Armada + Yellowhead	595^{abcd}	554^{abcd}	641^{abc}	575^{ab}
	Armada + Oxley II	561^{abcd}	481^{bcde}	543^{efgh}	545^{abcd}
Standard error between treatments		24.5	31.2	14.9 – 18.5	10.5 – 11.7

The total model looks at differences between treatments regardless of cut and ES & LS model looks at differences between treatments within each stockpile at each site. Treatment means within columns followed by the same letter are not significantly different using Tukey's multiple range test (P = 0.05). Final harvest dates at Arborg and Carman were October 16, 2015 and October 13 – 14, 2015, respectively.

Table 34. Nitrates analysis for mixed and pure stand stockpile perennial forage treatments harvested in October at Arborg and Carman for perennial final harvest. All values are reported on a DM basis.

Variable	Forage treatment	Arborg	Carman
		Mean	Mean
Nitrates ($g\ kg^{-1}\ NO_3$)	Killarney Orchardgrass	1.1	1.6[ab]
	Courtenay Tall Fescue	1.0	3.0[ab]
	Success Hybrid Brome	1.2	2.2[ab]
	Fleet Meadow Brome	0.9	2.4[ab]
	Armada Meadow Brome	1.0	1.8[ab]
	Algonquin Alfalfa	0.9	1.6[ab]
	Yellowhead Alfalfa	0.9	1.3[b]
	Oxley II Cicer Milkvetch	1.0	2.1[ab]
	Killarney + Algonquin	0.9	1.4[b]
	Killarney + Yellowhead	1.0	1.4[b]
	Killarney + Oxley II	0.9	1.9[ab]
	Courtenay + Algonquin	1.0	3.5[ab]
	Courtenay + Yellowhead	1.0	3.1[ab]
	Courtenay + Oxley II	1.2	3.7[a]
	Success + Algonquin	0.9	1.6[ab]
	Success + Yellowhead	0.9	1.7[ab]
	Success + Oxley II	1.3	2.9[ab]
	Fleet + Algonquin	1.0	1.9[ab]
	Fleet + Yellowhead	1.3	1.7[ab]
	Fleet + Oxley II	1.1	3.0[ab]
	Armada + Algonquin	1.2	2.1[ab]
	Armada + Yellowhead	0.9	2.4[ab]
	Armada + Oxley II	1.0	2.3[ab]
Standard error between treatments		0.12	0.47 – 0.52

The total model looks at differences between treatments regardless of cut and ES & LS model looks at differences between treatments within each stockpile at each site. Treatment means within columns followed by the same letter are not significantly different using Tukey's multiple range test ($P = 0.05$). Final harvest dates at Arborg and Carman were October 16, 2015 and October 13 – 14, 2015, respectively.

Table 35. Calcium analysis for mixed and pure stand stockpile perennial forage treatments harvested in October at Arborg and Carman for perennial final harvest. All values are reported on a DM basis.

Variable	Forage treatment	Arborg		Carman	
		ES	LS	ES	LS
Ca (g kg^{-1})	Killarney Orchardgrass	6.1^{fgh}	4.9^{d}	4.4^{efg}	4.7^{hi}
	Courtenay Tall Fescue	5.2^{h}	4.8^{d}	4.0^{fg}	4.4^{i}
	Success Hybrid Brome	6.7^{efgh}	5.3^{bcd}	3.9^{g}	6.0^{efghi}
	Fleet Meadow Brome	5.9^{gh}	4.9^{cd}	5.0^{defg}	4.8^{hi}
	Armada Meadow Brome	5.6^{gh}	4.8^{d}	5.4^{cdefg}	5.2^{fghi}
	Algonquin Alfalfa	14.7^{ab}	10.2^{abcd}	9.7^{ab}	13.0^{ab}
	Yellowhead Alfalfa	14.0^{abc}	10.8^{ab}	7.7^{bcd}	11.9^{abc}
	Oxley II Cicer Milkvetch	17.6^{a}	14.1^{a}	11.8^{a}	15.0^{a}
	Killarney + Algonquin	14.8^{ab}	8.5^{bcd}	7.8^{bcd}	9.2^{bcdef}
	Killarney + Yellowhead	12.5^{abcde}	8.9^{abcd}	7.4^{bcde}	6.1^{efghi}
	Killarney + Oxley II	$10.0^{bcdefgh}$	10.8^{ab}	7.9^{bcd}	5.9^{efghi}
	Courtenay + Algonquin	14.5^{abc}	7.8^{bcd}	6.6^{bcdefg}	6.7^{defghi}
	Courtenay + Yellowhead	7.7^{defgh}	7.3^{bcd}	5.0^{defg}	5.3^{fghi}
	Courtenay + Oxley II	6.9^{efgh}	8.4^{bcd}	7.3^{bcde}	5.0^{ghi}
	Success + Algonquin	13.7^{abcd}	10.5^{abc}	8.2^{bc}	9.8^{bcde}
	Success + Yellowhead	13.8^{abcd}	9.7^{abcd}	6.9^{bcdefg}	10.3^{bcd}
	Success + Oxley II	16.5^{a}	10.3^{abcd}	9.2^{ab}	12.3^{abc}
	Fleet + Algonquin	13.7^{abcd}	9.2^{abcd}	8.8^{ab}	8.6^{cdefgh}
	Fleet + Yellowhead	12.1^{abcdef}	8.0^{bcd}	7.1^{bcdef}	6.4^{defghi}
	Fleet + Oxley II	8.4^{cdefgh}	9.7^{abcd}	8.5^{bc}	8.0^{defghi}
	Armada + Algonquin	13.2^{abcd}	8.6^{abcd}	7.6^{bcd}	8.9^{cdefg}
	Armada + Yellowhead	$10.2^{bcdefgh}$	8.4^{bcd}	7.1^{bcdef}	6.3^{defghi}
	Armada + Oxley II	$11.5^{abcdefg}$	10.8^{ab}	8.9^{ab}	7.3^{defghi}
Standard error between treatments		1.13	1.08	0.55 – 0.71	0.68 – 0.76

The total model looks at differences between treatments regardless of cut and ES & LS model looks at differences between treatments within each stockpile at each site. Treatment means within columns followed by the same letter are not significantly different using Tukey's multiple range test ($P = 0.05$). Final harvest dates at Arborg and Carman were October 16, 2015 and October 13 – 14, 2015, respectively.

Table 36. Contrast analysis for mineral variables Ca, Mg, P, and K of stockpiled perennial forages at Arborg, October 16, 2015. Average botanical composition ratios (grass: legume) were used to compare mixed treatments against their pure counterparts.

	Ca (g kg^{-1})		Mg (g kg^{-1})		P (g kg^{-1})		K (g kg^{-1})	
Comparison	Estimate	*P*	Estimate	*P*	Estimate	*P*	Estimate	*P*
K+AL vs K, AL	-3.5	0.0004	-0.5	0.130	-0.4	0.002	-0.4	0.778
K+Y vs K, Y	-0.5	0.585	-0.9	0.007	-0.7	<.0001	-2.5	0.110
K+O vs K, O	-4.0	0.0003	-1.4	0.0003	-0.6	<.0001	-0.4	0.797
C+AL vs C, AL	-2.3	0.021	-0.8	0.018	-0.1	0.384	-0.6	0.691
C+Y vs C, Y	1.9	0.048	-0.4	0.238	-0.3	0.016	-1.8	0.225
C+O vs C, O	-0.5	0.605	-0.4	0.228	-0.1	0.268	2.7	0.092
S+AL vs S, AL	-1.3	0.204	-0.3	0.364	-0.3	0.008	-0.4	0.809
S+Y vs S, Y	5.0	0.624	0.2	0.553	-0.4	0.009	-2.0	0.235
S+O vs S, O	2.1	0.061	0.3	0.361	0.001	0.992	2.5	0.139
F+AL vs F, AL	-4.0	0.677	-0.8	0.033	-0.3	0.047	-0.5	0.765
F+Y vs F, Y	-1.1	0.270	-0.4	0.285	-0.3	0.006	-3.7	0.014
F+O vs F, O	-2.1	0.047	-0.3	0.446	-0.07	0.609	0.7	0.663
AR+AL vs AR, AL	1.0	0.948	-0.5	0.132	-0.4	0.006	-2.6	0.104
AR+Y vs AR, Y	-1.0	0.938	0.1	0.674	-0.5	0.0001	-1.9	0.214
AR+O vs AR, O	-5.9	<.0001	-1.6	<.0001	-0.3	0.013	-3.0	0.079
SE range	0.96 – 0.11		0.33 – 0.38		0.12 – 0.14		1.49 – 1.71	

Forage treatments: Killarney orchardgrass (K); Courtenay tall fescue (C); Success hybrid brome (S); cv.'s Fleet (F) and Armada meadow brome (AR); cv.'s Algonquin (AL) and Yellowhead alfalfa (Y); and Oxley II cicer milkvetch (O). A (+) represents a mixture whereas a (,) represents the two corresponding pure forages. Positive estimates indicate that the mixed treatment was greater compared to the pure treatment that comprised that mixture. Negative estimates indicate that the straight treatments were greater compared to the mixed treatment. Average botanical composition values used for this analysis were from August 5, 2015 because no botanical composition data were available for October. Samples and cutting took place at an early stockpile (ES) in June, 2015 and a late stockpile (LS) in late July/early August, 2015.

Table 37. Contrast analysis for mineral variables Ca, Mg, P and K of stockpiled perennial forages at Carman, October 13 – 14, 2015. Average botanical composition ratios (grass: legume) were used to compare mixed treatments against their pure counterparts.

	Ca (g kg^{-1})		Mg (g kg^{-1})		P (g kg^{-1})		K (g kg^{-1})	
Comparison	Estimate	*P*	Estimate	*P*	Estimate	*P*	Estimate	*P*
K+AL vs K, AL	0.4	0.559	-3	0.122	-0.5	0.0003	-3.7	0.050
K+Y vs K, Y	-1.1	0.070	-0.4	0.842	-0.5	0.003	0.8	0.683
K+O vs K, O	-1.3	0.052	-4	0.040	-0.3	0.061	-1.4	0.486
C+AL vs C, AL	0.7	0.284	-3	0.078	-0.4	0.019	-2.0	0.317
C+Y vs C, Y	-0.1	0.817	-3	0.167	-0.3	0.086	0.4	0.828
C+O vs C, O	-0.4	0.497	-3	0.130	-0.2	0.116	-0.2	0.934
S+AL vs S, AL	0.7	0.275	-2	0.201	-0.4	0.010	-2.7	0.145
S+Y vs S, Y	-0.5	0.360	3	0.057	-0.08	0.562	-0.7	0.719
S+O vs S, O	-2.9	<.0001	-5	0.011	-0.001	0.992	-5.3	0.004
F+AL vs F, AL	0.5	0.387	-1	0.409	-0.4	0.003	-2.7	0.152
F+Y vs F, Y	0.1	0.853	3	0.096	-0.3	0.037	-0.1	0.944
F+O vs F, O	-0.9	0.166	-2	0.234	-0.2	0.239	-3.3	0.086
AR+AL vs AR, AL	1.5	0.012	-1	0.425	-0.4	0.004	-3.2	0.086
AR+Y vs AR, Y	0.2	0.697	-0.5	0.794	-0.3	0.064	-1.9	0.312
AR+O vs AR, O	-1.2	0.054	-6	0.002	-0.2	0.148	-1.2	0.527
SE range	0.59 – 0.65		1.7 – 1.9		0.14 – 0.16		1.83 – 2.01	

Forage treatments: Killarney orchardgrass (K); Courtenay tall fescue (C); Success hybrid brome (S); cv.'s Fleet (F) and Armada meadow brome (AR); cv.'s Algonquin (AL) and Yellowhead alfalfa (Y); and Oxley II cicer milkvetch (O). A (+) represents a mixture whereas a (,) represents the two corresponding pure forages. Positive estimates indicate that the mixed treatment was greater compared to the pure treatment that comprised that mixture. Negative estimates indicate that the straight treatments were greater compared to the mixed treatment. Average botanical composition values used for this analysis were from August 5, 2015 because no botanical composition data were available for October. Samples and cutting took place at an early stockpile (ES) in June, 2015 and a late stockpile (LS) in late July/early August, 2015.

Table 38. Magnesium analysis for mixed and pure stand stockpile perennial forage treatments harvested in October at Arborg and Carman for perennial final harvest. All values are reported on a DM basis.

Variable	Forage treatment	Arborg	Carman	
		Mean	ES	LS
Mg (g kg^{-1})	Killarney Orchardgrass	3.3^{defg}	3.1^{abcd}	2.9^{abcdefg}
	Courtenay Tall Fescue	4.1^{abcdef}	3.2^{abc}	3.3^{ab}
	Success Hybrid Brome	2.6^{g}	1.7^{efg}	2.2^{efgh}
	Fleet Meadow Brome	2.7^{fg}	2.1^{cdefg}	2.4^{cdefgh}
	Armada Meadow Brome	2.6^{g}	1.8^{efg}	1.7^{h}
	Algonquin Alfalfa	3.1^{efg}	1.4^{g}	1.8^{h}
	Yellowhead Alfalfa	3.9^{abcdefg}	1.6^{fg}	3.2^{ab}
	Oxley II Cicer Milkvetch	5.3^{a}	3.0^{abcd}	3.5^{a}
	Killarney + Algonquin	3.8^{bcdefg}	2.4^{bcdefg}	2.4^{bcdefgh}
	Killarney + Yellowhead	4.7^{abcd}	2.6^{abcdef}	3.2^{abc}
	Killarney + Oxley II	4.9^{ab}	3.6^{a}	3.2^{abcd}
	Courtenay + Algonquin	4.4^{abcde}	2.8^{abcdef}	3.0^{abcdef}
	Courtenay + Yellowhead	4.4^{abcde}	3.5^{ab}	3.3^{ab}
	Courtenay + Oxley II	4.8^{abc}	3.4^{ab}	3.7^{a}
	Success + Algonquin	3.3^{defg}	1.8^{efg}	2.0^{gh}
	Success + Yellowhead	3.7^{bcdefg}	1.6^{fg}	2.3^{defgh}
	Success + Oxley II	4.9^{ab}	2.6^{abcdef}	3.1^{abcde}
	Fleet + Algonquin	3.8^{bcdefg}	2.0^{defg}	2.0^{h}
	Fleet + Yellowhead	3.7^{bcdefg}	1.8^{efg}	2.2^{fgh}
	Fleet + Oxley II	3.4^{cdefg}	3.0^{abcd}	2.5^{bcdefgh}
	Armada + Algonquin	3.6^{bcdefg}	1.7^{efg}	1.9^{h}
	Armada + Yellowhead	3.2^{efg}	2.1^{cdefg}	1.9^{h}
	Armada + Oxley II	4.2^{abcde}	2.8^{abcde}	2.4^{cdefgh}
Standard error between treatments		0.27	0.27 – 0.32	0.20 – 0.21

The total model looks at differences between treatments regardless of cut and ES & LS model looks at differences between treatments within each stockpile at each site. Treatment means within columns followed by the same letter are not significantly different using Tukey's multiple range test (P = 0.05). Final harvest dates at Arborg and Carman were October 16, 2015 and October 13 – 14, 2015, respectively.

Table 39. Phosphorous analysis for mixed and pure stand stockpile perennial forage treatments harvested in October at Arborg and Carman for perennial final harvest. All values are reported on a DM basis.

Variable	Forage treatment	Arborg	Carman
		Mean	Mean
P (g kg^{-1})	Killarney Orchardgrass	1.8^{bcdef}	2.4^{abc}
	Courtenay Tall Fescue	1.7^{cdef}	2.1^{bcd}
	Success Hybrid Brome	1.7^{cdef}	2.3^{abc}
	Fleet Meadow Brome	1.6^{def}	2.2^{abc}
	Armada Meadow Brome	1.5^{ef}	2.2^{abc}
	Algonquin Alfalfa	1.6^{cdef}	1.5^{d}
	Yellowhead Alfalfa	1.4^{f}	1.9^{cd}
	Oxley II Cicer Milkvetch	2.0^{abcd}	2.0^{cd}
	Killarney + Algonquin	2.1^{abc}	2.4^{abc}
	Killarney + Yellowhead	2.3^{ab}	2.8^{a}
	Killarney + Oxley II	2.5^{a}	2.7^{ab}
	Courtenay + Algonquin	1.8^{bcdef}	2.2^{abc}
	Courtenay + Yellowhead	1.8^{bcdef}	2.3^{abc}
	Courtenay + Oxley II	1.9^{bcde}	2.3^{abc}
	Success + Algonquin	2.0^{abcde}	2.1^{bcd}
	Success + Yellowhead	1.8^{bcdef}	2.1^{bcd}
	Success + Oxley II	2.0^{abcd}	2.2^{abc}
	Fleet + Algonquin	1.9^{bcdef}	2.2^{abc}
	Fleet + Yellowhead	1.8^{bcdef}	2.3^{abc}
	Fleet + Oxley II	1.7^{cdef}	2.3^{abc}
	Armada + Algonquin	1.9^{bcde}	2.1^{bc}
	Armada + Yellowhead	1.9^{bcde}	2.4^{abc}
	Armada + Oxley II	1.8^{bcdef}	2.4^{abc}
Standard error between treatments		0.10	0.17 – 0.18

The total model looks at differences between treatments regardless of cut and ES & LS model looks at differences between treatments within each stockpile at each site. Treatment means within columns followed by the same letter are not significantly different using Tukey's multiple range test (*P* = 0.05). Final harvest dates at Arborg and Carman were October 16, 2015 and October 13 – 14, 2015, respectively.

Table 40. Potassium analysis for mixed and pure stand stockpile perennial forage treatments harvested in October at Arborg and Carman for perennial final harvest. All values are reported on a DM basis.

Variable	Forage treatment	Arborg		Carman
		ES	LS	Mean
K (g kg^{-1})	Killarney Orchardgrass	18.5^{abcd}	18.1^{ab}	27.8^{abcde}
	Courtenay Tall Fescue	19.1^{abcd}	17.7^{ab}	35.0^{a}
	Success Hybrid Brome	17.1^{abcd}	13.2^{b}	19.5^{fgh}
	Fleet Meadow Brome	16.2^{abcd}	12.7^{b}	25.2^{cdefg}
	Armada Meadow Brome	14.9^{abcd}	13.4^{b}	25.2^{cdefg}
	Algonquin Alfalfa	12.8^{cd}	20.4^{ab}	17.0^{h}
	Yellowhead Alfalfa	11.4^{d}	14.2^{b}	18.5^{gh}
	Oxley II Cicer Milkvetch	23.0^{a}	26.4^{a}	27.4^{abcde}
	Killarney + Algonquin	16.0^{abcd}	20.1^{ab}	24.7^{cdefgh}
	Killarney + Yellowhead	17.2^{abcd}	16.9^{ab}	25.1^{cdefg}
	Killarney + Oxley II	20.9^{abc}	17.8^{ab}	29.2^{abcd}
	Courtenay + Algonquin	16.0^{abcd}	20.1^{ab}	29.0^{abcd}
	Courtenay + Yellowhead	18.9^{abcd}	14.8^{b}	32.1^{abc}
	Courtenay + Oxley II	18.9^{abcd}	15.0^{b}	33.9^{ab}
	Success + Algonquin	12.8^{cd}	20.4^{ab}	20.4^{efgh}
	Success + Yellowhead	14.4^{bcd}	15.4^{b}	19.5^{fgh}
	Success + Oxley II	22.3^{ab}	21.3^{ab}	27.5^{abcde}
	Fleet + Algonquin	13.8^{cd}	19.5^{ab}	22.4^{defgh}
	Fleet + Yellowhead	18.2^{abcd}	16.5^{b}	22.7^{defgh}
	Fleet + Oxley II	16.3^{abcd}	14.3^{b}	29.2^{abcd}
	Armada + Algonquin	17.0^{abcd}	20.4^{ab}	22.3^{defgh}
	Armada + Yellowhead	16.1^{abcd}	14.4^{b}	24.8^{cdefgh}
	Armada + Oxley II	15.6^{abcd}	19.0^{ab}	26.9^{bcdef}
Standard error between treatments		1.54	2.00	1.56 – 1.74

The total model looks at differences between treatments regardless of cut and ES & LS model looks at differences between treatments within each stockpile at each site. Treatment means within columns followed by the same letter are not significantly different using Tukey's multiple range test (P = 0.05). Final harvest dates at Arborg and Carman were October 16, 2015 and October 13 – 14, 2015, respectively.

4.6 CONCLUSIONS

As per the hypothesis, there were significant differences in performance (i.e. yield, nutritive value, accessibility) between pure grass or legume forages and/or grass-legume mixtures and differences between stockpile treatments. Grazing grass-legume mixtures compared to pure grass or pure legume would be more preferential to producers wanting to stockpile graze cows when considering both yield and nutritive value. The current study suggests that a grass-legume mixture of Courtenay tall fescue and Oxley II cicer milkvetch on an ES system would be the best candidate to proceed into a second research phase of animal trials to test cow performance on stockpiled perennial forage in the late fall/early winter in Manitoba. A cost analysis is also needed to further understand the economic advantage of stockpile grazing these specific species. Financial information including direct (i.e. cow cost, seed, shelter, seeding and harvesting) and indirect (i.e. labour, fuel, veterinarian) costs would need to be collected from conventional overwintering production and extended grazing, specifically stockpile grazing, production to be compared (Larson 2013). More research is needed to test stand characteristics of this grass-legume mixture including persistence over several years, the impact of stockpile grazing on continued yield and the physical capacity to remain accessible to grazing cattle in the snow.

5. GENERAL DISCUSSION

In Western Canada, there is limited literature on stockpile grazing of annual and perennial forages in Manitoba climate. Cost of feeding is the greatest financial input for beef producers, particularly in the winter. There has been an increased interest in and practice of extended grazing systems in Western Canada. In the Canadian prairies, there is an average winter-feeding period of 160 d and if all beef cattle were grazed for one more day every fall, the beef industry could potentially save $3.1 million annually (Saskatchewan Forage Council 2011; Larson 2013). Stockpile grazing is an effective way to extend the grazing season and provide a low-cost food source after conventional forage growth has ceased (McCartney et al. 2004a; McCartney 2016). A study conducted at the Canada Research Centre in Brandon, Manitoba found that pregnant cows in an extended grazing treatment, compared to a dry lot treatment, maintained body weight better in four out of the five production years (Legesse et al. 2011). Legesse et al. (2011) found that cows on the dry lot treatments experienced 1.8 times greater risk of being culled and had lower rates of calf survival. This suggests that winter grazing systems not only have an economic advantage regarding reduced feed costs but show improvement in cattle performance despite weather conditions (Shepard et al. 2015). Several annual and perennial forages have been researched for suitability in extended grazing systems in Canada, but more research is needed on cultivar suitability, based on yield potential and nutritional value, under Manitoba conditions. Stockpile grazing forages and corn is practiced by approximately 36% of producers in Western Canada who utilize extended grazing strategies (Sheppard et al. 2015).

The objectives of this thesis were; (i) assessment of 23 pure and mixed perennial forage treatments under either an early or late stockpiling system on establishment, late fall/early winter yield and nutritive value, (ii) assessment of seven annual forage treatments in pure stands on late fall/early winter yield and nutritive value; (iii) to measure standing height in the late fall/early winter to assess potential accessibility of the stockpile forages; (iv) to assess plant stage of maturity at time of grazing of stockpiled forages; (v) to compare nutritive value and yield to cow nutrient and DMI requirements and estimate carrying capacity.

Assessment of 23 pure and mixed perennial forage treatments revealed that C+O had the highest late fall/early winter yield at both study sites and for both stockpile systems (ES and LS). Courtenay + Oxley II (C+O) final yields were greater for the ES system than the LS system. Success of mixtures versus success of pure stands was site dependant. In general, pure forages had greater yields at Arborg whereas forage mixtures had greater yields at Carman. Although research on Success hybrid bromegrass indicated that the cultivar produced higher yields than its parent cultivars, the current study found it to be one of the least successful pure and/or mixtures in this trial. In a stockpile grazing trial in Manitoba, Courtenay tall fescue had a four-year average yield of 1628 kg ha^{-1} whereas in combination with Oxley II cicer milkvetch the mixture yielded of 2612 kg ha^{-1} (MA 2008). In the current study at the Carman site on either stockpile system (ES and LS), C+AL and C+Y yields ranged from 4414 kg ha^{-1} to 8888 kg ha^{-1} which compares with the results reported by Thompson (2013) and Courtenay and C+O fall yields exceeded those reported by MA (2008). Early stockpile (ES) final yields for C+O were higher than LS yields at both sites with a difference of about 7000 kg ha^{-1} between sites suggesting a significant site effect. Courtenay (92%) had a high percent germination rate and although Oxley II (52%) had a lower percent germination than Algonquin (70%) or Yellowhead (65%). Oxley II maintained its nutritive quality better into the fall which could account for the success of this cultivar in this trial (Table A6). From a producer stand point, C+O managed for either the ES or LS grazing system would be suitable for stockpile grazing; the preference being as to whether the producer desires to achieve one or two mid season grazing or haying events.

Of the seven annual forage treatments, corn had the greatest yield potential and sufficient nutritive value for late fall/early winter stockpile grazing beef cows in Manitoba. In addition to assessing yield and nutritive value at potential time of grazing in late fall/early winter, profiles were generated for each forage from late summer to assess changes over time in the growing season and to evaluate if yield and nutritional quality would persist in the fall. There was a general trend over time that yields increased, while NDF increased, and nutritive value decreased. Fall rye, westerwold ryegrass, and corn were the only treatments that demonstrated an increased or stable nutritive value later into the late fall/early winter. The high nutritive value of westerwold ryegrass in October was achieved through cutting the stand at 10 cm in late-July or early-August. This forage harvested in midsummer could be used during drylot feeding in the winter months. Mid-summer harvest allowed the stand to remain vegetative for longer and although it reached an advanced state of maturity (early to late heading), the stand remained green into October in all site-years. Although the nutritive value of fall rye and westerwold ryegrass was superior to corn, corn yield, depending on site, was at least four times greater and could support more cattle per hectare. Corn has great potential for stockpile grazing because of its high energy and yield potential (Ball et al. 2008) and cows feeding on standing corn can consume 13 to 18 kg DM per day (Lardner and Glen 2015). Advantages of grazing standing corn includes greater biomass compared to small cereal grains, adequate energy and protein for cows in the fall and winter, and reduced risk of acidosis; however, later gestating cows may require protein supplementation (Lardner and Glen 2015). The current study validates that corn, seeded in May could provide adequate nutrition for dry cows and the high yields would allow greater carrying capacity than the other treatments.

Snow depth and snow characteristics are also important factors to consider when grazing into the winter (Hamilton 2006). Cattle can graze in up to 60 cm of soft snow under optimal conditions, but accessibility issues arise in the presence of winds creating a hard ice crust on the snow surface, thus, producers must monitor snow conditions to ensure adequate forage intake (Hutton et al. 2004; Hamilton 2006). Accessibility due to plant height would not be an issue if stockpiling corn but could be an issue if stockpiling cereal grains, annual grasses, and/or perennials as they are not as robust as corn. In the current study perennial forage height ranged from 22 to 34 cm and annual forages (excluding corn) ranged from 33 to 124 cm, however, access to this forage would be dependent on winter weather conditions at time of grazing (Karn et al. 2005). Winter snow accumulation in western Canada can reduce the accessibility of standing forages and limit utilization by cattle (Aasen et al. 2004; Hamilton 2006). Sufficient yields of stockpiled perennial forages are required for cattle to facilitate grazing through the snow (Baron et al. 2005). Additionally, consideration of the animal's energy expenditure to break through the crusted snow is important when considering their nutrient demands during winter months (NRC 2016; Hutton et al. 2004).

At time of harvest, perennial grasses and legumes had variable SOM with grasses being vegetative to early reproductive whereas legumes were in a late reproductive stage. Grass-legume mixtures maintained their forage quality into the fall better on the LS system than on the ES system given the lesser decline of TDN and CP. Forage treatments on the LS system maintained their forage quality better than the ES system because the forages were less mature, remaining mostly vegetative (as opposed to reproductive), having been cut an additional time during the summer months and thus having less time to accumulate fiber and maintain protein and energy. Grasses had a maximum of 50% leaf senescence whereas alfalfa had a high degree of leaf senescence, while Oxley II had little to no senescence. Meadow bromegrass consistently provides high yields from year to year in western Canada, however, the longer the period before grazing, the lower the nutritive value (Baron et al. 2005). As the grass enters reproduction, the energy of the plant is shifted to reproductive structures (seeds) as opposed to vegetative structures (leaves) and there is increased lignification of the stem, which is indigestible to cattle, thus the nutritive value decreases (Baron et al. 2005; Mathis and Sawyer 2007). Previous research on extended grazing suggests that mixtures retain their nutritive value better than monocrops into the fall (Aasen et al. 2004), which agrees with the findings of the current study. For the annuals, Westerwold and fall rye remained vegetative whereas corn and the cereals were all in a late reproductive stage; early dough to full seed maturation. For cereal crops, desired stage of maturity for grazing is the early dough stage by the first frost (Hutton et al. 2004; McCartney et al. 2004). In this study, barley, oats, and millet should have been planted later in the summer so that full maturity was not reached by time of grazing (McCartney et al. 2004; Sheppard et al. 2015). Annuals also have more flexibility in timing of seeding as they grow faster than perennials. This allows producers to time for stockpile forages accordingly and seed later into the season if higher forage quality and lesser stage of maturity is desirable (McCartney et al. 2008).

One of the objectives of the current study was to compare nutritive value and yield of the perennial and annual forage treatments with the greatest potential for stockpile grazing to cow nutrient and DMI requirements and thus estimate carrying capacity. This information will enable producers to select forages based on their potential utilization for beef cattle in Canada in the late fall/early winter with taking physiological state of cattle (cow), climate, and accessibility (i.e. snow depth) into consideration. This study examined if high yielding treatments would meet the nutrient requirements of cows during winter and during gestation, as their requirements relative to growing cattle are lower. Cow performance during winter grazing can only be estimated from the nutritive and yield data shown in this study and is based on known requirements for maintenance, pregnancy, and growth. Out of the 30 forages treatments tested in this trial, corn and C+O demonstrated the best potential for large scale stockpile grazing of beef. Climatic differences (i.e. accumulated rainfall, GDD, average daily temperatures) were variable between sites and years contributing to significant differences in forage treatment performance (Table A2, Figure A2, Figure A3, Figure A4). Roblin and Arborg soils had poor drainage so when there was heavy rainfall, the ground would remain saturated, whereas during periods without rainfall, the soils were cracked and hard. Carman had moderately well drained soils and 2015 had more GDD than found in 2014 which may account for high productivity at the Carman site compared to the others. Corn TDN and CP values from the 2015 growing season would meet the nutritional requirements of a dry beef cow (up to 648 kg) in the middle trimester of pregnancy with the potential need for additional protein and calcium supplementation (AARD 2011; NRC 2016). Mid gestation cows at mature weight of 648 kg and expected calf birth weight of 39 kg require a DMI (including potential wastage; 3% BW) of 19 kg^{-1} d^{-1} (AARD 2011). The average yield of the three sites in October 2015 (31 591 kg ha^{-1} DM) would, in theory, be able to support approximately 30 mid gestation cows (680 kg) for 55 days on one hectare of land. Courtenay + Oxley II on the ES or LS system would meet the nutritional requirements of a dry beef cow (up to 648 kg) in the middle trimester of pregnancy (AARD 2011). The average final yield between sites for C+O on the ES system and LS system was 6776 kg ha^{-1} and 4028 kg ha^{-1}, respectively. The C+O final yield of 10 247 kg ha^{-1} for Carman ES system would support approximately 30 mid gestation cows (648 kg) for 18 d on one ha versus C+O final yield of 6508 kg ha^{-1} for Carman LS system at 11 d on one ha. In the current study, while the nutritive value for the LS system was significantly higher than for the ES system; either system would meet cow nutrient requirements, with the differences arising in terms of yield and subsequently carrying capacity. Therefore, C+O in the ES system and corn would be the most suitable forages for late fall/early winter stockpile grazing in beef cows under Manitoba conditions.

Stockpile grazing is an effective extended grazing method to reduce feed costs for cow-calf and backgrounding operations in western Canada. There are gaps in the literature regarding animal utilization of stockpiled forages and subsequence performance (bodyweight) under Manitoba conditions as well as a lack of information of new, adapted cultivars suitable for this method of extended grazing. This research contributes to these knowledge gaps and provides information to western Canadian beef producers on annual and perennial forages that can be successfully grown in Manitoba. This study estimates cow performance based on cow nutrient requirements, DMI, accessibility and yield potential of forage treatments, however, further research needs to be completed on cow performance while grazing these forages under Manitoba conditions.

6. LIST OF REFERENCES

AARD. 2011. Alberta Agriculture and Rural Development CowBytes beef ration balancer program. Version 5. Alberta, Canada.

Aasen, A., Baron, V.S., Clayton, G.W., Dick, A.C., and McCartney, D.H. 2004. Swath grazing potential of spring cereals, field pea and mixtures with other species. Canadian Journal of Plant Science. **84**: 1051-1058.

Acharya, S.N. 2001. AC Oxley II cicer milkvetch. Canadian Journal of Plant Science. **81**: 749-751.

Acharya, S.N. 2009. Veldt cicer milkvetch. Canadian Journal of Plant Science. **89**: 511-513. agdex9239/$file/420_56-2.pdf?OpenElement [2016 May 14].

Anez-Osuna, F., Penner, G.B., Larson, K., Jefferson, P.G., Lardner, H.A., and McKinnon, J.J. 2015. Effect of rumen degradable energy supplementation on forage utilization and performance of steers grazing stockpiled cool season perennial grass pastures. Canadian Journal of Animal Science. **95**: 255-265.

Baenziger, H. 1975. Algonquin alfalfa. Canadian Journal of Plant Science. **55**: 1093-1094.

Ball, D., Ballard, E., Kennedy, M., Lacefield, G., and Undersander, D. 2008. Extending grazing and reducing stored feed needs, Grazing Lands Conservation Initiative. Publication 8-01, Bryan, TX, USA.

Barnhart, S.K. 2010. Stockpiled forages: a way to extend the grazing season. Iowa State University Extension [Online]. Available: https://store.extension.iastate.edu/Product/pm1772-pdf [2014 Dec 08].

Baron, V.S., Doce, R.R., Basarab, J. and Dick, C. 2014. Swath grazing triticale and corn compared to barley and a traditional winter feeding method in central Alberta. Canadian Journal of Plant Science. **94**: 1125-1137.

Baron, V.S., Aasen, A., Oba, M., Dick, A.C., Salmon, D.F., Basarab, J.A., and Stevenson, C.F. 2012. Swath-grazing potential for small-grain species with a delayed plating date. Agronomy Journal. **104**: 393-404.

Baron, V.S., Dick, A.C., Bjorge, M., and Lastiwka, G. 2005. Accumulation period for stockpiling perennial forages in western Canadian prairie parkland. Agronomy Journal. **97**: 1508-1514.

Baron, V.S., Najda, H.G., McCartney, D.H., Bjorge, M., and Lastiwka, G.W. 2003. Winter weathering effects on corn grown for grazing in short-season area. Canadian Journal of Plant Science. **83**: 333-341.

Beaver, J.M. and Olson, B.E. 1997. Winter range use by cattle of different ages in south-western Montana. Applied Animal Behaviour Science. **51**: 1-13.

Biligetu, B., Jefferson, P.G., Muri, R., and Schellenberg, M.P. 2014. Late summer forage yield, nutritive value, compatibility of warm- and cool-season grasses seeded with legumes in western Canada. Canadian Journal of Plant Science. **94**: 1139-1148.

Boadi, D.A., Wittenburg, K.M., Scott, S.L., Burton, D., Buckley, K., Small, J.A., and Ominski, K.H. 2004. Effect of low and high forage diet on enteric and manure pack greenhouse gas emissions from a feedlot. Canadian Journal of Animal Science. **84**: 445-453.

Canadian Beef. 2016. Fact Sheets: get the skinny on Canadian Beef. Canadian Beef [Online]. Available: https://canadabeef.ca/fact-sheets/ [2018 Mar 02].

Coblentz, W.K., Brink, G.E., Hoffman, P.C., Esser, N.M., and Bertram, M.G. 2014. Fall-grown oat to extend the fall grazing season for replacement dairy heifers. Journal of Dairy Science. **97**: 1645 – 1660.

Coleman, S.W. 1992. Plant-animal interface. Journal of Production Agriculture. **5**: 7-13.

Coulman, B. 2006. Success hybrid bromegrass. Canadian Journal of Plant Science. **86**: 745-747.

Coulman, B. 2009. AC Armada meadow brome. Technical bulletin [Online]. Available: http://www1.foragebeef.ca/$Foragebeef/frgebeef.nsf/all/frg109/$FILE/speciesgrassesarmada.pdf [2016 May 14].

Crummett, D. 2015. Forage cocktails to the rescue: warm-season annuals offer high-quality grazing during the summer pasture slump. Farm Journal. **139**: 62.

Cuomo, G., Johnson, D., and Head, B. 2012. Pasture management: stockpiled forage to extend the grazing season. University of Minnesota Extension [Online]. Available: http://www.extension.umn.edu/agriculture/beef/components/docs/stockpiled_forage_to_extend_the_grazing_system.pdf [2014 Dec 08].

Dick, A.C., Baron, V.S. and Aasen, A. 2008. Agronomic management of stockpiled pastures. Agrifacts: Practical Information for Alberta's Agricultural Industry. Alberta Government [Online]. Available: https://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex12422/$file/420_56-4.pdf?OpenElement [2018 Mar 10].

Drapeau, R., Belanger, G., Tremblay, G.F., and Michaud, R. 2007. Yield, persistence, and nutritive value of autumn-harvested tall fescue. Canadian Journal of Plant Science. **87**: 67-75.

Eilers, R.G. 1983. Soils of the Roblin area with interpretations for agriculture, engineering, and recreational land use. Soils report No. D47 Canada-Manitoba soil survey. Agriculture

Canada, Manitoba Department of Agriculture, and Department of Soil Science, University of Manitoba [Online]. Available: http://sis.agr.gc.ca/cansis/publications/surveys/mb/mbd47/mbd47_report.pdf [2018 April 30].

Elgersma, A. and Soegaard, K. 2016. Effects of species diversity on seasonal variation in herbage yield and nutritive value of seven binary grass-legume mixtures and pure grass under cutting. European Journal of Agronomy. **78**: 73-83.

Environment Canada. 2018. Meteorological service of Canada. 1981-2010 Canadian climate normals and averages [Online]. Available: http://climate.weather.gc.ca/climate_normals//$file/420_56-2.pdf?OpenElement [2017 May 14].

Fox, D.G., Sniffen, C.J., and O'Connor, J.D. 1988. Adjusting nutrient requirements of beef cattle for animal and environmental variations. Journal of Animal Science. **66**: 1475-1495.

Glunk, E. and Lewis, K. 2014. Forage seminar Cut Bank, Montana. Montana State University Extension [Online]. Available: http://msuextension.org/glacier/ag_files/Forage_sampling_Ration_Balancing.pdf [2017 May 14].

Goplen, B.P., Baenziger, H., Bailey, L.D., Gross, A.T.H., Hanna, M.R., Michaud, R., Richards, K.W., and Waddington, J. 1980. Growing and managing alfalfa in Canada. Agriculture Canada Publication 1705/E [Online]. Available: http://publications.gc.ca/collections/collection_2014/aac-aafc/agrhist/A53-1705-1987-eng.pdf [2016 May 16].

Government of Saskatchewan. 2017. Beef cow rations and winter feeding guidelines [Online]. Available: https://www.saskatchewan.ca/business/agriculture-natural-resources-and-industry/agribusiness-farmers-and-ranchers/livestock/cattle-poultry-and-other-livestock/cattle/beef-cow-rations-and-winter-feeding-guidelines# [2018 Jan 02].

Hall, M.H. 2008. Smooth bromegrass. Penn State Extension: Agronomy facts 27 [Online]. Available: https://extension.psu.edu/smooth-bromegrass [2018 Mar 02].

Hamilton, T. 2006. Snow grazing saves feed costs. Ontario Ministry of Agriculture, Food, and Rural Affairs [Online]. Available: http://www.omafra.gov.on.ca/english/livestock/beef/news/vbn0706a4.htm [2014 Dec 08].

Hancock, D.W. and Collins, M. 2006. Forage preservation method influences alfalfa nutritive value and feeding characteristics. Crop Science. **46**: 688-694.

Hanway, J.J. and S.W. Ritchie. 1984. How a Corn Plant Develops. Special Report No. 48. Iowa State University, Ames, IA.

Havens. A., Lastiwka, G., Laughton, D. Westerlund, D., Heyden, J., Rigney, R., Zylstra, J., Stone, J., Bergen, R. and Vandermey, D. 2006. Year Round Grazing 365 Days. Agricultural Research and Extension Council of Alberta [Online]. Available: https://www.agrireseau.net/bovinsboucherie/documents/00105%20p.pdf [2018 June 30].

Hickson, R.E., Morris, S.T., Kenyon, P.R. and Lopez-Villalobos, N. 2006. Dystocia in beef heifers: A review of genetic and nutritional influences. New Zealand Veterinary Journal. **54**: 256-264.

Hitz, A.C. and Russell, J.R. 1998. Potential of stockpiled perennial forages in winter grazing systems for pregnant beef cows. Journal of Animal Science. **76**: 404-415.

Horton, G.M.J., Manns, J.G., Nicholson, H.H. and Harrop, G.A. 1981. Behavioral activity, serum progesterone and feedlot performance of heifers fed melengesterol acetate and monensin. Canadian Journal of Animal Science. **61**: 695–702.

Hunt, L. 2003. Technical information for the Canadian Forage Beef Industry: nitrates [Online]. Available:http://www1.foragebeef.ca/$foragebeef/frgebeef.nsf/all/ccf57?opendocument&site=fbca [2016 May 14].

Hutton, G., Perillat, B., McCartney, D., and Ohama, A. 2004. Agri-facts: swath grazing in Western Canada. Alberta Agriculture Food and Rural Development [Online]. Available: http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex9239/$file/420_56-2.pdf?OpenElement [2014 Dec. 08].

Islam, A. 2018. Forage identification: orchardgrass. Department of Plant Science, University of Wyoming [Online]. Available: http://www.uwyo.edu/plantsciences/uwplant/forages/grasses/orchardgrass.html [2018 Mar 02].

Jefferson, P. and Lardner, B. 2012. Fall rye for pasture. Western Beef Development Centre: fact sheet #2012.02 [Online]. http://www.wbdc.sk.ca/pdfs/fact_sheets/2012/2012-02_Fall%20Rye_FactSheet.pdf [2017 May 14].

Jefferson, P.G. and Coulman, B. 2015. Stockpiled forage quality of new cicer milkvetch varieties. 17th Annual Summer Field Day. Western Beef Development Centre, Lanigan, SK, Canada.

Jose, D., Damiran, D., Penner, G., McKinnon, J., Larson, K., and Lardner, B. 2017. Effect of winter grazing system on beef cow performance and system costs. Western Beef Development Centre fact sheet #2017.01 [Online]. Available: http://www.wbdc.sk.ca/pdfs/fact_sheets/2017/2017_01_WBDC%20Fact%20Sheet_Corn_Graze_Cow.pdf [2018 Jan 02].

Jungnitsch, P.F., Schoenau, J.J., Lardner, H.A., and Jefferson, P.G. 2011. Winter feeding beef cattle on the western Canadian prairies: impacts on soil nitrogen and phosphorus cycling and forage growth. Agriculture, Ecosystems, and the Environment. **141**: 143-152.

Kallenbach, R.L., Bishop-Hurley, G.J., Massie, M.D., Kerley, M.S., and Roberts, C.A. 2003. Stockpiled annual ryegrass for winter forage in the lower Midwestern USA. Crop Science. **43**: 1414-1419.

Kalu, B.A. and Fick, G.W. 1981. Quantifying morphological of alfalfa for studies in herbage quality. Crop Science. **23**: 1167-1172.

Karn, J.F., Tanaka, D.L., Liebig, M.A., Ries, R.E., Kronberg, S.L., and Hanson, J.D. 2005. An integrated approach to crop/livestock systems: wintering beef cows on swathed crops. Renewable Agriculture and Food Systems. **20**: 232-242.

Kelln, B., Lardner, H., McKinnon, J.J., Campbell, J.R., Larson, K., and Damiran, D. 2011. Effect of winter feeding system on beef cow performance, reproductive efficiency, and system cost. The Professional Animal Scientist. **27**: 410-421.

Kelln, B., Lardner, H., Schoenau, J., and King, T. 2012. Effects of beef cow winter feeding systems, pen manure and compost on soil nitrogen and phosphorous amounts and distribution, soil density, and crop biomass. Nutrient Cycling in Agroecosystems. **92**: 183-194.

Kopp, J.C., McCaughey, W.P., and Wittenburg, K.M. 2003. Yield, quality and cost effectiveness of using fertilizer and/or alfalfa to improve meadow bromegrass pastures. Canadian Journal of Animal Science. **83**: 291-298.

Krause, A.D., Lardner, H.A., McKinnon, J.J., Hendrick, S., Larson, K., and Dammiran, D. 2013. Comparison of grazing oat and pea crop residue versus feeding grass-legume hay on beef-cow performance, reproductive efficiency, and system cost. The Professional Animal Scientist. **29**: 535-545.

Kreplin, C. and Yaremcio, B. 2000. Effects of nutrition on beef cow reproduction. Agrifacts: Practical Information for Alberta's Agricultural Industry. Alberta Government [Online]. Available: http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex3527/$file/420-51-1.pdf?OpenElement [2017 May 14].

Kulathunga, D.G.R.S., Penner, G.B., Schoenau, J.J., Damiran, D., Larson, K., and Lardner, H.A. 2016. The effect of perennial forage system on forage characteristics, soil nutrients, cow performance, and system economics. The Professional Animal Scientist. **32**: 784-797.

Lardner, B. and Glen, B. 2015. Cows on corn need attention. The Western Producer [Online]. Available: http://www.producer.com/2015/01/cows-on-corn-need-attention/ [2016 May 14].

Lardner, B. and Larson, K. 2011. Swath grazing CDC SO-1 oat and red proso millet with beef cows. Western Beef Development Centre fact sheet #2011-03.1 [Online]. Available: http://www1.foragebeef.ca/$Foragebeef/frgebeef.nsf/all/frg1/$FILE/swathgrazecdcoat.pdf [2018 Jan 02].

Lardner, B., Larson, K., and Pearce, L. 2012. Winter grazing beef cows with standing corn. WBDC Fact Sheet#2012-0.3. Western Beef Development Centre, Lanigan, SK, Canada.

Larson, K. 2013. 2012 Saskatchewan cow-calf cost of production analysis. Western Beef Development Centre fact sheet #2013–02 [Online]. Available: http://www.wbdc.sk.ca/pdfs/fact_sheets/2013/2013-02%202012%20SK%20cow-calf%20Cost%20of%20Production%20Analysis.pdf [2018 Jan 02].

Legesse, G., Small, J.A., Scott, S.L., Kebreab, E., Crow, G.H., Block, H.C., Robins, C.D., Khakbazan, H., and McCaughey, P.W. 2011. Bioperformance evaluation of various pasture and winter feeding strategies for cow-calf production. Canadian Journal of Animal Science. **92**: 89-102.

Livestock Marketers of Saskatchewan. 2018. Industry facts: Careers in the cattle sector [Online]. Available: https://beefcareers.ca/industry-facts/ [2018 Jan 02].

Loeppky, H.A., Bittman, S., Hiltz, M.R., and Frick, B. 1996. Seasonal changes in yield and nutritional quality of cicer milkvetch and alfalfa in northeastern Saskatchewan. Canadian Journal of Plant Science. **76**: 441-446.

Lunn, D. 2006. Improving feed efficiency in feedlot cattle. Nutrifax: nutrition news and information update (Shur-Gain) [Online]. Available: http://www.nutrecocanada.com/docs/shur-gain---beef/improving-feed-efficiency-in-feedlot-cattle.pdf [2018 Jan 12].

MA. 2008. Winter grazing options [Online]. Available: https://www.gov.mb.ca/agriculture/crops/production/forages/pubs/winter_grazing_options.pdf [2017 April 09].

MA. 2015. Guidelines for estimating beef cow-calf production costs in Manitoba [Online]. Available: https://www.gov.mb.ca/agriculture/business-and-economics/financial-management/pubs/cop_beef_cowcalf.pdf [2018 June 28].

MA. 2016. Agricultural climate of Manitoba [Online]. Available: https://www.gov.mb.ca/agriculture/weather/agricultural-climate-of-mb.html [2016 May 14].

MA. 2017. Guidelines for estimating beef feedlot finishing costs in Manitoba [Online]. Available: https://www.gov.mb.ca/agriculture/business-and-economics/financial-management/pubs/cop-beef-feedlotfinishing.pdf [2018 June 28].

Mathis, C.P and Sawyer, J.E. 2007. Nutritional management of grazing beef cows. Veterinarian Clinics Food Animal Practice. **23**: 1-19.

McCartney, D. 2017. Extended grazing. Beef Cattle Research Council [Online]. Available: http://www.beefresearch.ca/research-topic.cfm/extended-grazing-45#bale [2018 Jan 12].

McCartney, D. 2016. Extended grazing. Beef Cattle Research Council [Online]. Available: http://www.beefresearch.ca/research-topic.cfm/extended-grazing-45 [2016 May 14].

McCartney, D. and Fraser, J. 2010. The potential role of annual forage legumes in Canada: a review. Canadian Journal of Plant Science. **90**: 403-420.

McCartney, D., Basarab, J.A., Okine, E.K., Baron, V.S., and Depalme, A.J. 2004a. Alternative fall and winter feeding systems for spring calving beef cows. Canadian Journal of Animal Science. **84**: 511-522.

McCartney, D., Townley-Smith, L., Vaage, A., and Pearen, J. 2004b. Cropping systems for annual forage production in northeast Saskatchewan. Canadian Journal of Plant Science. **84**: 187-194.

McCartney, D., Fraser, J., and Ohama, A. 2008. Annual cool season crops for grazing by beef cattle: a Canadian review. Canadian Journal of Animal Science. **88**: 517-533.

McCartney, D., Fraser, J., and Ohama, A. 2009. Potential of warm-season annual forages and *Brassica* crops for grazing: A Canadian review. Canadian Journal of Animal Science. **89**: 431-440.

McCaughey, P. 2009. AC Killarney orchardgrass. Technical bulletin [Online]. Available: https://www.brettyoung.ca/sites/default/files/atoms/files/AC%20Killarney%20Nov%202009.pdf [2016 May 14].

McDonald, P., Edwards, R.A., Greenhalgh, J.F.D, and Morgan, C.A. 2002. Animal nutrition. 6th ed. Pearson Education Ltd., Gosport, England. 693 pp.

McKinnon, J. 2016. Dietary energy levels for backgrounding calves. Canadian Cattlemen Magazine [Online]. Available: https://www.canadiancattlemen.ca/2016/01/04/dietary-energy-levels-for-backgrounding-calves/ [2018 Jan 02].

McLelland, M. and Brook, H. 1999. Seeding fall rye. Alberta Agriculture and Forestry [Online]. Available: http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex4455 [2016 May 14].

Mills, G.F. and Haluschak, P. 1993. Soils of the Carman Research Station. Special report series No. 93-1 Manitoba Soil Survey Unit and Manitoba Land Resource Unit. Agriculture Canada, Manitoba Department of Agriculture, and Department of Soil Science, University of Manitoba [Online]. Available: http://www.manitoba.ca/agriculture/land/soil-survey/pubs/fss02s00931.pdf [2018 April 30].

Moore, K.J., Moser, L.E., Vogel, K.P., Waller, S.S., Johnson, B.E., and Pedersen., J.F. 1991. Describing and quantifying growth stages of perennial forage grasses. Agronomy and Horticulture - Faculty Publications, University of Nebraska. Paper 507.

Nagaraja, T.G. and Titgemeyer, E.C. 2006. Ruminal acidosis in beef cattle: the current microbiological and nutritional outlook. Journal of Dairy Science. **90**: 17-38.

Najda, H. and Yoder, C. 2005. Tall fescue seed production in western Canada. Agrifacts: Practical Information for Alberta's Agricultural Industry [Online]. Available: http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex9860/$file/127_15-3.pdf?OpenElement [2018 Jan 02].

National Beef Research Strategy. 2012. Beef Cattle Research Council – National Beef Value Chain Roundtable.

Nelson, C.J. and Burns, J.C. 2006. Fifty years of grassland science leading to change. Crop Science. **46**: 2204-2217.

NRC, 2016. Nutrient requirements of beef cattle. (8th Ed.). National Academy Press, Washington, D.C.

Parish, J. and Rhinehart, J. 2008. Mineral and vitamin nutrition for beef cattle [Online]. Available: http://www.thebeefsite.com/articles/1549/mineral-and-vitamin-nutrition-for-beef-cattle/ [2018 Jan 02].

Pedersen, P. 2008. Soybean growth and development. Iowa State University Soybean Extension and Research Program. Iowa State University Extension.

Peel, D.S. 2003. Beef cattle growing and backgrounding programs. The Veterinary Clinics: Food and Animal Practice. **19**: 365-385.

Peng, X. 2017. Potential of stockpiled annual and perennial forage species for fall and winter grazing in the Canadian Great Plains Region. M.Sc. thesis, University of Saskatchewan, Saskatoon, SK. 130 pp.

Penner, G. Block, H., Beattie, A, McKinnon, J., and Lardner, B. 2015. Effect of maturity at cutting for forages used in swath grazing or green feed systems: optimizing the yield of digestible nutrients. Final Report for the Agriculture Development Fund Project 20100175. Saskatchewan Ministry of Agriculture.

Podolsky, G. 1982. Soils of the Arborg-Riverton area. Soils report No. D46 Canada-Manitoba soil survey. Agriculture Canada, Manitoba Department of Agriculture, and Department of Soil Science, University of Manitoba [Online]. Available: http://sis.agr.gc.ca/cansis/publications/surveys/mb/mbd46/mbd46_report.pdf [2018 April 30].

Prescott, M.L., Havstad, K.M., Olson-Rutz, K.M., Ayers, E.L., and Petersen, M.K. 1994. Grazing behaviour of free-ranging beef cows to initial and prolonged exposure to fluctuating thermal environments. Applied Animal Behaviour Science. **39**: 103 -113.

Saskatchewan Forage Council. 2011. An economic assessment of feed costs within the cow/calf sector. Western Canadian Feed Innovation Network [Online]. Available: http://www.saskforage.ca/images/pdfs/Projects/Feed%20Costs/Cow-calf_Feed_Cost_Analysis-Final_Sept_2011.pdf [2018 March 13].

Seed Manitoba. 2015. Variety selection and growers source guide (December 2014). Manitoba Seed Growers' Association, Manitoba Agriculture, Food, and Rural Development, and the Manitoba Co-operator [Online]. Available: www.seedmb.ca [2016 May 14].

Seed Manitoba. 2016. Variety selection and growers source guide (December 2015). Manitoba Seed Growers' Association, Manitoba Agriculture, Food, and Rural Development, and the Manitoba Co-operator [Online]. Available: www.seedmb.ca [2016 May 14].

Sheppard, S.C., Bittman, S., Donohoe, G., Flaten, D., Wittenburg, K.M., Small, J.A., Berthiaume, R., McAllister, T.A., Beauchemin, K.A., McKinnon, J., Amiro, B.D. MacDonald, D., Mattos, F., and Ominski, K.H. 2015. Beef cattle husbandry practices across Ecoregions in Canada in 2011. Canadian Journal of Animal Science. **95**: 305-321.

Smith, S. R., Jr., Bouton J. H. and Hoveland, C. S. 1992. Persistence of alfalfa under continuous grazing in pure stands and in mixtures with tall fescue. Crop Sci. **32**: 1259–1264.

Statistics Canada. 2011. Cattle industry overview. Statistics Canada [Online]. Available: http://www.statcan.gc.ca/pub/23-012-x/2010002/part-partie1-eng.htm [2018 Jan 02]

Statistics Canada. 2016. Census of agriculture, land use Table 004-0203 [Online]. Available: http://www5.statcan.gc.ca/cansim/a47 [2018 June 28].

Statistics Canada. 2018. Cattle inventories, by province (Manitoba). Statistics Canada [Online]. Available: http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/prim50h-eng.htm [2018 Mar 02].

Strydhorst, S.M., King, J.R., Lopetinsky, K.J., and Harker, K.N. 2008. Forage potential of intercropping barley with faba bean, lupin, or field pea. Agronomy Journal. **100**: 182-190.

The Weather Network. 2017. Farmzone: St-Félicien - Dolbeau - Normandin, Quebec [Online]. Available: www.farmzone.com [2017 Dec 01].

Thompson, D. J. 2013. Yield and nutritive value of irrigated tall fescue compared with orchardgrass: in monocultures or mixed with alfalfa. Canadian Journal of Plant Science. **93**: 799-807.

USDA. 2010. United States Department of Agriculture Economic Research Service: commodity cost and returns [Online]. Available: https://www.ers.usda.gov/data-products/commodity-costs-and-returns/ commodity-costs-and-returns/#Historical Costs and Returns: Cow-Calf [2018 March 13].

Villalobos, L.A. 2015. Annual cool-season forage systems for fall grazing by cattle. Ph. D. thesis, Colorado State University, Fort Collins, CO. 24 pp.

Volesky, J.D., Adams, D.C., and Clark, R.T. 2002. Windrow grazing and baled-hay feeding strategies for wintering calves. Journal of Range Management. **55**: 23.

Western Beef Development Centre (WBDC). 2015. Western Canadian cow-calf survey: aggregate results [Online]. Available: http://www.wbdc.sk.ca/pdfs/economics/WCCCS_Summary_Overall_Jun2015.pdf [2016 May 14].

Yaremcio, B. 1991. Nitrate poisoning and feeding nitrate feeds to livestock. Agrifacts: Practical Information for Alberta's Agricultural Industry [Online]. Available: http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex851/$file/0006001.pdf?OpenElement [2018 Jan 02].

Yoshihara, Y., Mizuno, H., Ogura, S., Sasaki, T., and Sato, S. 2013. Increasing the number of plant species in a pasture improves the mineral balance of grazing beef cattle. Animal Feed Science. **179**: 138-143.

Zadoks, J.C., Chang, T.T., and Konzak, C.F. 1974. A decimal code for the growth stages of cereals. Weed Research. **14**: 415-421.

7. APPENDIX

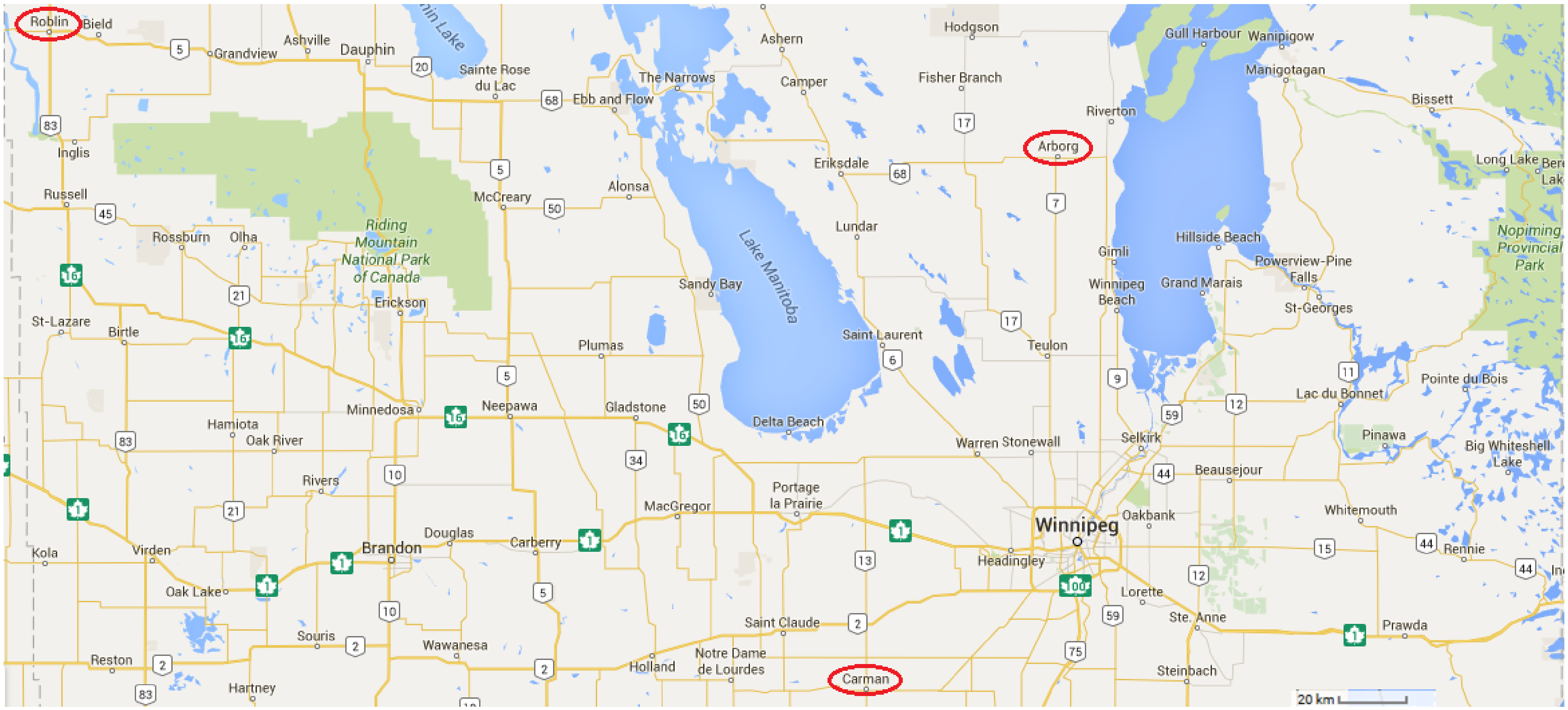

Figure A1. Map acquired from Google© Maps of southern and central Manitoba. The three field sites Arborg, Carman, and Roblin for the forage evaluation project are circled in red on the map.

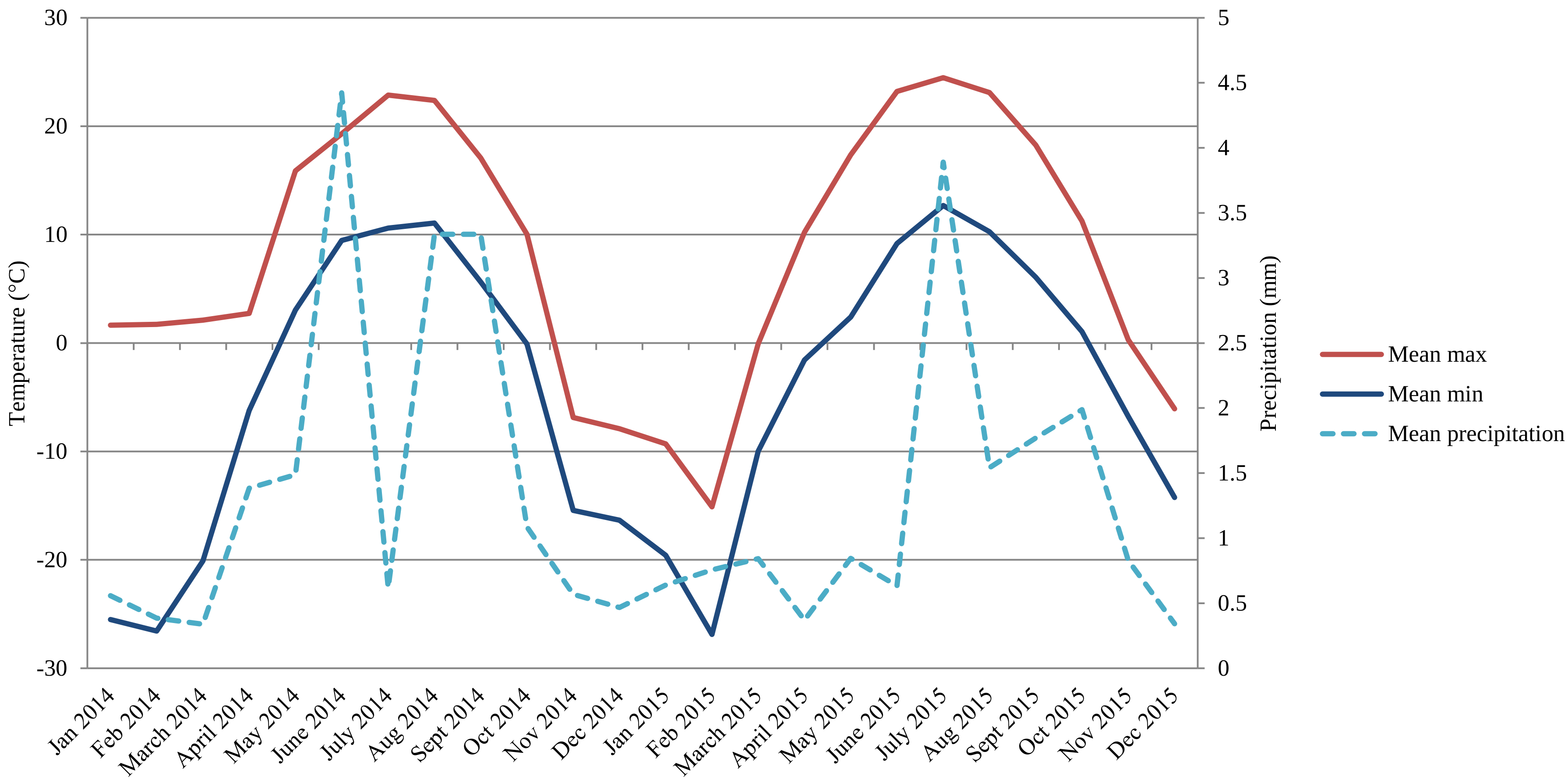

Figure A2. Mean monthly maximum temperatures, minimum temperatures, and daily precipitation at Roblin from June 2014 until December 2015 (study period). Mean maximum and minimum temperatures are on the primary y-axis and mean precipitation is on the secondary y-axis.

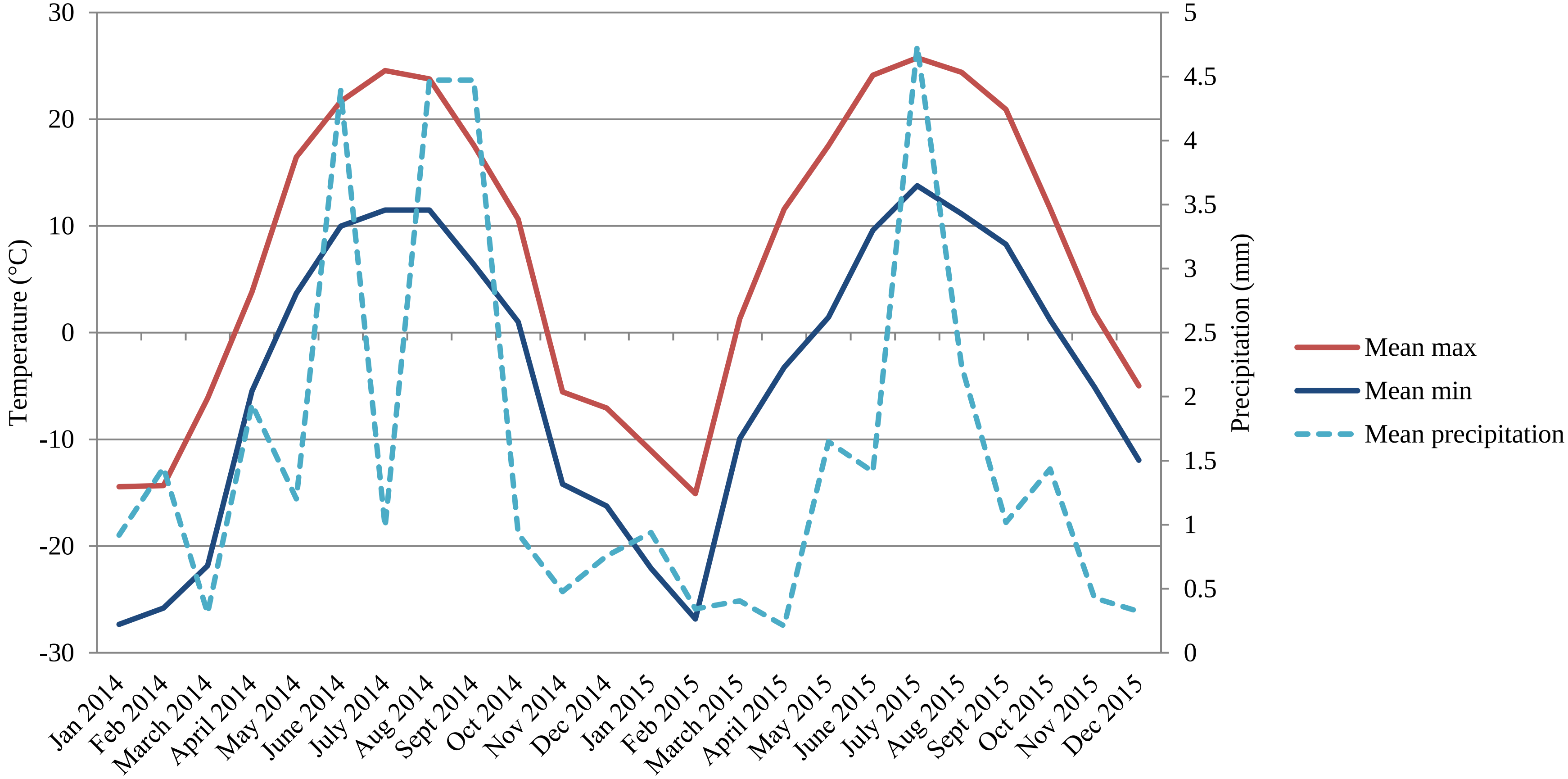

Figure A3. Mean monthly maximum temperatures, minimum temperatures, and daily precipitation at Arborg from June 2014 until December 2015 (study period). Mean maximum and minimum temperatures are on the primary y-axis and mean precipitation is on the secondary y-axis.

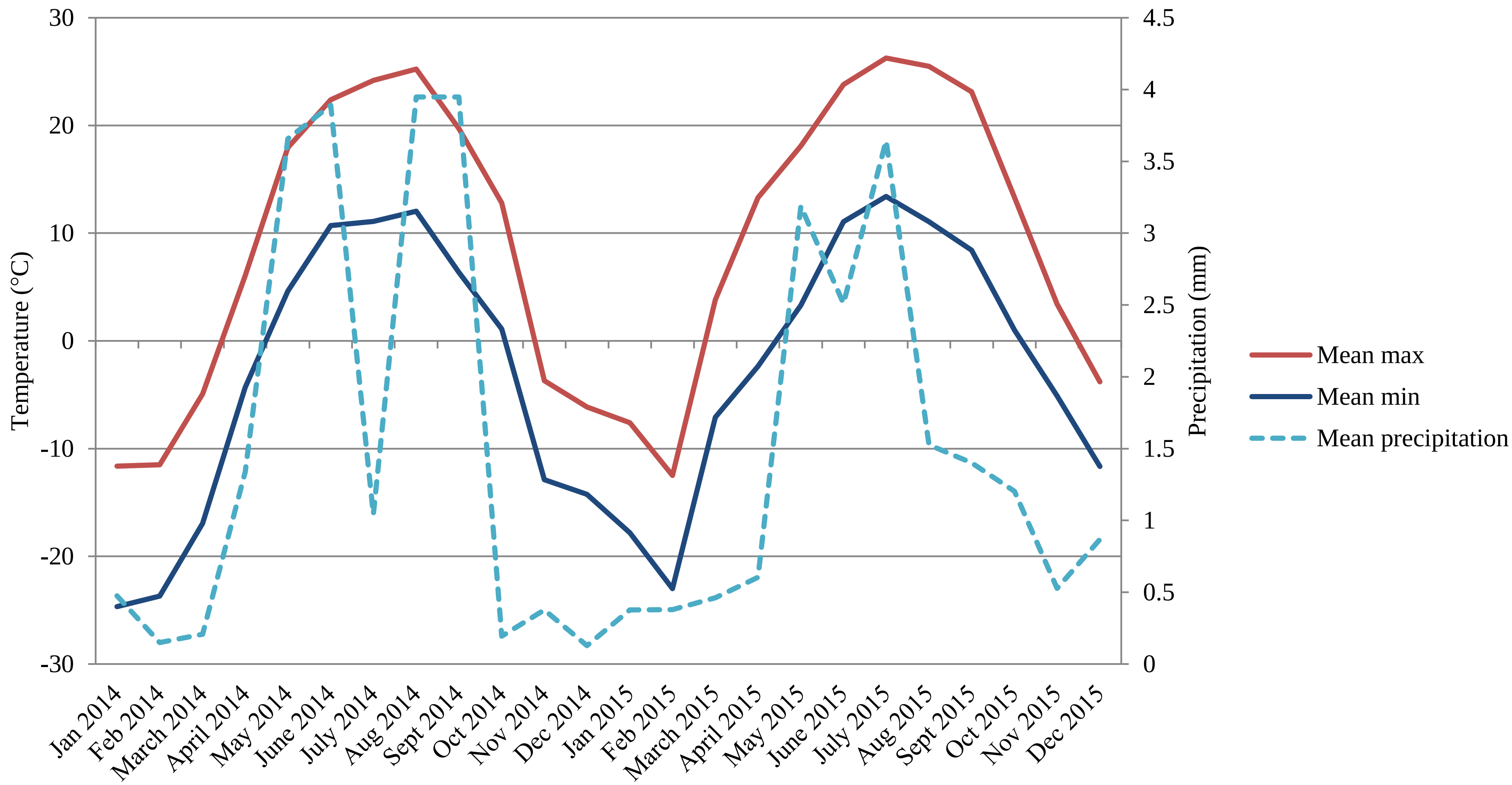

Figure A4. Mean monthly maximum temperatures, minimum temperatures, and daily precipitation at Carman from June 2014 until December 2015 (study period). Mean maximum and minimum temperatures are on the primary y-axis and mean precipitation is on the secondary y-axis.

Table A1. Average mineral content for the 5 site-years at timepoints 1, 2, and 3. No statistics were carried out on these values. All values are reported on a DM basis.

Site	Mineral	Treatment	TP1	TP2	TP3
Roblin 2014	P (g kg^{-1})	Oat	2.8	2.4	2.5
		Fall rye	3.9	4.4	4.5
		Barley	2.7	2.6	3.0
		Westerwold ryegrass	2.9	3	2.2
		Foxtail millet	2.4	2.9	2.5
		Corn	2.5	2.5	2.8
		Soybean	1.4	3.2	4.1
	K (g kg^{-1})	Oat	30.7	20.8	16.1
		Fall rye	38.6	36.1	25.7
		Barley	25.4	12.6	6.8
		Westerwold ryegrass	28.9	24.1	17.0
		Foxtail millet	32.7	30.8	17.9
		Corn	26.5	17.3	11.9
		Soybean	11.9	27.1	20.9
Arborg 2014	P (g kg^{-1})	Oat	1.8	1.9	1.9
		Fall rye	2.6	3.4	3.9
		Barley	2.0	2.2	2.2
		Westerwold ryegrass	2.2	3.1	2.5
		Foxtail millet	4.5	1.6	1.5
		Corn	1.9	1.3	1.6
		Soybean	2.2	2.5	2.8
	K (g kg^{-1})	Oat	30.0	18.4	15.5
		Fall rye	43.0	22.8	16.7
		Barley	16.4	10.6	7.6
		Westerwold ryegrass	29.9	24.5	19.3
		Foxtail millet	29.1	23.1	17.3
		Corn	24.4	10.2	9.3
		Soybean	17.2	15.6	17.8
Roblin 2015	P (g kg^{-1})	Oat	2.4	2.1	2.3
		Fall rye	4.5	4.0	4.3
		Barley	2.5	2.9	2.7
		Westerwold ryegrass	3.5	2.4	2.2
		Foxtail millet	2.8	2.0	1.7
		Corn	2.9	2.1	1.9
		Soybean	3.3	2.9	2.3

Site	Mineral	Treatment	TP1	TP2	TP3
Roblin 2015	K (g kg^{-1})	Oat	19.8	15.3	9.8
		Fall rye	58.7	45.7	25.0
		Barley	17.8	13.1	7.8
		Westerwold ryegrass	29.3	28.3	20.5
		Foxtail millet	60.4	44.2	24
		Corn	29.7	15.5	11.0
		Soybean	30.1	27.5	20.5
Arborg 2015	P (g kg^{-1})	Oat	2.7	2.2	2.3
		Fall rye	3.8	3.9	3.8
		Barley	2.8	2.5	2.7
		Westerwold ryegrass	2.6	2.8	2.0
		Foxtail millet	1.8	1.8	1.5
		Corn	2.9	2.5	1.9
		Soybean	3.6	3.7	3.3
	K (g kg^{-1})	Oat	37.2	21.1	19.7
		Fall rye	58.4	44.0	34.3
		Barley	31.5	15.5	16.6
		Westerwold ryegrass	31.8	32.6	22.7
		Foxtail millet	63.0	44.8	25.3
		Corn	41.8	16.9	11.0
		Soybean	29.1	28.6	20.7
Carman 2015	P (g kg^{-1})	Oat	2.7	2.8	2.5
		Fall rye	3.9	4.0	3.7
		Barley	2.6	3.1	3.0
		Westerwold ryegrass	3.7	2.8	2.3
		Foxtail millet	2.3	2.1	2.0
		Corn	2.3	2.1	2.0
		Soybean	3.3	2.9	2.7
	K (g kg^{-1})	Oat	30.2	23.8	17.2
		Fall rye	47.4	34.1	33.4
		Barley	17.5	14.8	8.0
		Westerwold ryegrass	34.5	27.0	24.7
		Foxtail millet	47.1	23.3	17.3
		Corn	21.0	17.4	9.6
		Soybean	33.9	30.5	23.2

Harvest dates TP1, TP2, and TP3, respectively: Roblin 2014: 05/08/14. 01/09/14. 01/10/14; Arborg 2014: 06/08/14, 02/09/14, 02/10/14; Roblin 2015: 04/08/15, 01/09/15, 01/10/15; Arborg 2015: 04/08/15, 02/09/15, 02/10/15; 15/10/15; and Carman 2015: 06/08/15, 03/09/15, 02/10/15. Note there is only one sample to represent soybean at Roblin 2014 for TP3.

Table A2. Precipitation and growing degree days at Roblin, Arborg, and Carman in 2014 and 2015. Precipitation and Growing Degree Days (GDD) was reported from Seed Manitoba (2015, 2016) from May 1st to October 4th 2014 and 2015. Normal accumulations were calculated using the long-term average for the past 30 years. Crop Heat Units (CHU) were reported from The Weather Network © for the same time ranges.

		Precipitation		Growing degree days		
Year	Site	Actual (mm)	% of normal	Actual	% of normal	Crop Heat Units (CHU)
2014	Roblin	328	106	1230	90	2159
	Arborg	362	121	1370	99	2107
	Carman	345	115	1480	94	2625
2015	Roblin	272	78	1521	105	2348
	Arborg	342	104	1670	113	1940
	Carman	376	113	1772	105	2905

Table A3. Tetany ratios for Arborg for June 26 – 30, August 5, and October 16, 2015. Mineral values were acquired from tables 3, 10, 28, 29, and 31. Tetany ratios were calculated using MA conversion methods. The ratios are expressed as K/(Ca+Mg) in milliequivalents (mEq) kg^{-1} of dry matter. Ratios exceeding MA recommendations (greater than 2.2) are bolded.

	June 26 – 30		August 5	October 16	
Forage treatment	Early stockpile	Late stockpile	Late stockpile	Early stockpile	Late stockpile
Killarney Orchardgrass	1.88	1.96	**2.27**	0.87	0.84
Courtenay Tall Fescue	1.52	1.44	1.38	0.88	0.73
Success Hybrid Brome	1.80	1.66	2.02	0.86	0.65
Fleet Meadow Brome	1.69	1.61	1.93	0.84	0.67
Armada Meadow Brome	1.81	1.71	2.19	0.84	0.70
Algonquin Alfalfa	0.48	0.46	0.61	0.35	0.64
Yellowhead Alfalfa	0.41	0.36	0.52	0.31	0.38
Oxley II Cicer Milkvetch	0.87	n/a	0.57	0.48	0.55
Killarney + Algonquin	0.83	0.82	0.76	0.40	0.67
Killarney + Yellowhead	0.99	0.64	0.52	0.46	0.50
Killarney + Oxley II	1.78	1.30	0.87	0.62	0.46
Courtenay + Algonquin	0.90	0.86	0.55	0.40	0.63
Courtenay + Yellowhead	0.78	0.79	0.78	0.69	0.49
Courtenay + Oxley II	1.33	1.22	0.76	0.67	0.46
Success + Algonquin	1.01	0.77	0.68	0.36	0.61
Success + Yellowhead	0.75	0.87	0.61	0.40	0.47
Success + Oxley II	1.88	1.62	1.25	0.50	0.54
Fleet + Algonquin	1.11	0.87	0.63	0.38	0.60
Fleet + Yellowhead	0.83	0.93	0.60	0.54	0.56
Fleet + Oxley II	1.57	1.52	1.35	0.60	0.48
Armada + Algonquin	1.04	1.19	0.70	0.49	0.67
Armada + Yellowhead	1.11	0.68	0.77	0.54	0.53
Armada + Oxley II	1.60	1.87	1.03	0.48	0.50

Table A4. Tetany ratios for Carman for June 15 – 17, July 21, and October 13 – 14, 2015. Mineral values were acquired from tables 6, 10, 28, 29, and 31. Tetany ratios were calculated using MA conversion methods. The ratios are expressed as K/(Ca+Mg) in milliequivalents (mEq) per kg of dry matter. Ratios exceeding MA recommendations (greater than 2.2) are bolded.

	June 15 – 17		July 21	October 13 – 14	
Forage treatment	Early stockpile	Late stockpile	Late stockpile	Early stockpile	Late stockpile
Killarney Orchardgrass	**3.62**	**3.52**	**4.34**	1.56	1.44
Courtenay Tall Fescue	2.20	**2.47**	**3.02**	1.83	1.92
Success Hybrid Brome	**3.18**	**2.90**	**3.75**	1.19	1.26
Fleet Meadow Brome	**2.80**	**3.42**	**4.86**	1.41	1.59
Armada Meadow Brome	**3.33**	**3.35**	**5.14**	1.51	1.65
Algonquin Alfalfa	1.15	1.13	1.35	0.56	0.66
Yellowhead Alfalfa	1.12	1.06	1.31	0.77	0.64
Oxley II Cicer Milkvetch	1.71	2.06	2.05	0.65	0.83
Killarney + Algonquin	1.70	1.49	1.46	0.96	1.06
Killarney + Yellowhead	**2.28**	1.88	1.56	1.00	1.24
Killarney + Oxley II	**2.60**	**2.64**	**3.25**	1.01	1.42
Courtenay + Algonquin	1.43	1.45	1.54	1.18	1.42
Courtenay + Yellowhead	1.32	1.70	1.74	1.38	1.67
Courtenay + Oxley II	2.17	**2.25**	**2.61**	1.22	1.71
Success + Algonquin	1.28	1.67	1.62	0.79	0.92
Success + Yellowhead	1.43	1.45	1.51	0.86	0.84
Success + Oxley II	**2.43**	**2.49**	**2.55**	0.98	0.86
Fleet + Algonquin	1.58	1.84	1.43	0.79	1.12
Fleet + Yellowhead	2.13	1.99	2.11	1.03	1.28
Fleet + Oxley II	**3.05**	**2.94**	**2.53**	0.92	1.45
Armada + Algonquin	1.74	2.12	1.50	0.96	1.07
Armada + Yellowhead	1.93	**2.29**	1.96	1.14	1.41
Armada + Oxley II	**2.75**	**3.51**	**2.55**	0.99	1.27

Table A5. Day 70 plant counts for Arborg and Carman perennials on August 14, 2014 and September 18 – 22, 2014, respectively.

	Arborg 2014				Carman 2014			
Forage treatment	Grass		Legume		Grass		Legume	
	Plants $m^{2\ -1}$	Plants ha^{-1}	Plants $m^{2\ -1}$	Plants ha^{-1}	Plants $m^{2\ -1}$	Plants ha^{-1}	Plants $m^{2\ -1}$	Plants ha^{-1}
Killarney Orchardgrass	39	390 000	-	-	247	2 470 000	-	-
Courtenay Tall Fescue	67	670 000	-	-	320	3 200 000	-	-
Success Hybrid Brome	50	500 000	-	-	60	600 000	-	-
Fleet Meadow Brome	123	1 230 000	-	-	257	2 570 000	-	-
Armada Meadow Brome	160	1 600 000	-	-	219	2 190 000	-	-
Algonquin Alfalfa	-	-	25	250 000	-	-	221	2 210 000
Yellowhead Alfalfa	-	-	19	190 000	-	-	143	1 430 000
Oxley II Cicer Milkvetch	-	-	19	190 000	-	-	80	800 000
Killarney + Algonquin	25	250 000	14	140 000	161	1 610 000	96	960 000
Killarney + Yellowhead	29	290 000	16	160 000	179	1 790 000	78	780 000
Killarney + Oxley II	21	210 000	8	80 000	205	2 050 000	54	540 000
Courtenay + Algonquin	46	460 000	10	100 000	125	1 250 000	97	970 000
Courtenay + Yellowhead	40	400 000	11	110 000	137	1 370 000	67	670 000
Courtenay + Oxley II	38	380 000	7	70 000	177	1 770 000	53	530 000
Success + Algonquin	22	220 000	10	100 000	33	330 000	68	680 000
Success + Yellowhead	23	230 000	16	160 000	35	350 000	72	720 000
Success + Oxley II	18	180 000	9	90 000	29	290 000	36	360 000
Fleet + Algonquin	51	510 000	17	170 000	88	880 000	83	830 000
Fleet + Yellowhead	82	820 000	23	230 000	101	1 010 000	68	680 000
Fleet + Oxley II	71	710 000	7	70 000	112	1 120 000	46	460 000
Armada + Algonquin	75	750 000	16	160 000	113	1 130 000	81	810 000
Armada + Yellowhead	80	800 000	15	150 000	119	1 190 000	73	730 000
Armada + Oxley II	80	800 000	8	80 000	92	920 000	33	330 000

Table A6. Germination tests of forage seeds for annual and perennial trials in late April, 2015.

Forage treatment	Percent germination (%)
Killarney Orchardgrass	34
Courtenay Tall Fescue	92
Success Hybrid Brome	34
Fleet Meadow Brome	87
Armada Meadow Brome	93
Algonquin Alfalfa	70
Yellowhead Alfalfa	65
Oxley II Cicer Milkvetch	52
Haymaker Oats	97
Hazlet Fall Rye	89
Maverick Barley	100
Aubade Westerwold	88
Golden German Foxtail Millet	89
Fusion Corn	100
Mammoth Soybean	81

Seeds were placed in a petri dish for four weeks and number of germinated seeds were counted every seven days. Percent germination rates were calculated.

Table A7. Mineral requirements in g kg^{-1} for mid gestating cows and maximum tolerable concentrations derived from NRC (2016).

Mineral	Requirement	Maximum Tolerance
Ca*	1.7	44
Mg	1	4
P*	1.4	**
K	6	30

*dependent on cow body weight

**deficiency is more of a concern for phosphorus requirements. Excess can be metabolized by microbes in the rumen

Nutritional Analysis Calculations:

Relative Feed Value
RFV = (DDM * DMI)/100
Where:
DDM = digestible dry matter
DMI = dry matter intake

Digestible Energy
DE (kcal/kg) = GE – FE
Where:
GE = gross energy
FE = fecal energy

Metabolizable Energy
ME (kcal/kg) = (GE – FE – UE)/kg of food consumed
Where:
GE = gross energy
FE = fecal energy
UE = urinary energy

Total Digestible Nutrients (for forages)
$TDN = 0.98*(100\text{-}NDFn\text{-}CP\text{-}ash\text{-}EE) + e^{-0.012*ADIN} *CP + 2.25*(EE\text{-}1) + 0.75*(NDFn\text{-}Lig)*[1\text{-}(lig/NDF)^{.667}] – 7$
Where:
Neutral detergent fiber nitrogen-free (NDFn) = NDF-NDICP (%DM)
Neutral detergent insoluble crude protein (NDICP) = Neutral detergent insoluble nitrogen (NDIN) * 6.25
ADIN is expressed as a percent of total nitrogen (ADIN/N*100).