Seasonal forage dry matter production and quality of 29 dryland grasses in Montana

by Kurtis Russell Blunt

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Animal and Range Science
Montana State University

Abstract:
Producers must have accurate and reliable measurements of both forage production and quality in their pastures. Previous studies with dryland grasses in Montana have mostly been limited to adaptation or yield performance of a few species at a single location.

The first objective of this study was to document yield and forage quality characteristics of adapted dryland grass varieties over a three-year period at three separate locations. Another objective was to accurately predict forage quality constituents of numerous dryland forage grasses using near infrared spectroscopy (NIRS). A third objective was to generate predictive models for crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), and in vitro digestible dry matter (IVDDM) using date or growing degree days. And finally, the last objective of this study was to demonstrate how forage quality information generated in this study can be useful for future improvement of animal carrying capacity predictions.

Twenty-nine dryland grass varieties were established at three Montana locations. Data were collected over a three-year period. Forage production and quality data were gathered under a wide range of climatic conditions. Interactions among years, varieties, and locations illustrated the variability of the climate in Montana and biological differences of varieties at different locations.

This study makes a strong case for the use of NIRS technology in estimating forage quality of dryland grasses in Montana. Compared to traditional wet chemistry procedures, NIRS proved to be much faster and generated accurate results.

Predictive models using date and growing degree days generated estimates of forage quality similar to NIRS but standard errors associated with model parameters limited statistical differences among varieties for season-long forage quality. However, it was determined that the rates of forage quality decline among many of the varieties studied were different ($P < 0.01$). The r^2 values for predicted forage quality ranged from 0.39 (Rosana, ADF) to 0.85 (Schwendimar, ADF) for the AGGD models and all were highly significant.

Strong negative correlations between yield and quality were not found in this study ($-0.3<0.3$). ADF and NDF were highly correlated ($r>0.79$). It appears that with optimal management, both forage production and quality can be. optimized.

Preliminary use of this data suggests that energy becomes limiting first as the growing season progresses, followed by intake and protein. Further studies should be devoted to modeling pasture carrying capacity with forage quality data.

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Master of Science

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Montana State University
Bozeman, Montana

June 2001

APPROVAL

of a thesis submitted by

Kurtis Russell Blunt

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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Date July 14, 2001

ACKNOWLEDGEMENTS

Foremost, I would like to thank my graduate advisor, Dr. Dennis Cash, for the advice, patience, and guidance he provided during the course of this program. I would also like to thank Dr. Jan Bowman, Dr. Bok Sowell, Dr. Clayton Marlow, and Dave Wichman for serving on my graduate committee. Special thanks to Larry Holzworth, Mark Majerus, Connie Reynolds, and Dave Wichman for their assistance in creating and maintaining this project. Additionally I would like to thank Dr. Ray Ditterline and Dr. Andrew Lenssen for their input, support, time, and assistance in the analysis and review of my work on this project. A special thank you to the Montana State University – Foundation Seed Program for providing the funding and assistance that made this project possible. Finally I would like to thank my parents, Ken and Karen, for instilling in me the work ethic, determination, and integrity that was required to complete this project.

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The first objective of this study was to document yield and forage quality characteristics of adapted dryland grass varieties over a three-year period at three separate locations. Another objective was to accurately predict forage quality constituents of numerous dryland forage grasses using near infrared spectroscopy (NIRS). A third objective was to generate predictive models for crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), and *in vitro* digestible dry matter (IVDDM) using date or growing degree days. And finally, the last objective of this study was to demonstrate how forage quality information generated in this study can be useful for future improvement of animal carrying capacity predictions.

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CHAPTER 1

INTRODUCTION

Livestock producers are responsible for about half of the two billion dollars generated annually by Montana agriculture. Range, pasture, and harvested forages comprise about two-thirds of Montana's land base. Most livestock graze native range and/or improved pastures in Montana, utilizing about 40 million of the total 93 million acres in the state. As input costs for raising livestock increase, producers are looking for ways to stretch their forage base and maximize available nutrients, particularly producers maintaining dryland pastures. With an improved knowledge of level of production and standing forage quality, producers can better evaluate their forage base during and after the growing season to potentially reduce their cost of supplementation and winter feed costs. Even slight improvements in forage quality or grazing efficiency could result in significant economic benefits for producers and communities.

Taken literally, forage quality is most often measured by livestock performance. Certain concentrations of nutrients and cell contents have been proven to produce desired livestock responses. These responses can be measured in terms of maintenance, gain, and reproductive success. Crude protein, acid detergent fiber, neutral detergent fiber, and in vitro digestible dry matter concentrations are the most commonly measured forage quality constituents used to predict animal performance. Presently, laboratory wet chemistry analyses are the predominant methods of analyzing these constituents. Even though many producers routinely test their hay base for forage quality very few have any estimate of their standing forage quality. This can limit livestock performance because dryland pastures are often the major forage source for producers. Consequently, there is a high demand for fast, accurate and economical analyses of standing forages, using scientifically accepted methods that accurately predict livestock response. While researchers continue to develop new technology, improvements that accelerate the process and allow more producers to have a better knowledge of their dryland forage base are sorely needed.

Most of the current information dealing with forage production and quality of dryland forage grasses in Montana is generated by the Montana Agricultural Experiment Station (MAES) research centers. Forage yield trials often encompass a relatively small number of species or varieties available due to limited resources and staff. The information generated is published in station reports, but the results are generally site specific as only one station has conducted the evaluation. Thus, adaptation and yield trials are usually useful only for local producers to estimate potential production. Even with this realization there have been few studies to evaluate phenological and nutritional components of dryland forage grasses in Montana across several locations and years with standardized methodology.

Forage grass production on range or in non-irrigated improved pastures is directly related to the amount of moisture and nutrients available to the plants and individual species or varietal adaptations to environmental stress. Adequate precipitation during the months of April, May and June are critical for maximum forage production. Time of harvest or grazing and the age of stands also affect production. Phenological stage of maturity is highly correlated to dry matter production with maximum production for most species occurring during the period between boot and anthesis. Production of dry matter decreases substantially beyond anthesis as resources are diverted from vegetative production to reproductive structures and the development of the seeds themselves. Maximum dry matter production for dryland grasses also generally begin to decline after the second and third years after establishment.

The forage quality constituents of dryland grasses are affected by many of the same factors that determine dry matter production. Phenology, available nutrients, regrowth and species or varietal differences affect the livestock response generated from forage grasses throughout the growing season and beyond. In general, grasses are most digestible when they are in the vegetative stage when leaf:stem ratios are the highest. As forage plants mature, the leaf:stem ratio decreases with the shift from vegetative production to reproductive structures. Digestible and indigestible fiber constituents replace soluble cell contents as plants become more mature reducing the concentrations of nutrients and energy. High fiber levels reduce the ability of livestock to process the forage, which in turn reduces intake.

Potential for dry matter production and forage quality is highly variable among grass species depending on time of harvest or grazing, and the phenology of the plant at harvest. Species and individual cultivars have been developed to offer producers more choices to supplement or improve their existing forage base.

The use of near infrared reflectance spectroscopy has gained scientific credibility and acceptance since the 1970's when Norris et al. (1976) first used it to predict forage quality constituents. The technique involves the bombardment of specific bands of near infrared light wavelengths into a ground forage sample. These specific wavelengths are reflected by chemical bonds associated with individual forage quality constituents, and the concentration of each constituent in the sample can be determined. Advancements and improvements in the hardware and software have reduced sample analysis time and expense, and increased the accuracy of predicted concentrations of forage quality constituents in analyzed samples.

The objectives of this project were to document yield and forage quality characteristics of adapted dryland grass varieties over three complete growing seasons at three different locations in Montana. Twenty nine varieties of dryland grass were evaluated throughout the grazing season to estimate forage production and quality. Near Infrared Reflectance Spectroscopy (NIRS) equations were used to predict several forage quality constituents. Further, predictive equations to estimate forage quality constituents using date or growing degree days were developed. A future goal for this study will be to fine-tune AUM predictions for these species with their availability of crude protein or digestible dry matter based on growth stage or climate data.

Hypotheses to be tested were: 1) NIRS can accurately and consistently predict forage quality constituents of dryland forage grasses in Montana throughout the year, 2) the decline in forage quality with maturity is similar among species, and 3) forage quality constituents can be accurately predicted by the day of the year and accumulated heat units.

CHAPTER 2

LITERATURE REVIEW

Dryland Forage Grass Species

Livestock production is responsible for the nearly two billion dollars generated annually by agriculture in Montana every year. The primary source of forage for these livestock is the 40 million acres of range and pasture land (Montana Agricultural Statistics 2000).

Many cool season perennial species and cultivars are used by Montana producers to balance their forage bases, reduce pressure on native pastures and provide emergency forage during drought and other periods of low production (Smoliak et al, 1990). The most popular grasses in Montana used for hay and pasture production are *Agropyron cristatum* (L.) Gaertn. (fairway crested wheatgrass) and *Thinopyrum intermedium* (Host) Barkworth & D.R. Dewey (intermediate or pubescent wheatgrasses) (Smoliak et al, 1990). Other grasses used for pasture production are *Elymus lanceolatus* (Scribn. & J.G. Sm.) Gould (thickspike wheatgrass), *E. trachycaulus* (Link) Gould ex. Shinners (slender wheatgrass), *E. wawawaiensis* J. Carlson (Snake River wheatgrass), *Leymus angustus* (Trin.) Pilger (Altai wildrye), *Leymus cincereus* (Scribn. & Merr.) A. Love (Great Basin wildrye), *Nassella viridula* (Trin.) Barkworth (green needlegrass), *Pascopyrum smithii* (Rydb.) A. Love (western wheatgrass), *Psathyrostachys juncea* (Fisch.) Nevski (Russian wildrye), and *Pseudoroegneria spicata* (Pursh) A. Love (bluebunch wheatgrass) (Smoliak et al., 1990).

A. cristatum (L.) Gaertn. (fairway crested wheatgrass) is an introduced, persistent, drought tolerant, winter hardy grass with an extensive bunchgrass root system. It is noted for the ability to withstand heavy utilization once established and is extremely competitive if planted in a mix. (USDA, NRCS 2000).

A. desertorum (Fisch. ex Link) J. A. Schultes (standard crested wheatgrass) is also an introduced species. It is more drought tolerant than fairway crested wheatgrass and is specifically adapted to the Great Plains, intermountain and the northwest regions of the United States and is more tolerant of saline soil conditions than fairway crested wheatgrass (USDA, NRCS 2000).

A. cristatum x A. desertorum (hybrid crested wheatgrass) was developed to increase the competitiveness of crested wheatgrass in colder environments. New cultivars of hybrid crested wheatgrass have better forage yield than either parents (USDA, NRCS 2000).

A. fragile (Roth) Candargy (Siberian wheatgrass) is an introduced bunchgrass similar to fairway and standard crested wheatgrasses but it has finer leaves and stems. It is also the most drought tolerant of the three and remains the most palatable as summer progresses (USDA, NRCS 2000).

E. lanceolatus (Scribn. & J.G. Sm.) Gould (thickspike wheatgrass) is a native species. It is long-lived, drought tolerant, has good seedling vigor and is strongly rhizomatous. Thickspike is very well adapted to stabilize disturbed areas, but it has relatively low forage yield when compared to other species. Thickspike wheatgrass does not compete well when planted with aggressive species, but seedling vigor, rhizomes and drought tolerance makes it well suited for reclaiming low rainfall areas (USDA, NRCS 2000).

E. trachycaulus (Link) Gould ex Shinners (slender wheatgrass) is a relatively short-lived cool season native bunch grass species. It is less drought tolerant than crested or western wheatgrasses but it has good tolerance to alkaline conditions. Slender wheatgrass maintains high forage production for the first three to four years, then generally declines (Smoliak et al, 1990). It is moderately tolerant of grazing, but it performs the best when in grown in a pasture and hay situation with a legume (USDA, NRCS 2000).

E. wawawaiensis J. Carlson (Snake River wheatgrass) was originally identified as bluebunch wheatgrass, and is one of the most drought tolerant native bunchgrasses in the United States. This species is best suited for pasture and rangeland use and becomes somewhat coarse during the summer (USDA, NRCS 2000)..

Leymus angustus (Trin.) Pilger (Altai wildrye) is an introduced species that is predominately a bunchgrass but may also develop short rhizomes. It is winterhardy and very drought tolerant. It performs well in dry conditions and in saline soils but has limited seedling vigor and initial competitiveness. Once established, this species is very persistent and competitive (Smoliak et al, 1990). Aftermath growth must be removed by clipping or grazing to maintain maximum seed yield as normal seed yield is generally relatively low. Altai wildryes perform best in areas where annual precipitation exceeds 35 cm (Smoliak et al, 1990).

L. cincereus (Scribn. & Merr.) A. Love (Great Basin wildrye) is a native, long-lived cool season bunchgrass that can become very large and coarse. It has an extensive deep coarse fibrous root system and is well adapted to the stabilization of disturbed areas. Great Basin wildrye is one of the first grasses to green up in the spring and is reported to maintain high forage quality and palatability beyond the growing season. (USDA, NRCS 2000). Careful grazing management is very important with this species due to an elevated growing point; a residual stubble height of 25 to 30 centimeters is recommended to reduce grazing damage. It is considered excellent wildlife habitat and can provide shelter from the wind (USDA, NRCS 2000).

Nassella viridula (Trin.) Barkworth (green needlegrass) is a long-lived native bunchgrass that is highly palatable for livestock and wildlife. Under range conditions this species is generally found in areas of slightly higher moisture accumulation. It is very common throughout the grazing lands of the western United States but is usually not the predominant species in the plant community. It is generally seeded in plant mixtures, as pure stands have been know to experience partial die out (Smoliak et al, 1990).

Pascopyrum smithii (Rydb.) A. Love (western wheatgrass) is the most common and well known species of native grass in the West. It is strongly rhizomatous and palatable to all classes of livestock and wildlife. Poor germination and initial competitiveness result in stands that are often not fully established for several years. This species greens up in March to early April and matures in mid-July to August (USDA, NRCS 2000).

Psathyrostachys juncea (Fisch.) Nevski (Russian wildrye) is a long-lived, introduced bunchgrass. It is tolerant of drought, cold and mild salinity. Growth begins about two weeks after standard crested wheatgrass in the spring, the forage is palatable for a longer period than most other dryland grasses (USDA, NRCS 2000). Russian wildrye is not well suited to hay production due to the growth form of mostly basal leaves that are difficult to recover with conventional haying equipment. Careful management is required as it does not tolerate prolonged continuous grazing. Russian wildrye pastures should be planted in pure stands and fenced to allow for strict grazing management (USDA, NRCS 2000).

Pseudoroegneria spicata (Pursh) A. Love (bluebunch wheatgrass) is a native, perennial bunchgrass. It is long-lived and very palatable to wildlife and livestock but will not tolerate intensive prolonged grazing. Bluebunch wheatgrass has a fairly high growing point, and 15 centimeters of growth in the spring is recommended before turnout of animals. Deferred and rest-rotation grazing programs are effective in maintaining stand health (USDA, NRCS 2000).

Thinopyrum intermedium (Host) Barkworth & D.R. Dewey (intermediate or pubescent wheatgrass) is an introduced species used in hay and pasture lands throughout the West. It is a long-lived grass that can have short rhizomes with some cultivars becoming sod forming under irrigation (Ross, 1963; Smoliak et al., 1990; USDA, NRCS 2000). It is palatable to all classes of livestock and wildlife and is considered to be good forage throughout the growing season and into the fall and winter. This species is used to stabilize disturbed areas due to its rhizomatous root system. Excellent wildlife cover can be created using this species when strips are left ungrazed. This species will not tolerate heavy continuous utilization and established stands should be allowed to attain 10 to 30 centimeters of growth before livestock are turned in during the spring (USDA, NRCS 2000). Stands have consistently out-yielded grass/legume mixes so stocking rates can be set higher than other stands of forage grasses. Varieties of pubescent wheatgrass perform well in areas where annual precipitation exceeds 28 cm (USDA, NRCS 2000).

Forage production of dryland grasses

There are many factors that affect dryland forage production in Montana. The combination of precipitation, available soil nutrients, timing and frequency of grazing or harvest, and the age of the stand in improved pastures determine production and forage quality (Stitt, 1958).

Suleiman et al. (1999) reported that prairie grasses matured much earlier, and maximum forage yield was achieved earlier in the growing season during years of below normal precipitation. Stitt (1958) found that long-term (eight year) forage production of several forage grasses in central Montana were highly correlated ($r^2 = .86$, $P < .01$) with total precipitation received during April and May. White (1986) reported a 50% decline in dry matter production of Russian wildrye and crested wheatgrass following a 25% decline in April through June precipitation near Sidney, MT.

Waller et al. (1985) reported cool season grasses have an optimum temperature range for forage production of 15 to 24 °C. Generally soil temperatures between approximately 4 to 7 °C must be reached before the initialization of growth in the spring (Waller et al., 1985).

Cool season grasses are more productive in the spring and fall due in part to cooler temperatures, shorter photoperiods, and generally higher soil moisture. As summer progresses, growth rate declines and dormancy are induced by higher temperatures and lower precipitation (Waller et al., 1985). In fall, as temperatures decrease and if soil moisture becomes available, some cultivars may resume growth.

Nitrogen (N) fertilization is important for cool-season grasses and annual dry matter production is positively related to the level of applied N (Moyer et al., 1995; Overman et al., 1994). However, cool temperatures early in the spring limit the amount of N made available to plants by soil organisms. This is believed to be one of the major reasons why cool season grasses consistently respond to N fertilizer in many areas of the Great Plains (Waller et al., 1985). Dryland and rangeland fertilization is not widely practiced, as producers perceive it to be uneconomical. This perception was challenged by Lorbeer et al. (1994) in trials where 50 and 100 pounds of N per acre applied to native and introduced stands of forage grass at Havre, MT. Fertilized plots significantly outyielded unfertilized plots at an economical level for 7 years. Wight and Black (1979) found that N fertilization of cool season grasses near Sidney, MT increased forage yield.

Biomass production increases steadily in the spring until peak production is reached. This is followed by a period of relatively low production due to rapid decline in growth rate (Fairbourn, 1983). Most forage grasses reach maximum *in vitro* dry matter digestibility (IVDMD) production between the boot stage and anthesis (Fairbourn, 1983).

Timely harvest or grazing prior to boot stage may delay summer dormancy in grasses that generally mature before the onset of hot, dry weather (Waller et al., 1985). Summer productivity could potentially be increased if the vegetative stage is maintained longer into the summer (Waller et al., 1985).

White and Wight (1981) reported a rapid loss of dry matter production one to two months after peak production. They attributed this loss to the release of seeds, rapid decline in the translocation of nutrients to vegetative structures, and reduction in overall respiration leading to higher fiber and lignin concentrations.

Stand age also affects the production of dryland forage grasses. Lorbeer et al. (1994) reported that introduced forage grasses usually reach peak production in the second or third year after establishment. Yields of intermediate and crested wheatgrasses were found to be significantly highest during the first year after establishment than the second and third years (Wichman and Dubbs, 1986). Similarly, Lawrence (1973) found the maximum yield of intermediate wheatgrass stands occurred during the second year after establishment. In a four-year study near Swift Current, SK, Russian wildrye production was found to peak during the second year post establishment (Leyshon et al., 1990). Another long-term study in southern Saskatchewan involving Russian wildrye reported maximum forage production was highest in the first three years after planting (Kilcher et al., 1976).

Forage quality of dryland grasses

Plant maturity is the main factor affecting the forage quality of grasses and legumes (Kalu and Fick, 1983; and Nelson and Moser, 1994). Thus plant maturity can affect how well forage quality can be matched to animal requirements (Mitchell et al., 2001). White (1986) and White and Wight (1984) found that forage quality of dryland grasses was inversely proportional with forage dry matter yield. Suleiman et al. (1999) reported that knowledge of the yield of grasses as they mature helps to maximize the utilization of nutrients that can be captured by grazing. Dubbs (1970), Stannard and Kelley (1993), and White (1986) have reported that forage quality of grasses can vary based on the growth stage of the plant at the time of consumption or harvest, species differences, and available nutrients prior to and during the growing season. Cool season grasses utilize nutrients less efficiently as temperature increases during the growing season, but they generally have higher crude protein concentrations than warm season grasses (Waller et al., 1985).

Forages are more digestible to livestock early in their growth cycle. Abdalla et al. (1988) attributed this to a continuous reduction in the leaf:stem ratio from initial growth in the spring until the onset of dormancy in the later summer or fall. Forage quality of grasses decline as the plant matures (Murray et al., 1978; Newell and Moline, 1978; Stannard and Kelley, 1993). They attributed this decline to a reduction in mineral uptake as photosynthetic processes continued to proceed throughout the flowering and seed development stages. Perry and Baltensperger (1979), Griffin and Jung (1983), and

Mitchell et al. (1994) found that warm-season grasses follow this trend as well. Mayland et al. (1992) noted that the decline in forage quality and digestibility with advanced maturity was associated with more carbon in the plant cell. Carbon is bound in less digestible structural elements in the plant cell, and other important mineral concentrations are diluted when digestibility decreases. Mayland et al. (1992) also reported that *in vitro* digestible dry matter and other mineral concentrations decreased linearly as the plants matured. A study conducted in 1981 by White and Wight reported the *in vivo* digestibility of dryland forage grasses declined 22% between April and December.

Certain nutrients must be present in order for forage grasses to maintain productivity and forage quality. Aside from available moisture, N is the most important nutrient to plants. With fertilization, plant uptake of N increases as the rate of N applied increases (Black and Reitz, 1969). Lawrence et al. (1970), Reid et al. (1966), and Smitka et al. (1960) found that crude protein concentrations of crested wheatgrass, intermediate wheatgrass, orchardgrass (*Dactylis glomerata* L., Russian wildrye, and smooth bromegrass (*Bromus inermus* L.) increased as the rate of applied N increased. Monson and Burton (1982), and Puoli et al. (1991) found that this trend occurred in warm season grasses as well. Lorbeer et al. (1994) noted that the amount of crude protein produced per hectare was significantly higher in plots fertilized with N than unfertilized plots, and that this was still at an economical level 7 years later.

Forage quality varies among species. Russian wildrye at anthesis was reported to have sufficient crude protein to enable yearling steers to gain up to one kilogram per day while crested wheatgrass at the same stage of maturity could only support mature cow maintenance (White, 1986). Wichman and Dubbs (1986) reported that intermediate and pubescent wheatgrasses produced more kilograms of crude protein per hectare than Russian wildrye or crested wheatgrass. Comparisons of a particular forage quality constituent per unit area are useful, however limitations on intake must also be considered.

Analysis of dryland forage grass quality

The ultimate measure of forage quality is livestock performance. Estimates of predicted animal performance are based upon forage quality constituents that can be tested by conventional wet chemistry procedures or near infrared reflectance spectroscopy (NIRS). Constituents used to determine forage quality are crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), and *in vitro* digestible dry matter (IVDDM). Crude protein concentration in forages is a measure that can indicate whether or not the forage can meet the daily protein requirements of an animal. Measures of crude protein are based on the total concentration of forage N from both protein and non-protein sources. Crude protein estimates of pasture or standing forages is more predictive of available protein than hays or processed forages. Acid detergent fiber concentration is a measure of the amount of highly indigestible plant material in the forage and can be used to estimate energy content. The lower the amount of indigestible components in the forage, the more the animal will be able to digest. Neutral detergent fiber concentration is a measure of the cell wall material present in the forage. Increasingly higher concentrations of cell wall material equates to less forage being potentially consumed and processed. For this reason NDF is negatively related to intake. *In vitro* digestible dry matter is an estimate of the amount of forage that is potentially digestible and is based on actual or simulated feeding trials with animals or by procedures creating environments similar to the rumen (Church and Pond, 1988; Gray, 1988).

Near infrared reflectance spectroscopy is a new technology for analyzing forage quality that is accurate, economical, precise, simple and quick (Barnes, 1973). Further, NIRS can be used to predict parameters related to livestock performance, and has gained acceptance for use by the scientific community. Norris et al. (1976) were the first to use NIRS to estimate forage quality. Shenk, Westerhaus, Abrams, Barnes, and Martens are some of the many researchers that have evaluated and improved NIRS technology through their research. This technology estimates the concentration of each forage quality constituent in the sample by measuring the amount of specific wavelengths of infrared light that are reflected off certain chemical bonds associated with each constituent (Marten et al., 1985; Shenk and Westerhaus, 1994). Near infrared reflectance spectroscopy (NIRS) has provided fast, and increasingly accurate, and inexpensive method of estimating the forage quality constituents of forages (Fahey & Hussein, 1999). The NIRS procedure has been used to predict CP, NDF, ADF, IVDDM, fecal nitrogen and a number of other parameters associated with forage quality, forage intake and digestibility. The NIRS technique has been proven to be an accurate method of predicting forage quality components when the following criteria are met: 1) laboratory analyses of the calibration samples must be accurate; 2) proper wavelengths must be selected; 3) calibration samples adequately represent unknown samples; 4) proper data processing techniques must be used (Marten, 1985; Hruschka, 1987). Norris et al. (1976) accurately predicted CP, ADF, NDF, and lignin concentrations of legumes and forage grasses. Mayland et al. (1992) compared the seasonal trends in quality of *Agropyron* spp. and chose the NIRS method for analysis. Ward et al. (1982) successfully predicted CP (r^2 = 0.98) and ADF (r^2 = 0.90) in range forage using NIRS. Albrecht et al. (1987) analyzed cell-wall carbohydrates and starch in alfalfa using NIRS. Suleiman et al. (1999) accurately analyzed nutrient and mineral concentration of grasses in east-central Alberta using NIRS technology, across several stages of growth at harvest. Clark et al. (1989) measured trace elements of alfalfa, crested wheatgrass, and tall fescue and concluded that NIRS was generally more accurate in predicting trace mineral concentrations than by using the NRC table values. In Montana, Murphy (1996) developed NIRS equations that accurately predicted CP, ADF, NDF, and IVDDM of five dryland forage grasses.

CHAPTER 3

MATERIALS AND METHODS

Dryland Forage Grasses

Twenty-nine forage grass varieties were selected from 14 species used commonly in dryland situations in Montana and the west (Table 1). The varieties were: 'Douglas', 'Hycrest', 'CDII', and 'Nordan' crested wheatgrass; 'P-27' and 'Vavilov' Siberian wheatgrass; 'Critana', 'Bannock', and 'Schwendimar' thickspike wheatgrass; 'Pryor' and 'Revenue' slender wheatgrass; 'Secar' Snake River wheatgrass; 'Pearl', 'Prairieland', and 'Eejay' Altai wildrye; 'Trailhead' and 'Magnar' Great Basin wildrye; 'Rosana' western wheatgrass; 'Bozoisky-Select', 'Mankota', and 'Swift' Russian wildrye; 'Goldar' blueblunch wheatgrass; 'Greenleaf', 'Luna', and 'Manska' pubescent wheatgrass; and 'Oahe', 'Reliant', and 'Rush' intermediate wheatgrass (complete variety descriptions are shown in Appendix A – Table 69).

Experimental Design

This research project was funded by the Montana State University Foundation Seed Program, in cooperation with the NRCS Plant Materials Center in Bridger, MT. Grasses for this study were planted at three Montana locations: the USDA-NRCS Plant Materials Center near Bridger, the Central Agricultural Research Center near Moccasin, and the Montana State University Research Farm near Bozeman.

Table 1. Cool season perennial grasses evaluated for forage yield and quality at Bozeman, Bridger and Moccasin, MT in 1997, 1998 and 1999.

Scientific name	Common name	Variety
Agropyron cristatum (L.) Gaertn.	Fairway crested wheatgrass	Douglas
A.cristatum X A. desertorum	Crested wheat grass hybrid	Hycrest
	Crested wheat grass hybrid	CDII
A. desertorum (Fisch. Ex Link) J.A.Schultes	Standard crested wheatgrass	Nordan
A. fragile (Roth) Candargy	Siberian crested wheatgrass	P-27
	Siberian crested wheatgrass	Vavilov
Elymus lanceolatus (Scribn. & J.G. Sm.) Gould	Thickspike wheatgrass	Critana
	Thickspike wheatgrass	Bannock
	Thickspike wheatgrass	Schwendimar
E. trachycaulus (Link) Gould ex Shinners	Slender wheatgrass	Pryor
	Slender wheatgrass	Revenue
E. wawawaiensis (J. Carlson)	Snake River wheatgrass	Secar
Leymus angustus (Trin.) Pilger	Altai wildrye	Pearl
	Altai wildrye	Prairieland
	Altai wildrye	Eejay
L. cinereus (Scribn. & Merr) A. Love	Great Basin wildrye	Trailhead
	Great Basin wildrye	Magnar
Nassella viridula (Trin.) Barkworth	Green needlegrass	Lodorm
Pascopyrum smithii (Rydb.) A. Love	Western wheatgrass	Rosana
Psathyrostachys juncea (Fisch.) Nevski	Russian wildrye	Bozoisky-Select
	Russian wildrye	Mankota
	Russian wildrye	Swift
Pseudoroegneria spicata (Pursh) A. Love	Bluebunch wheatgrass	Goldar
Thinopyrum intermedium (Host) Barkworth & D.R. Dewey	Pubescent wheatgrass	Greenleaf
	Pubescent wheatgrass	Luna
	Pubescent wheatgrass	Manska
	Intermediate wheatgrass	Oahe
	Intermediate wheatgrass	Reliant
	Intermediate wheatgrass	Rush