ALTERNATIVE FORAGES FOR BEEF CATTLE PRODUCTION IN THE INTERMOUNTAIN WEST

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Authorization to Submit Thesis

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Abstract

Rising hay expenses and long winters result in high winter feed costs to maintain beef cattle. Studies assessed forage yield and nutritional quality of warm season grasses and winter annual forages. Forage yield of warm season grasses differed amongst species ($P <$ 0.001) and years ($P <$ 0.05). Corn and sorghum x sudangrass had the highest three year averages (5859.3 ± 578 kg/ha and 5422 ± 605 kg/ha, respectively) of the warm season species. Winter annual production was a complete crop failure in year 1 with triticale/AWP (10,680 ± 602 kg/ha), triticale (8400 ± 602 kg/ha), and cereal rye (8250 ± 632 kg/ha) having the greatest yields (P = 0.001), followed by control (3440 ± 884 kg/ha) and AWP (3,360 ± 625 kg/ha) in year 2. Austrian winter pea had greater *In situ* dry matter degradation, CP and lower NDF and ADF than the cereal grains ($P <$ 0.05).

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Table of Contents

List of Tables

List of Figures

Chapter 1: Literature Review

History of the Early Beef Industry

Early settlers to the Intermountain West region of the United States were generally associated with one of three groups: livestock enterprises, farmers, or prospectors. As open range disappeared under settlement and irrigation projects, public rangelands became highly degraded and grazing of government lands was subsequently restricted through the Taylor Grazing Act of 1934 (Taylor Grazing Act, 1934). Public land grazing was further managed by the Federal Land Policy and Management Act of 1976 (BLM, 2009). Eventually, ranchers themselves turned to hay production to support their herds and ensure adequate feed supplies (Vavra, 1998).

The cattle industry in Idaho has changed drastically since the first herds reached the state during the 1860s. Early cattle operations utilized the readily-available free range to feed their animals, wintering in the lower-elevation valleys and working the cattle into the high country during the hot summer months, then returning to lower elevations when cold weather returned. Early herds were brought from Texas and marketed to miners, or driven to railheads to be shipped to the Eastern states for consumption. The free-range cattle industry peaked in Idaho in the 1880s (Brosnan, 1918). The winter of 1885-1886 in conjunction with a lack of stored forages devastated the cattle herds in the Pacific Northwest (Barnes, 1913) and this, in conjunction with increasing settlements and irrigation developments (Brosnan, 1918), resulted in a shift of the beef industry. The distinction between ranchers and farmers became blurred as ranchers diversified their operations and turned to raising forages for feed (Murphy, 1935).

Development of Irrigation

A majority of the settlers to the semi-arid western states came from humid regions where the climate patterns and dependable precipitation made irrigation unnecessary. Two approaches to farming in the semi-arid West developed: use of dryland species and fallowing of ground to produce a crop (Widstoe, 1920), or development of irrigation systems to provide water for growing crops. The first recorded irrigation in Idaho occurred at the Native American mission in Lapwai in 1835, and the state's first permanent, irrigated settlement, in Franklin was founded in 1860.

Early settlements in the semi-arid regions of the state often bordered small creeks and streams where irrigation ditches and canals could easily divert water. As these easily-accessible areas became occupied, the state's irrigation companies and districts were formed. The difficulty of large-scale irrigation across the semi-arid west resulted in a need for outside capital. Outside capital was used for irrigation developments, and when returns on investment were slow, projects would be sold or abandoned (Brosnan, 1918). Eventually irrigation projects resulted in a shortage of water when streams and rivers became over appropriated. As water rights became contested, Idaho adopted the doctrine of prior appropriation, adjudicated water rights, developed the office of Idaho State Engineer (Murphy, 1935), and formed the department now known as the Idaho Department of Water Resources to oversee water management (IDWR, 2012).

The Carey Act in 1894 and the Reclamation Act of 1902 (Bureau of Reclamation, 2012) opened the door for the large-scale developments of Western waters. Early irrigation utilized flood irrigation. As technologies improved, hand-moved sprinkler pipe, wheel-line irrigation, and center-pivot irrigation techniques were developed (Niebling, 1997). Advances in irrigation have resulted in an increased ability for farmers and ranchers to apply irrigation water specific to the needs of individual crops, maximizing water efficiency. However, increased efficiency is often associated with an increase in costs (Robinson, 1978).

Mountainous terrain, deep river canyons, and long distances between springs and streams made it difficult if not impossible to bring irrigation to all areas of the semi-arid west. The difficulty associated with irrigating much of the land in the West gave rise to dryland farming. "Dry farmers," through the use of specific cultivation methods and plant selection, were able to raise crops in areas where irrigation proved unfeasible or rainfall was insufficient for traditional crop production. Dry-farmed areas attempt to raise crops in regions which receive approximately 10"-20" of precipitation a year, much of it coming during the winter months (Brosnan, 1918). Successful dry farmers were able to grow crops under arid conditions by creating a pool of stored water in the soil, then carefully manipulating the physical water-loss variables to ensure adequate soil moisture to sustain the crops until harvest (Widstoe, 1920).

Current Status of Idaho's Agriculture

Forage production is essential in many Idaho counties to sustain local cattle enterprises as well as serve as a cash crop for export to other regions (Shewmaker, 2005). Idaho ranked second in the nation for receipts from all hay and alfalfa hay in 2011 with alfalfa hay averaging $223/ton and other hay averaging $148/ton (USDA-NASS, 2012).

Forages support the Idaho beef, dairy, and horse industries, as well as an export market of high-quality hay (Hoyt, 2011).

The expense associated with harvested and stored feeds is the single greatest cost incurred for the cow/calf operation, with producers feeding an average of 1.5-2.37 tons of forage per animal in the west (Gilliam, 1984; Short, 2001). Rapid growth of the dairy industry in the West and Southwestern states (St-Pierre, 2011) has resulted in an increase in hay prices from an average price of $80/ton for all hay in 1988-90 to $151.33/ton in 2009-11 (USDA-NASS, 1991; USDA-NASS, 2012). Possible management options for reducing expenses associated with stored forages include procuring stored forage for a cheaper price (e.g., alternative forages, silage/baleage, improved yields), extending the grazing season (e.g., stockpiled forages, windrow grazing, crop aftermath, winter annuals), or changes in herd management (e.g., calving dates, spring/fall calving).

While alternative forages do represent additional management challenges, the use of novel or non-traditional crops may reduce forage related expenses for beef producers in the West. Alternative forages can be utilized using an ecological approach (e.g., cool- vs. warm-season species) to accomplish specific ranch management needs (e.g., early season vs. late season grazing; quantity vs. quality of forage).

Idaho Weather Patterns

Weather patterns and moisture availability in the Intermountain West region vary according to a variety of factors including elevation, topography, and oceanic currents (Wolter, 2010). The variations can be extreme between regions and elevations (WRCC, 2014). On average, Idaho has a Mediterranean climate with erratic precipitation, cold winters, and hot summers. The greatest amount of precipitation falls in the months of May and June (W.R.C.C., 2013). In higher elevations, winter precipitation, in the form of snow, allows the moisture to accumulate for spring and summer plant growth.

Plant Adaptations and Specializations for Improved Forage Production

Physiological adaptations provide plant species with characteristics, making them desirable for forage production under certain environmental factors. Human recognition of species adaptations, combined with breeding programs to emphasize favorable traits, has given rise to modern agricultural crops and agronomic management practices (Vogel and Lamb, 2007). It has long been recognized that reconciling environmental adaptations of plant species with a management approach to suit those adaptations, can result in increased forage production (Jung and Reid, 1966).

Annual and perennial grasses used in agricultural production are often referred to as either warm-season or cool-season species, dependent upon the season in which a plant maximizes its growth potential and/or exhibits competitive advantage (Volenec and Nelson, 2007). Cool-season species are found in several life forms; winter annuals, spring annuals, biennials, and perennials. Warm-season species life forms can be; annual, biennial, or perennial in nature.

Plant growth is dependent upon its ability to sequester CO_2 from the air in order to produce metabolites through photosynthesis (Nelson, 1996). Photosynthesis is the process of combining carbon dioxide (CO_2) and water molecules (H_2O) with energy from sunlight to produce glucose ($C_6H_{12}O_6$) which can be stored and later utilized by the plant (Baly, 1928). Plants have evolved three primary methods of CO_2 fixation, with cool-season forage crops utilizing the C_3 pathway and warm-season forage crops utilizing the C_4 pathway. The third pathway, Crassulacean acid metabolism (CAM)(Thomas and Beevers, 1949), is found primarily in succulents (Black and Osmond, 2003). Additional species have been found to be intermediates between the C_3 and C_4 pathways (Gibson, 2009), or possess the ability to switch between pathways (Black and Osmond, 2003).

Each pathway is named based upon the compound created during CO_2 fixation. The C_3 pathway was originally identified by Calvin and Basham (1963), who recognized that energy from sunlight is captured in plant chlorophyll and used to incorporate CO_2 into 3-phosphoglyceric acid (3PGA), a three-carbon compound. Hatch and Slack (1967) described CO_2 being fixed into four-carbon sugars, and the C_4 dicarboxylic acid pathway was described in 1970 (Downton, 1970). The CAM pathway is named for plants of the Crassulaceae family where the acid was originally identified (Black and Osmond, 2003).

The method in which CO_2 is fixed by the plant affects its ability to convert sunlight to sugars depending upon environmental conditions, and is of importance in understanding how to best utilize plants for production in different management scenarios. Some other common evaluation criteria associated with forage species include water use efficiency (WUE), nitrogen use efficiency (NUE), light use efficiency (LUE), ability to conduct photosynthesis at high or low temperatures (Gibson, 2009), and drought tolerance. Water use efficiency is defined by agronomists as the amount of biomass produced per unit of water (Tambussi et al., 2007). Nitrogen use efficiency is defined as a measure of a plant's ability to produce biomass for each unit of nitrogen (N), and LUE is a measure of the plant's ability to capture light in photosynthesis for biomass production (Wedin, 2004).

Cool-season grasses perform better at cooler temperatures and produce higher quality forage because they have less structural carbohydrates and higher levels of protein, primarily rubisco (Volenec and Nelson, 2007). Warm-season grasses have better WUE and NUE, and are more efficient at translocating carbon (Moser et al., 2004). At higher temperatures, C_4 grasses have better LUE (Gibson, 2009). The increased WUE of C_4 grasses does not necessarily correlate to drought tolerance, and the higher NUE does not appear to give C_4 grasses an advantage over C_3 grasses in nitrogen-limited soils (Sage and Pearcy, 1997;Lambers et al., 1998).

Forage Quality

Forage quality is defined as the ability of forage to support maintenance and production in livestock animals (Cochran et al., 2007). Mott (1973) included the rate of consumption of forage as a variable affecting forage quality. Forage quality is normally associated with physiological features that producers can observe, e.g. plant maturity, amount of leaf present, color and aroma (Cochran et al., 2007). Major ruminant feeding systems use an adaptation of the net energy system. Three factors affect the net energy (NE) an animal absorbs from its feed: 1) energy consumed, 2) feed digestibility, and 3) energy utilization efficiency (Minson, 1981). Experiments to determine net energy values of forages for ruminants are expensive, so both laboratory and animal methods are used as predictors of NE values (Cochran et al., 2007)..

Digestibility and passage rates of carbohydrates in ruminant animals are affected by the proportion of starch, water soluble carbohydrates, and structural carbohydrates. Soluble carbohydrates and starches are highly digestible with greater than 90 percent being bioavailable to ruminants (Van Soest, 1967). Primary structural carbohydrates are hemicellulose, cellulose, and lignin. Lignin is indigestible and its structure within the plant affects the digestibility of hemicellulose and cellulose (Van Soest, 1982). Passage rate within the rumen is affected by the percent and type of structural carbohydrates present within feeds, often limiting animal intake in forage-based diets.

Variation in plant structural qualities is exhibited in differences between C_3 and C_4 grasses. Cool season C_3 grasses are lower in structural carbohydrates as compared to warm season C_4 grasses (Buxton et al., 1996b). Presence of sclerenchyma fibers in C_4 grasses running from vascular bundles to the plant epidermis form an “I-beam” construction (Gould and Shaw, 1983) which results in increased mastication for grazing animals and increased structural carbohydrate levels in comparison with C_3 grasses (Moser et al., 2004). Despite the higher amounts of structural carbohydrates in warm-season grasses, their structural carbohydrates are more highly digestible; however, chemical and physical factors slow degradation and fermentation rates (Coleman et al., 2004). Higher levels of digestibility can be related to the fact that ADF levels are similar between C_3 and C_4 grasses, with C_4 grasses having higher amounts of NDF (Reid et al., 1988). Nitrogen is present in the form of protein, or non-protein nitrogen (NPN) inside plants, with protein nitrogen constituting about 70% of a plant’s nitrogen (Van Soest, 1982). Non-protein nitrogen is utilized by microbes in the rumen of ruminants. Remaining plant protein can be further divided into rumen-degradable protein (RDP) and rumen-undegradable intake protein (RUP), or rumen by-pass protein. Current National Research Council (NRC) values of digestibility of RUP for forages are thought to overestimate actual digestion, since proteins may be bound in indigestible structural carbohydrates (Negi et al., 1988) which reduce protein digestibility (Haugen et al., 2006). Additionally, proteins may bind to carbohydrates in the presence of heat and water, making them unavailable to the animal in a process called the Maillard reaction (Van Soest, 1982).

Protein concentrations within C_3 and C_4 grasses in a vegetative stage are adequate for a mature non-lactating beef animal; however, percent protein in all grasses decreases as plants mature and the leaf-to-stem ratio decreases and may become nutritionally deficient when plants go through senescence (Minson, 1990; NRC, 2000). Soil nitrogen levels can influence the amount of N present in the forage, with increased levels often attributed to an increase in NPN (Van Soest, 1982). Some grasses can cause nitrate toxicity when dangerous levels of N are accumulated within the plant due to abiotic and biotic variables. For a more detailed explanation of nitrate toxicity, refer to the section on plant anti-qualitative factors (p. 16).

Variations exist among the protein content of C_3 and C_4 grasses. The Kranz anatomy found in the leaves of C_4 grasses, with its improved photosynthesis efficiency (Gibson, 2009) results in a decreased amount of rubisco in plant leaves (Moser et al., 2004), reducing the protein content of forage and increasing the potential for a deficiency of RDP (Minson, 1981). Some warm-season species have been found to have higher percentages of RUP than cool-season species (Mullahey et al., 1992).

It is believed that both C_3 and C_4 grasses contain adequate levels of Fe, K, Mn, Cl, Mo, S, and Ni for mature beef cows, but NRC has not set recommended values for Cl, Mo, and Ni (Buxton et al., 1996a; NRC, 2000)(refer to Table 1). Other macro- and micro-minerals need to be provided to grazing animals as a supplement. Variability amongst groups as well as regional variability amongst plant species exist, For example, sorghum x sudangrass hybrid (*Sorghum bicolor* (L.) Moench) is naturally deficient in sulfur (NRC, 2000), while selenium concentrations can vary regionally dependent upon the concentration of selenium present in the soil (Edmonson et al., 1993).

Beef Cow Nutritional Demands

Nutritional requirements for beef cattle vary depending upon age and stage of production (NRC, 2000). Primary nutritional demands placed upon a beef cow include growth (up to 5 years of age), maintenance, fetal growth, lactation and recovery from parturition. For a mature beef cow, the nutritional demands follow a cyclical nature and can be broken into four gestational periods; first trimester, second trimester, third trimester, and postpartum period (Kellums and Church, 2002). The demands of younger cows follow the same nature, but nutritional requirements for growth need to be taken into account. Replacement heifers will have a continual increase in demands for nutrients from the time of conception to calving due to the need for growth of heifer as well as fetus (NRC, 2000).

First trimester (95 days) for a mature beef cow begins with conception of the fetus, with the primary nutritional demands being placed on the cow coming from lactation and maintenance. Second trimester (95 days) is when the calf is weaned from the cow, and little nutritional demands are placed upon the cow for fetal growth, resulting in the lowest nutritional requirements. Third trimester (95 days) is when the majority of fetal development takes place, and nutritional demands increase as the cow approaches parturition with approximately 70% of fetal development occurring in the third trimester (NRC, 2000). Recent research into fetal programming has placed more importance on the nutrition of the cow during gestation for the development of skeletal muscle, marbling, and reproductive abilities (Du et al., 2010; Funston et al., 2012). The postpartum period (80 days) is when nutritional requirements for the beef cow are highest, with feed intake being approximately 35-50% greater compared to non-lactating cows (Agricultural Research Council, 1980). Increased feed requirements are due to demands of maintenance, lactation and recovery from parturition.

In addition to physiological needs of a cow, environmental variables play a role in determining energy requirements of beef cows. Heat and cold stress result in variations in the amount of feed consumed by beef cows (Minton, 1986), with intake increasing as temperature drops below the thermoneutral zone and decreasing when temperatures are above the thermonuetral zone. The thermoneutral zone of beef cattle will vary depending upon hair length, time allowed to adjust to temperature change (adjustment period), wind speed, mud, and when hair is wet or dry hair (NRC, 2000).

To maximize cost efficiency, management approaches for beef cattle take into account environmental variability of forage production, environmental conditions, and how the relationship of physiological stages relate to feed availability. Cattle consuming low quality forages high in structural carbohydrates which are typical of mature forages, can be limited by protein concentration (Coleman et al., 2004), gut fill, and digesta passage rates (Van

Soest, 1982). Protein supplements can help maintain proper cattle nutrition during times of poor forage quality, with optimal supplementation occurring when forage protein concentrations are below 6 to 8 percent (NRC, 1987). Management Systems that graze mature grasses either stockpiled or windrowed, prefer that cattle nutritional demands be at their lowest level to minimize additional supplementation.

Mineral Requirements and Interactions

Forage plants are adequate in some essential minerals while lacking in other minerals that are required by beef animals (Table 1). Variables affecting adequacy of plant mineral composition include plant species, phenology, chemical form of mineral present in plant, interrelationships of minerals with other minerals and nutrients, and production status. In addition, some forage plants may contain minerals in concentrations that are lethal to grazing animals, or may contain anti-qualitative compounds (Van Soest, 1982).

The need for salt (NaCl) supplementation of ruminants has long been recognized. Phosphorus and calcium are essential minerals that must be present in the diet in the right proportions, preferable a 2:1 to 1.2:1 ratio (Hale and Olson, 2001). Grasses are often deficient in Calcium, and unfertilized pastures and ranges are often found to be deficient in Phosphorus for grazing cows (Van Soest, 1982). Selenium, an essential micronutrient is a mineral of much debate with documented cases of animals dying from a lack of selenium (white muscle disease) as well as being exposed to high amounts of selenium (Ullrey, 1992). Recommended levels of selenium for a mature beef cow are 0.10 mg/kg while maximum tolerable concentration is 2.00 mg/kg (National Research Council, 2000).

Interactions amongst minerals, as well as compounds found within plants, can alter the bioavailability of minerals to ruminants. Chemical bonding of Mo and S inside the rumen results in the formation of thiomolybdates. Thiomolybdates bind with Cu, making it unavailable for absorption by ruminates, and when thiomolybdates are present in excess, they can enter the blood stream and mobilize tissue Cu (Minson, 1990; Suttle, 1991). The affinity of Cu to bind to other minerals results in a high variability of copper requirements, with the recommendation of 10 mg Cu/kg of feed based upon projected levels of 2 mg Mo/kg of feed and 0.25 % S/kg feed (NRC, 2000).

Plant Anti-Qualitative Factors

Forage species have evolved various mechanisms to survive herbivory, with these mechanisms falling into one of two categories: avoidance and tolerance. Avoidance can occur through the formation of physical deterrents such as thorns or spines, or the creation of chemical compounds causing the plant to be undesirable or toxic. Grazing tolerance is the development of adaptations that allow the plant to survive the grazing event, and to initiate regrowth. Examples of tolerance include prostrate growth, low meristems, and tillering (Hendrickson and Olson, 2006).

Numerous chemical compounds can be found in plant species influencing the palatability of plants and can result in performance losses in animals or even morbidity. Some of the more commonly found compounds include flavonoids, tannins, isoflavones, terpenoids, essential oils, cutin, alkaloids, cyanides, and organic acids (Van Soest, 1982).

Nitrate and cyanide compounds are common anti-quality factors found in cultivated annual forages in the Intermountain West. A proper understanding of the plant phenology cycle and the nature of these compounds can allow a manager to make decisions in relation to forage harvest and animal consumption in order to minimize animal harm and losses.

A cyanide compound that is frequently encountered in sorghums, sudan grasses and sorghum x sudangrass crosses is dhurrin, a cyanogenicglucoside (Moser et al., 2004). Young plants, regrowth, and plants that have been in a drought accumulate a greater amount of dhurrin (Fjell et al., 1991). When the plant tissues are ruptured through being grazing, chopping, or freezing, the dhurrin changes to hydrocyanic acid (prussic acid). Frost will result in cyanide gas being present in the leaves for a short time, but gas will dissipate as tissues dry.

Nitrate toxicity occurs when environmental conditions result in the accumulation of plant compounds that are normally utilized for plant growth and function. Nitrate toxicity, also known as nitrate intoxication (Pfister, 1988) or cornstalk disease (Mayo, 1895), is the result of excessive amounts of nitrate being present in the feed supply. Nitrates (NO_3^-) are the most prevalent form of nitrogen available for plant uptake from the soil due to bacteria conversion of ammonia (NH_4^+) to nitrite (NO_2^-), and from nitrite to nitrate through the process of nitrification (Anthonisen et al., 1976). These nitrates are then absorbed by the plant, reduced and combined with carbohydrates to form amino acids. When the rate of nitrate absorption exceeds the rate of utilization by the plant, accumulation of nitrates occurs within vegetative bodies of the plants (Barker et al., 1971). Nitrate levels have been shown to peak at the prebloom stage (Wright and Davidson, 1964).

Factors shown to affect plant nitrate levels include: stage of growth, amount of soil nitrogen, specific plant parts, and light intensity (Crawford et al., 1961). Water stress, which causes stomata closure and reduction of CO_2 in the cell, has been shown to result in decreased nitrate reductase (NR) activity and an accumulation of nitrates in the leaves (Kaiser and Forster, 1989). Nitrate Reductase is considered a key enzyme in nitrate accumulation in plants (Walters and Walker, 1979 Molybdenum has been identified as an essential nutrient for NR function, and Molybdenum deficiencies can result in decreased activity of NR (Walters and Walker, 1979).

Opinions differ about the effects of chronic levels of nitrates on animal performance (Jones et al., 1965; Nielsen, 1974), but nitrite will inhibit cellulose digestion in its presence (Van Soest, 1982). Animals suffering from nitrate toxicity will have labored breathing, increased heart rate, trembling, staggering and, in some cases, apparent blindness. Animals cease to eat, experience frequent urination, lay on breast or side, and die with little or no struggling. Cyanosis of tongue, rectum, vulva and sclera occurs, and the blood has a chocolate coloring (Davidson et al., 1941). Once the nitrite enters the blood stream it interacts with hemoglobin, rapidly oxidizing the iron located inside the heme group (Unnikrishan and Rao, 1992). This converts the hemoglobin to methemoglobin. Methemoglobin is unable to bind oxygen for transport in the blood, and if enough hemoglobin is oxidized the animal has difficulties transporting oxygen to the cells, and death will result if untreated (Bradley et al., 1940). Clinical signs of nitrate toxicity appear when 40% of hemoglobin is converted to methemoglobin, and death occurs when methemoglobin reaches 70-80%. Increasing the amount of sugar and starch in ruminant diets increases tolerance to higher levels of nitrates in feed (Van Soest, 1982).

Nitrates located within forages consumed by ruminants are reduced by bacteria from nitrate to nitrite and eventually ammonia where it is either utilized by ruminal microbiota in the synthesis of amino acids or absorbed by the animal and excreted as nitrogenous waste (Wallace and Cotta, 1988). When levels of nitrate and/or nitrite are high enough in the feed source, conversion to ammonia occurs slow enough that nitrite can be absorbed into the blood stream (Davidson et al., 1941). Water high in nitrates has also been shown to result in nitrite absorption into the blood system (Campbell et al., 1954).

Chapter 2: Utilizing Warm Season Summer Annuals for Fall Grazing

Abstract

Rising hay expenses and long winters result in high winter feed costs to maintain mature beef cattle. Increasing forage available for late fall and early winter grazing should reduce winter feeding costs compared to stored forages. Objectives of this study were to assess the forage yield and late season grazing potential of no-till planted warm season grasses for use to extend the grazing season in high elevation, short growing season environments. Forage yield differed amongst species ($P < 0.001$) and years ($P < 0.05$). Corn and sorghum x sudangrass had the highest three year averages (5859.3 ± 578 kg/ha and 5422 ± 605 kg/ha, repectively). Corn had the greatest single season yield (9596 ± 827 kg/ha). Cool conditions in 2010 resulted in a decrease in yields of all forages ($P < 0.05$). No differences in CP, ADF, or NDF were observed ($P > 0.05$). Windrow grazing is an opportunity to utilize the summer annual species to extend the grazing season.

Study Site

Forage yield and grazing trials were conducted at the University of Idaho Nancy M. Cummings Research Extension and Education Center (NMCREEC; N 45°17’10”, W113°53’6”) to assess forage production and late-season grazing potential of warm-season species seeded with minimal or no tillage from 2008-2010. The study site had an elevation of 1160 m with soils at the test plot belonging to the silty clay Zeegee-Ajax complex (WSS, 2010). A test plot was designed and fenced to include three 7.32 m x 152.4 m replicates of five summer annual species over three years: German foxtail millet (*Setaria italica* (L.) P.

Beauv.), pearl millet (*Pennisetum americanum* (L.) R. Br.), sorghum x sudangrass hybrid (*Sorghum bicolor* (L.) Moench), teffgrass (*Eragrostis tef* (Zuccagni) Trotter), and corn (*Zea mays* L.). Treatments were modified after the first year, with proso millet(*Panicum miliaceum* L.) replacing pearl millet, and corn planters and varieties changing each growing season.

Materials and Methods

Planting /Growing Season

Year 1 - 2008 Growing Season

The first cutting of alfalfa/grass hay was removed and the test plot area was treated with 4.68 L/ha glyphosate herbicide in early to mid-June. Treatments were randomly assigned, and teff treatments were lightly disked for minimal tillage. Minimal tillage of the heavy sod resulted in a rough seed bed for Teff grass treatments. Teff grass (var. Tiffany; Target Seed, Parma, ID) was seeded with a Brillion drill (Brillion model SS6, Landoll Corp., Brillion, WI:Table 2) on 27 June, with each replicate receiving 10.1 kg/ha of seed. After seeding, teff treatments were rolled with a steel drum roller to insure soil/seed contact. Soil was deemed too hard for non-tilled treatments to be planted. Plots were irrigated for twelve hours the 27th and 28th of June to soften the soil, and planting resumed on 30 June.

Sorghum x sudangrass (var. Green Grazer V; Allied Seed, Nampa, ID) was planted utilizing a Haybuster no-till drill (Haybuster model 1206, Jamestown, ND) at 20.2 kg/ha with 283.5 kg of additional weight added to the drill. Pearl millet (var. PP102M; Production Plus, Plainview, TX) was planted the same day with the Haybuster drill at a rate of 22.4

kg/ha, but only 2 replicates were planted due to a lack of seed. German foxtail millet (var. R-strain; Missouri Southern Seed, Rolla, MO) was planted on 1 July with the Haybuster drill set for 22.4 kg/ha. Actual planting rate was calculated at 39.2 kg/ha. Corn grazing varieties (var. Amazing Graze and Amazing Graze "Northern"; Baldridge Hybrid, Cherry Fork, OH) were planted with the Haybuster drill set according to forage soybean recommendations. Drop bibs were mounted on the backs of the openers, and every fourth cup was left open, resulting in 60.96 cm row spacing. Replicates 1 and 2 were planted with the Amazing Graze variety; replicate 3 had its outside rows planted to Amazing Graze and middle rows to Amazing Graze "Northern".

Plots were irrigated after planting (Table 3) utilizing solid-set sprinkler irrigation. Nitrogen was broadcast onto test plots using a tractor-pulled fertilizer cart at a rate of 44.9 kg of N/ha. Plots were sprayed on 4 August with 1.2 L/ha of dichlorophenoxyacetic acid (2,4-D) herbicide to control spiny amaranth (*Amaranthus spinosus* L.) and other broadleaf weeds.

Year 2 – 2009 Growing Season

Plots were sprayed with glyphosate at 4.7 L/ha and replicates were re-randomized with teff treatments being lightly disked and roller-harrowed in the same manner as in Year 1. Teff was planted on 25 June with a Brillion grass seeder on seed setting 4, and rolled with a steel drum roller. Corn (var. HLCVR44; Hyland Seed, Blenheim, ON) was planted on 25 June with a John Deere (John Deere, Moline, IL) conventional corn planter with a 76.2 cm row width at an estimated 88,956 seeds/ha. Sorghum x sudangrass (var.Special Effort; Production Plus, Plainview, TX) was planted on 26 June at 20.2 kg/ha, white proso millet on 30 June at 20.2 kg/ha, and German foxtail millet on 1 July at 20.2 kg/ha (Table 2). The ground was noticeably softer than in the previous year, and no additional weights were added to the Haybuster no-till drill, with teff treatments resulting in a more uniform planting surface. Nitrogen was broadcast on test plots using a tractor-pulled fertilizer cart at the rate of 44.9 kg of N/ha on 17 July. Plots were irrigated throughout the growing season with solid-set sprinkler pipe (Table 3) and were sprayed once with dichlorophenoxyacetic acid, triisopropanolamine salt, 3,6-dichloro-2-pyridinecarboxylic acid, and mono ethanolamine salt (Curtail, Dow AgroSciences LLC, Indianapolis, IN) at 2.4 L/ha to control for spiny amaranth and lambs quarter (*Chenopodium album* L.).

Year 3 -2010 Growing Season

Plots were randomized and sprayed with glyphosate at 4.7 L/ha, then mowed with a 2.13-m John Deere rotary mower (model MX7 , John Deere, Moline, IL) to mulch heavy weed residue. Teff was planted at 6.7 kg/ha and white proso millet at 20.1 kg/ha on 1 July. German foxtail millet was planted at 26.8 kg/ha, sorghum x sudangrass at 30.6 kg/ha on 2 July, and corn planted on 3 July (Table 2). Planting followed the same procedures as the prior year with the exception of the corn, which was planted with a conventional 8-row planter with 60.96 cm row spacing (WIC Inc; Wickham, Quebec). Nitrogen was broadcast onto test plots using a tractor-pulled fertilizer cart at the rate of 44.9 kg/ha . Plots were sprayed with 1.8 L/ha of Dimethylamine salt of 2-methyl-4-chlorophenoxyacetic acid (MPCA-amine, Agriliance LLC, St. Paul MN) when plants reached an early vegetative stage. Forages were irrigated as needed throughout the growing season (Table 3).

Forage Sampling/Grazing Trial

Year 1 - 2008 Growing Season

The first year's teff production data were taken on 9 August utilizing a 0.3 m^2 frame for each of 5 samples from each replicate. Samples were taken by clipping all herbaceous matter within the frame at a height of 2.54 cm (1 in.). After removing all undesirable species (e.g. spiny amaranth), samples were placed into labeled paper bags, weighed, and dried for 48 hours in a forced-air oven at 37.8 °C. Teff treatments and plot headlands were cut for hay on 11 August and baled on 17 August.

The remaining treatments died from frost on 8 September, and a swath 4.7 m wide was cut on 18 September using a Hesston rotary swather (model 9260; AGCO, Duluth, GA). Swaths were cut down the respective centers of the pearl millet, sorghum x sudangrass, and German foxtail millet treatments to avoid any edge effect. Only two replicates instead of three were sampled for sorghum x sudangrass due to crop failure in the northernmost treatment from strong rhizomatous grass competition. Forage yield samples were taken immediately after swathing by weighing 4 samples from each replicate, each consisting of the plant material from 86.4 cm (34 in.) of windrow, or 0.0004 ha (0.001 ac.), Equation 1.

$$(4.7m * .864\, m)/10000 \;=\; 0.0004\, ha \qquad \text{Equation 1}$$

Four samples were taken per windrow, one randomly from each third of the test plot, and a fourth sample from a random site. Samples were weighed in the field by placing forage on a canvas sheet, which was then weighed using a Salter Brecknell hanging Scale (model ElectroSamson; Avery Weigh-Tronix, Fairmont, MN) capable of weighing 45 kg

±0.05 kg. A subsample, weighing approximately 250 g, was collected from each sample and used to calculate dry matter percentage and nutritional composition of the forage. Subsamples were weighed and dried for 48 hours in a forced-air oven at 37.8 °C, then chopped in a food processor and pooled by replicate, with a subsample taken from each pooled sample for nutritional analysis (one analysis per replicate). Teff regrowth samples were taken after killing frost in the same manner as previously recorded for teff to calculate total seasonal yield. Corn yield data were calculated from clippings of all corn plants in a 5.63 m section of row, or 0.0004 ha, Equation 2.

$$(5.63m * .71\, m)/10000 = \ 0.0004\, ha \qquad \text{Equation 2}$$

Forage from the clipped area was weighed and a subsample was collected from each replicate and dried to a constant weight to calculate dry matter and nutritional analysis.

Nutritional analysis was conducted utilizing Near Infrared Reflectance spectroscopy (NIR;Cumberland Valley Analytical Services Inc, Hagerstown, MD). Utilizing NIR, forages were tested for dry matter (DM), moisture, crude protein (CP), ADF protein, NDF protein, soluble protein, ADF, NDF, lignin, starch, fat, and ash. Values for degradable protein, TDN, NE_L, NE_M, NE_G (OARDC summative energy equation) and NFC were calculated. In addition, wet chemistry was used to test for the following minerals; calcium (Ca), phosphorus (P), magnesium (Mg), potassium (K), iron (Fe), manganese (Mn), zinc (Zn), and copper (Cu).

Plot perimeters were fenced with a 2-strand, high-tensile electric fence with portable New Zealand-style fencing around each individual treatment. Ten pregnant replacement heifers (≈21 months old) were randomly selected and divided into 2 groups. The heifers were weighed on 25 November, and one group grazed corn replicates while the other group grazed sorghum x sudangrass replicates. Heifers were weighed and the groups re-randomized on 5 December, before being switched to grazing German foxtail millet and pearl millet. Grazing was suspended the 12th through 28th of December due to excessively cold conditions and the difficulty of providing water to animals in the test plot area. Cattle were returned to German foxtail millet and started on teff plots 29 December, and the grazing trial ended on 5 January, 2009 (Table 4).

Year 2 – 2009 Growing Season

Teff harvest data and samples were lost due to procedural failure. The first killing frost was on 8 September, and varieties were swathed and sampled shortly thereafter. Sampling was conducted using the same procedures as in Year 1 with the exception of the corn. Corn sample row length was changed to 5.3 m to correspond with 76.2 cm row width rather than 71 cm row width. Forage analysis and grazing were conducted in the same manner as in Year 1.

$$(5.3m * .762\ m)/10000 = \ 0.0004\ ha \qquad \text{Equation 3}$$

Year 3 – 2010 Growing Season

Teff was harvested on 25 August in the same manner as in Year 1. White proso millet was swathed when grain reached the soft dough stage. Other species were swathed when plants were completely killed by frost, and all treatments were sampled in mid-November. Due to an erratic and thin corn stand, treatments were swathed and forage estimated utilizing the same windrow length as the other treatments. A Pesola PHS100 hanging scale with a precision of ±100 g was used to weigh field samples. The grazing trial was conducted from 6 December to 17 December, utilizing pregnant replacement heifers in three groups of eight individuals (Table 5). Heifers were grazed across test plots in systematic manner with no segregation of groups to treatments.

Statistical Analysis

Data for yield, DM, CP, ADF protein, NDF protein, soluble protein, ADF, NDF, lignin, starch, fat, ash, degradable protein, TDN, NE_L, NE_M, NE_G, NFC, Ca, P, Mg, K, Fe, Mn, Zn, and Cu were analyzed by utilizing a mixed covariate test (Proccovmix) (Statistical Analytical Systems, Cary, NC). The model included species, year, and species x year. Means of species and years were tested using least squared test (LSmeans). Pearl/proso millet data were combined to analyze forage yield across all three years. Teff was excluded when forage data were analyzed across all three years because of the loss of data in year 2. Reported values for the grazing study are yearly averages with no statistical comparisons made amongst species or years.

Results

Forage yield differed amongst species (P < 0.001) and years (P< 0.05). Averaged across all three years, corn (5859.3 ± 578.2 kg/ha) and sorghum x sudangrass (5421.9 ± 604.6 kg/ha) yielded more biomass than Pearl/Proso millet (3161.3 ± 604.6 kg/ha) with German foxtail millet (4448.8 ± 604.6 kg/ha) not different (P> 0.05) from the other treatments. Teff had greater yields (P< 0.05) than Pearl/Proso millet during the two years that yield data was collected; average of 5128.8 ± 474.9 kg/ha. Within species, there was no effect of year on total forage production (*P*= 0.06) between 2008 and 2009; however, production of all species was reduced (*P*< 0.05) in 2010. Corn yields for 2009 (9596.0 ± 826.5 kg/ha) were greater than all other treatments (*P*< 0.01) (Table 6). Sorghum x sudangrass yields in 2009 (6327.8 ± 826.5 kg/ha) were greater than in 2010 (3822.2 ± 826.5 kg/ha) (*P*< 0.05).

Forage analysis (Table 7, Table 8) of the species grown all three years (sorghum x sudangrass, german foxtail millet, corn) showed no difference (*P*> 0.05) among species in crude protein, adjusted crude protein, percent ADF, percent NDF, percent Ca, percent P, percent Mg, percent K, percent Na, ppm Fe, ppm Mn, ppm Zn, and ppm Cu. Corn had greater TDN than German foxtail millet, with sorghum x sudangrass being intermediate (*P* < 0.05). Sorghum x sudangrass had greater DIP than corn, with German foxtail millet being intermediate (*P*< 0.05). Pearl Millet in 2008 (Table 9) had greater CP than corn and teff (*P*< 0.05), greater ACP than corn, teff and sorghum x sudangrass (*P*< 0.05), lower ADF than corn and sorghum x sudangrass (*P*< 0.05), lower NDF than corn and German foxtail millet (*P*< 0.01) and lower Zn than German foxtail millet (*P*< 0.05). Teff in 2008 and 2010 (Table 9, Table 11) had greater TDN, CP, and ACP than German foxtail millet (*P*< 0.01), lower NDF than corn (*P*< 0.05), and greater Cu than corn, German foxtail millet, and sorghum x sudangrass (*P*< 0.01). In 2008, teff had greater TDN than sorghum x sudangrass and pearl millet (*P*< 0.05) and lower Zn than German foxtail millet (*P*< 0.05). In 2010, teff had greater TDN than proso and corn (*P*< 0.05), greater CP and ACP than corn and sorghum x sudangrass (*P*< 0.01), greater DIP and K than corn, German foxtail millet, and sorghum x sudangrass (*P*< 0.05), lower ADF than corn, German foxtail millet, proso millet, and sorghum x sudangrass (*P*< 0.01), lower NDF than German foxtail millet and proso millet (*P*< 0.01), greater P and Na than corn, German foxtail millet, proso millet and sorghum x sudangrass (*P*< 0.05), and greater Mg and Zn than proso millet (*P*< 0.05).

Year 1, cattle grazed two replicates of sorghum x sudangrass and pearl millet each, three replicates of corn and teff each, and four replicates of German foxtail millet. Year 2 and 3 cattle grazed three replicates of each of teff, proso millet, corn, German foxtail millet and sorghum x sudangrass.

Teff averaged 104.6 grazing days/ha, 44.8 grazing days/ha, and 95.6 grazing days/ha for year 1, 2 and 3 respectively. German foxtail millet averaged 168.1 grazing days/ha, 179.3 grazing days/ha, and 191.2 grazing days/ha for years 1, 2, and 3 respectively. Pearl millet averaged 134.5 grazing days/ha in year 1, while proso millet averaged 149.4 grazing days/ha, and 143.4 grazing days/ha in years 2 and 3, respectively. Sorghum x sudan averaged 224.1 grazing days/ha, 194.2 days/ha, and 262.9 grazing days/ha for years 1, 2, and 3 respectively. Corn averaged 149.4 grazing days/ha, 239.0 grazing days/ha, and 143.3 grazing days/ha for years 1, 2, and 3 respectively.

Discussion

Overall, yields at the NMCREEC were in the lower end of the range for sorghum x sudangrass, and lower than reported ranges for teff and pearl millet (Griggs et al., 2008) grown in the Intermountain West region. These lower yields are likely due to the decreased number of growing degree days (base 60) experienced in Salmon, compared to other reported locations (WRCC, 2013). High variability of summer annual species has been reported in the Intermountain West region by location (Griggs et al., 2008) and growing year (Shewmaker et al., 2005). Yearly variation in yield in this trial was similar to that observed in a Kimberly, ID trial (Shewmaker et al., 2005).

When selecting cultivars, seed company recommendations and university field trials should be carefully considered to gain an accurate insight into growing degree days needed for forage production. In addition, climatological data is available from the Western Regional Climate Center (WRCC) to compare seasonal variability at local weather stations.

Sorghum x sudangrass proved to be the most feasible crop for producing large quantities of forage utilizing resources commonly found in the region. In the present study, sorghum x sudangrass produced the most consistent yields and its yields were comparable to two other species investigated – corn and German foxtail millet. In addition, sorghum x sudangrass supported the most animal grazing days of any species producing over 200 animal grazing days per hectare. Finally, nutrient content of sorghum x sudangrass met the nutrient requirement of gestating cows. Seed is readily available and does not require specialized equipment for establishment.

Sorghum x sudangrass exhibits other characteristics which could be beneficial to Idaho agriculture outside of feeding livestock. Sorghum x sudangrass has been shown to suppress nematodes (Macguidin and Layne, 1995) when incorporated as a green manure into the soil. Sorghum x sudangrass also helps with soil compaction when cut for hay and allowed to re-grow, and is recommended for use as a cover crop due to its weed suppression, erosion control, and soil building properties (Valenzuela and Smith, 2002).

However sorghum x sudangrass is not a solution for all forage needs. No animals should be allowed to consume sorghum x sudangrass before it reaches 24" of height, or immediately after a frost due to prussic acid. Problems associated with movement of wheel line irrigation through a mature sorghum x sudangrass field were observed in another study conducted at the NMCREEC where sorghum x sudangrass was seeded earlier in the growing season.

While corn showed the potential for greatest forage yield in year two (Table 6), it also required specialized equipment for establishment. Yields were very sporadic year to year due to attempts of alternative approaches to incorporate a no-till approach with the corn planter. The best planter that we were able to use (year 2), resulted in the highest forage yields (see section entitled forage samples) and grazing days (see section entitled grazing trials) illustrating the huge variation that can occur without the proper equipment for a no-till application.

The use of Roundup Ready® corn seed helped control grasses that survived the initial herbicide treatment before planting. Cost of Roundup Ready® seed per acre is higher due to patents associated with the bio-technology, and while the added costs are recovered in management situations where corn is being raised for grain (Monsanto, 2004), economic research on the effect of weed pressure on total grazable and desirable biomass yield in a short growing season is needed. Concerns with the possibility of weedy species becoming resistant to herbicides through frequent use of Roundup Ready® crops have been expressed and is a growing public concern (Gillam, 2011). In addition, movement of hand irrigation pipe, or wheel lines in an established corn field would be very difficult. Soil erosion with flood irrigation on steeper slopes of benches limits use. Subjective observations indicated that wild ungulates also appeared to have a preference for herbivory on corn plants, and utilized tall plants for cover.

Teff is quick to establish and has potential in areas where soil erosion is of concern. In addition, teff appeared to not be as negatively affected by the reduction in GDD in season 3 as did the other test species. Further testing to evaluate the ability of teff to produce well in areas of high seasonal variability is needed.

Due to its fine stems, teff laid flat under snow and regrowth was more difficult for cattle to graze on un-swathed portions of treatments. The ability of teff to rapidly produce a crop necessitated cutting a hay crop and then grazing the regrowth. This characteristic makes it less desirable as an extended grazing crop as only a portion (approximately 25%) of the annual yield was available for grazing. Therefore, teff is not an acceptable standing or windrowed grazing crop for fall and winter cow nutrition.

Pearl and proso millets had the lowest yields and while pearl millet had higher CP, CP was not a limiting factor for gestating cows with any of the forages tested. However, proso millet could have a niche application in areas where bird hunting is desired (Hayslette and Mirarchi 2001), and forage production is secondary. Proso established seed during the test plot trials in 2010, but due to hard seed coats, it is unlikely that the grain added much feed value due to an inability of ruminants to digest unprocessed grain (Berglund, 2007). The high level of maturation associated with seed set, in addition to a lower leaf to stem ratio (Baltensperger et al., 1995) likely resulted in the higher levels of ADF and NDF observed with the proso millet.

German foxtail millet resulted in the second highest amount of animal grazing days in both 2008 and 2010 with only sorghum x sudangrass hybrid resulting in more animal grazing days. German foxtail millet shows potential for use in areas where windrowed or standing graze is desired, or as a potential use in locations where fear of grazing cattle gaining access to the forages while in a young stage would prohibit the use of sorghum x sudangrass hybrids. However, it is possible that German foxtail millet will accumulate nitrates while in a young stage or in stressed conditions (Lang, 2001).

Pregnant replacement heifers in second trimester with a mature weight of 533 kg have a NE_m requirement of 6.77 Mcal/d and a protein requirement of 334 g/d, while a mature beef cow of same weight would have a NE_m requirement of 8.54 Mcal/d and a protein requirement of 422 g/day (NRC, 2000). Assuming animals were consuming 2% of their given body weight per day, and were not subjected to environmental extremes outside of their thermoneutral zone, all tested forages contained adequate energy and protein to support the animals. However, extending the grazing season in the Intermountain west will most likely result in times where animals are subjected to environmental variables that may necessitate additional supplementation. Sorghum x sudangrass hybrids resulted in the most animal grazing days in 2008 and 2010 (224.1, 262.9 AUD/ha respectively).

The grazing trial experienced some difficulties due to location and weather conditions. Distance of test plots from scales and working facilities, and limited number of animal grazing days resulted in animals only being weighed at the beginning and end of the trial. The short duration of the grazing trial made it difficult to assess the impact grazing the forages had on animal body condition.

Sub-zero weather conditions made it extremely difficult to provide water to the grazing animals where the test plots had no electricity or flowing water and required water to be hauled every day. Similar to Turner and Angell (1987), heavy snowfall resulted in times where feeding of hay was necessary until the feeding trial could resume when the snow melted. The authors mention grazing of areas which accumulate snow and ice first, and to increase the amount of forage in raked-bunches. In our study, raking swathed windrows together may have enabled continued grazing.

A potential management scenario where producers could utilize the warm season grasses is in the renovation of fields used for alfalfa production. Alfalfa hay (*Medicago sativa*) is commonly grown throughout Idaho as a forage crop for hay production, but these stands eventually die out and are overtaken by grasses and forbs requiring cultivation and replanting. Allelopathy associated with mature alfalfa plants (Miller 1996), alfalfa pests and diseases (U. C. Davis, 1981), and weed control (Liebman & Dyck, 1993) make it beneficial to include a year of rest rotation before re-seeding alfalfa. This delay in replanting may lead to a reduction in forage production and additional expenses associated with sod cultivation.

Overgrown alfalfa fields produce greater first cutting yields, with subsequent cuttings resulting in decreased forage production (Spandl et al., 1997). Forage production may be increased during alfalfa replacement by planting of annual warm-season C_4 grasses after harvesting of the first cutting of hay. Warm season C_4 forages are productive during hot weather, with ideal growth occurring between 30° and 35°C (Buxton and Mertens, 1995), and provide greater water-use efficiency than C_3 forages (Volenec & Nelson, 2007). First cutting of alfalfa, in the higher elevations of Idaho, is typically finished by the end of

June. With the utilization of herbicides and no-till or minimal-till planting, these alternative C_4 grasses could be planted by the first of July, coinciding with the time frame of the current study

Conclusion

Summer annuals can produce abundant forage for late fall and early winter grazing in the high elevation (1200 m to 1500 m) Intermountain West. Irrigation is required to realize acceptable tonnage of forage. Of the five species tested in this study (sorghum x sudangrass, German foxtail millet, corn, proso millet, and teff), sorghum x sudangrass produced the most consistent yields and highest number of animal grazing days. Yearly variation in growing degree days will affect forage yields. All species tested would provide adequate nutrition for gestating cows when planted so heading coincides with the first killing frost. Producers need to manage fertilization and grazing practices to minimize potential problems with nitrate or prussic acid poisoning of livestock. An additional application of warm season annuals may be as a forage crop during hayfield renovation. Further research is needed on the economics of using summer annuals to extend the grazing season.

Chapter 3: Winter Annual Production of Non-irrigated Farmland in High-Elevation Intermountain West

Abstract

Increasing popularity of center pivots combined with rising pumping expenses have resulted in changes in management approaches to agricultural grounds in the high-elevations of the Intermountain West. Three species of winter annuals; Triticale (x *Triticosecale*Wittm.), Austrian winter pea (AWP) (*Pisumsativum* L.), and cereal rye (*Secale cereal* L.) were planted around dry corners of pivot irrigation with existing vegetation constituting a control treatment. Species were planted into no-tilled and extensively-tilled plots over two years. Treatments were control, triticale, AWP, cereal rye and triticale x AWP. Forage was analyzed for nutritional quality by a commercial laboratory, and ruminal degradability *in situ*. Test plots received 32.76 and 92.20 mm of precipitation from September-December for years one and two respectively. First year was a complete crop failure. Second year triticale/AWP (10,680 ± 602 kg/ha) triticale (8400 ± 602 kg/ha) and cereal rye (8250 ± 632 kg/ha) had the greatest yields (P = 0.001), followed by control (3440 ± 884 kg/ha) and AWP (3,360 ± 625 kg/ha). No differences were observed between tilled and no-tilled treatments (P = 0.098). Austrian winter pea had greater CP and lower NDF and ADF than the cereal grains (P< 0.05). In situ ruminal degradability was conducted for 3 time periods; 0, 24 and 96 hours. AWP had the highest Dry matter degradation. The potential for high yields of forage from non-irrigated corner areas exists, but may be greatly affected by year. Further research should investigate long term profitability of winter annual species for forage production of non-irrigated areas.

Study Site

Forage trials were conducted at the Nancy M. Cummings Research Extension and Education Center (NMCREEC; N 45°17’10”, W113°53’6”) to assess nutritional quality and forage production potential of winter annual species grown on non-irrigated areas. Soils at the test plot locations were either a Shenon Loam or a Shenon-Perreau loamy soil with test plot elevation of approximately 1160 m. Triticale(x *Triticosecale* Wittm.), Austrian winter pea (AWP) (*Pisumsativum* L.), and cereal rye (*Secale cereal* L.) were identified for their potential winter hardiness and were planted on dry corners of fields under center-pivot irrigation. Cereal rye seed proved to be difficult to procure locally because it is not well accepted in grain production areas due to its propensity to go wile; thus rye was planted only in the second year at NMCREEC.

Materials and Methods

Planting/Growing Season

Year 1 – Fall 2009 - Summer 2010

Two plots (hereafter Northeast, Southwest) were created on dry corners of two center pivots with each plot assigned 2 replicates (total of 4 replicates) of each of 5 treatments: control (currently established perennial forages predominately orchardgrass, alfalfa, and quackgrass); triticale; Triticale/AWP (triticale/AWP) mix; AWP; and cereal rye. Each treatment was randomly assigned for the first replicate, and then planted in the same order for the following 3 replicates. Treatments were 45.72 m x 7.32 m and received tillage every other 7.62 m, resulting in three 7.32 x 7.62-m tilled rectangles alternating with three 7.32 x

7.62-m non-tilled rectangles staggered across each replicate. A 0.61-m gap was left between treatments.

All treatments (except the control) were sprayed with 4.68 L/ha glyphosate herbicide on 21 September, 2009, then later disked with a John Deere offset disc (model 425, John Deere, Moline, IL) and the seedbed prepared with a Brillion roller harrow (model 41; Landoll Corp., Brillion, WI) before planting. A 3.66-m no-till drill (Model 1000; Haybuster, Jamestown, ND) with 17.78 cm row spacing was used to plant treatments. All triticale (cultivar Trical 102; Syngenta Cereals, Berthoud, CO) treatments were planted on 7 October, 2009, with the machine set for 89.7 kg/ha. All AWP treatments were planted on 9 October with the machine set at 56.1 kg/ha and all triticale/AWP treatments were planted on 9 October with the machine set for a rate of 89.7 kg/ha triticale, and 56.1 kg of AWP per hectare. Cereal rye treatment areas were left open because seed was not procured.

Fall plant counts were conducted on 13 November for the Northeast plot, and 24 November for the Southwest plot. Eighteen points per replicate were found by measuring 0.91 m of a row located 1.83 m from the southern edge of the 7.62 m section edge, with samples collected 1.83 m, 3.66 m, and 5.49 m from the western edge of the treatment. This was repeated for each section with 6 sections per treatment (3 tilled, 3 no-tilled), resulting in 18 observations per replicate. Plants per square foot were calculated by multiplying the number of plants per 3 ft of row by four and dividing the product by the drill row width (Rankin 2009).

$$Plants\ per\ ft.^2 = \frac{plants\ per\ 3\ ft.\ of\ row\ x\ 4}{drill\ width} \qquad \text{Equation 4}$$

Spring plant counts on the Southwest and Northeast plots were conducted on 2 April and 4 April, respectively, in the same manner as the fall counts. Densities (plants/m^2) within the plots of desired plant species were small, but deemed sufficient to allow growth throughout the course of the spring. The Northeast plot failed to show adequate densities of desired plant species and was abandoned for the growing season. The Northeast plot was sprayed with 4.675 L/ha glyphosate herbicide on 9 June, and weeds were mowed with a 2.13-m John Deere rotary mower on 22 June. The tilled treatments were V-ripped (Brillion model SCP-01, Landoll Corp., Brillion, WI) at a depth of 45.7 cm then roller harrowed (Brillion model 41, Landoll Corp., Brillion, WI) on 24 June and left fallow. The Northeast plot control treatments were lost to spray damage when the rest of the treatments were sprayed on 9 June.

Visual appraisal of plant biomass of the Southwest plot at harvest time was deemed insufficient to warrant extensive yield sampling, but samples of triticale and AWP were collected for nutrient analysis. Triticale and AWP samples were taken when the triticale reached the bloom stage and the AWP were at half bloom, half pod set. The samples were dried to a constant weight and analyzed through proximate analysis. Constant weight was determined when no change in weight occurred over a 24 hour period in the forced air drier set at 38 °C.

Year 2 – Fall 2010 – Summer 2011

Tilled and no-tilled sub-treatments were in the same order and location as Year 1. Tilled plots were V-ripped at a depth of 45.7-cm on 10 September, 2010, and roller harrowed on the same day in preparation for planting. Control treatments were V-ripped and roller harrowed in the same manner as the planted replicates. Both no-tilled and tilled sub-treatments were roller harrowed in an attempt to remove weedy winter annuals which had germinated in response to heavy rains.

Only two control replicates remained after the control treatments in the Northeast plot were accidentally sprayed with herbicide at the end of the first growing season. To control weeds and utilize space, extra replicates were planted to triticale and triticale/AWP in the Northeast plot. Block 1 was randomized and the other 3 blocks were planted in the same sequential order as in the first replicate. Triticale, triticale/AWP, and AWP were planted on 18 September, with beardless triticale (var. Beardless; Walton Feed, Montpelier, ID) replacing the Cultivar Trical 102. Cereal rye (var. VNS; Utah Seed, Clearfield, UT) was planted on 8 October. All varieties were planted with a Haybuster no-till drill (Model 1206; Haybuster, Jamestown, ND) with no adjustments in planter depth made for the tilled versus no-tilled sub-treatments. Actual planting rates were as follows; triticale was planted at 98.7 kg/ha, triticale/AWP at 85.1 kg/67.3 kg/ha, AWP at 115.5 kg/ha, and cereal rye at 125.6 kg/ha (Table 12). The seed in the planter was weighed before and after planting to allow for more accurate calculation of total kilograms planted per hectare.

Fall plant counts were not conducted in 2010 as the plots were covered earlier than expected with snow. Spring counts were conducted on 20 March, 2011, as soon as the plots were free of snow. Six random points for each replicate, 3 points each in the tilled and no-tilled sub-treatments were measured. Plants per square foot were calculated using same formula as in the prior year.

Forage Yield

Year 1 - Fall 2009 - Summer 2010

On the Southwestern plot, samples were collected of triticale, AWP, and the control treatment. Due to sporadic placement of desired vegetation, samples were gathered from across all treatments and sub-treatments. Ten samples of approximately 250 g were collected for each forage species (triticale, AWP, control) and dried in a forced air dryer at 38 °C until they reached a constant weight.

Year 2 – Fall 2010 – Summer 2011

Plots were sampled from 19-23 June, 2011, when treatments were in the early bloom stage. One treatment was harvested each day with control harvested the same day as the AWP, in the following order: cereal rye, triticale, triticale/AWP, AWP, and control. A strip was cut down the center of each sub-plot (e.g. Triticale-tilled) with a 2.74-m sickle bar mower (New Holland, New Holland, PA) the evening before sampling, with the exception of AWP. Plot samples were taken by removing desirable forage from a 3.05-m section of swathed row in the middle of each 7.62-m sub-treatment (2.13-5.18-m). All non-desirable species were eliminated from the samples by hand sorting. Samples were weighed utilizing a Pesola PHS100 hanging scale with a precision of ±100g. A sub-sample was collected by taking three samples from different parts of the bundle. Sub-samples were immediately weighed and used for dry matter determination, nutrient analysis, and in-situ testing.

The AWP was difficult to harvest with the sickle bar mower as the peas tended to clump, which made cutting difficult. An alternative harvest method was tested where a

Hesston rotary swather (model 9260, Agco, Duluth, GA) was used to cut a swath down the middle of the plot and take a subsample from the windrow. The swather macerated the peas and mixed large amounts of soil in with the windrow. The final approach was to pull the vegetation across the cutting bar of the sickle bar mower using a garden rake. This resulted in 3 replicates having a sample area of 2.74 x 3.05 m (8.36 m^2) and one replicate having a sample area of) 1.22 x 4.57 m (5.57 m^2). Samples were then dried and analyzed in the same manner as the other forage species.

Forage Analysis

Year 1 – Fall 2009 – Summer 2010

Subsamples were dried to a constant weight and stored inside a dry shed until analysis was conducted in 2011. Constant weight was determined when no change in weight occurred over a 24 hour period in the forced air drier set at 38 °C. Samples were ground in a Wiley mill (Eberbach Corp., Ann Arbor, MI) to pass through a 6 mm screen and pooled to give one value each for triticale, AWP, and control treatment.

Nutritional analysis was conducted using wet chemistry by a commercial laboratory (Dairy One, Ithaca, NY). Samples were tested for moisture, dry matter (DM), crude protein (CP), adjusted crude protein, ADF, NDF, NFC, and ash. Values for TDN, NE_L, NE_M, NE_G and RFV were calculated.

Year 2 – Fall 2010 - Summer 2011

Approximately 500 g, wet weight, of long-stem forage was removed from each sample to compose a sub-sample. Sub-samples consisted of a minimum of three grabs from different sections of the yield sample. Sub-samples were placed into paper grocery bags and weighed immediately. Due to the large volume of samples and limited dryer space, samples were initially dried for 24 hours at 38 °C, and later re-dried at 38 °C in a force air oven until they reached a constant weight. Samples were sealed in plastic bags, which were transported in plastic totes to Moscow, Idaho, to be ground through a Wiley mill. Approximately one month elapsed from initial sample collection to final dry weight recorded.

A Wiley mill fitted with a 6-mm screen was used to grind all dried, long stem forage samples. The mill was cleaned with compressed air after each sample. After grinding, a 5 g subsample was dried in a force air oven at 100°C for 24 hours to determine final dry matter. A desiccation chamber held the samples after removal from the oven until they equilibrated to room temperature. Tilled and un-tilled samples from each replicate were pooled and shipped to a commercial laboratory for nutritional analysis, with pooled samples being weighted based on yield produced.

In-situ **Degradation Trial**

The *in situ* trial used a 3x5x3 factorial design with 3 cows, 5 forages, and 3 hour intervals to investigate dry matter disappearance at 0, 24, and 96 hour intervals for forages grown in year 2. Protocol followed guidelines laid out by Vanzant (Vanzant et. al, 1998). Neutral Detergent Fiber disappearance was calculated and *in situ* true degradability (24 hour samples), and extended *in situ* true degradability (96 hour samples minus solubles) were calculated by treating post incubated samples with NDF detergent.

Each *in situ* sample was assigned a code for identification purposes. Codes were transcribed onto a 10 x 20-cm dacron forage *in situ* bag (10x20-cm; Ankom Technology, Macedon, NY) with 50 micron porosity, using a permanent marker. Bags were then weighed and approximately five grams of sample was added to each bag. Bags were triple sealed with an impulse sealer, and compartmentalized into 36 x 50-cm lingerie bags, according to cow and incubation time. Twenty *in situ* bags were placed into each lingerie bag and 4 lingerie bags were placed into each cow by the end of the experiment. All in-situ bags were removed at the same time at the end of the 96 hour incubation period.

In-situ degradation was conducted at the NMCREEC located in Salmon, Idaho. Three mature angus crossbred cows, in late lactation, were placed on a total mixed ration (TMR) consisting of 60% forage, 30% cracked corn, and 10% vitamin mineral mix 10 days before the beginning of the trial and were fed *ad libitum*. Bags were soaked in cold tap water for 20 minutes prior to insertion into the ventral rumen of the cow, with the exception of the 0 hour bags. Bags were attached to the plug of the cannula using a lanyard attached to the lingerie bag and an eye bolt through the cannula plug. Ninety-six-hour bags were inserted first, with 24 hour bags inserted following the same protocol three days later, and all bags removed at same time. Zero-hour bags were soaked for 20 minutes in cold tap water, prior to being hand washed with the 24- and 96-hour bags. All bags were removed from cows at the same time and placed into ice water for one minute. Samples were then removed from lingerie bags and hand-washed in tap water until the rinse water ran clear. After being washed, bags were placed on trays and dried in a force-air oven at 50°C for 48 hours, then stored in a plastic tote for transportation to Moscow, Idaho. *In situ* bags were re-dried in Moscow at 100°C in a force-air oven for 24 hours, then placed in a desiccation chamber to equilibrate with room temperature. Samples were then weighed and dry matter degradation calculated.

After calculation of dry matter degradation, *in situ* bags were treated with neutral detergent fiber (NDF) solution to calculate NDF disappearance and true digestibilities. The NDF chemicals were purchased as a concentrate from Ankom technology. The concentrate was mixed with de-ionized water and placed on a stir plate until the solution was clear and devoid of lumps. Twelve *in situ* bags were submerged at a time and boiled in 2000 mL NDF solution for 60 minutes. After boiling, samples were washed then dried at 100 °C in a force-air oven for 24 hours. Samples were removed and placed in a desiccation chamber until they reached room temperature, at which point they were weighed and NDF disappearance calculated.

Statistical Analysis

Yield, DM, CP, adjusted crude protein, ADF, NDF, NFC, ash, TDN, NE_L, NE_M, NE_G and RFV were analyzed using a mixed model procedure with covariate analysis (SAS; proccovmix). Model included treatment, sub-treatment and treatment x sub-treatment. Least squared test (LSmeans) was used to test significance of treatment and sub-treatment. Due to failure to properly randomize plots, confidence interval was set at 99%. *In situ* trial data for percent degradation, true digestibilities, and NDF disappearance were analyzed using a mixed model procedure with covariate analysis (SAS;proccovmix) at a 95%

confidence interval. Model included treatment, sub-treatment, treatment x sub-treatment, *In situ* hour, *In situ* hour x treatment, *In situ* hour x sub-treatment, *In situ* hour x treatment x sub-treatment. Least squared test was used to test treatment, *In situ* hour, sub-treatment, and *In situ* hour x treatment.

Results

Year 1 – Fall 2009 - Summer 2010

Plots received 32.8 mm of precipitation from September 2009-December 2009 (Figure 1: WRCC, 2013). Lack of rainfall resulted in poor germination and wide spread crop failure. Due to crop failure, following data are preliminary. Northeast plot plant counts in fall 2009 averaged 98.0 ± 15.1, 80.7 ± 17.2, and 9.7 ± 3.2 plants/m^2 for triticale, triticale/AWP, and AWP, respectively. Southwest plot averaged 93.7 ± 16.2 plants/m^2, 57.1 ± 6.5 plants/m^2, and 21.5 ± 4.3 plants/m^2 for triticale, triticale/AWP, and AWP, respectively. No significant numbers of plants survived the winter on the northeast plot. Southwest plot averaged 16.2 ± 5.4 plants/m^2, 6.5 ± 3.2 plants/m^2, and 4.3 ± 3.2 plants/m^2 of triticale, triticale/AWP, and AWP in Spring 2010, respectively. Forage yields were not taken for the 2009-2010 growing season. Nutrient analysis numerically showed AWP as having higher digestibility and feed value than control and triticale treatments (Table 15).

Year 2 – Fall 2010- Summer 2011

Study site received 133.1 mm of precipitation from September 2010 - December 2010 (Figure 1). Earlier than expected snowfall covered the plots before plant counts were conducted in the fall of 2010. Spring plant counts resulted in an average of 93.7 ± 6.5, 114.1

± 6.5, 32.3 ± 2.2, and 167.9 ± 10.8 plants/m^2 for triticale, triticale/AWP, AWP, and cereal rye, respectively.. The log of the plant count numbers were used for statistical analysis, with a significant difference in number of plants/m^2 between all treatments ($P < 0.05$).

Yield data were considered to be significantly different at the 99% confidence interval ($P < 0.01$). This greater level of significance was chosen to compensate for tilled and no-tilled blocks being in strips rather than randomly distributed within replicates. The triticale/AWP combination resulted in the highest yield in 2010-2011 with an average of 10,680 ± 602 kg/ha ($P = 0.02$) but because of the higher degree of confidence, is not considered significantly different from triticale and cereal rye. Triticale and cereal rye averaged 8,400 ± 602 and 8,250 ± 632 kg/ha, respectively, and control and AWP averaging 3,440 ± 884 and 3,360 ± 625 kg/ha, respectively. No significant differences were observed when all no-tilled treatments were compared with all tilled treatments ($P = 0.098$).

Forage analysis showed no difference ($P > 0.05$) in percent CP, Adjusted CP, NDF, NFC, TDN, NE_L, NE_M, NE_G, and RFV between triticale, triticale/AWP, cereal rye, and control samples in 2010-2011 grow year. Austrian winter pea had greater CP ($P < 0.0001$), adjusted CP ($P < 0.0001$), NFC ($P < 0.01$), TDN ($P < 0.01$), NE_L($P < 0.0001$), NE_M ($P < 0.001$), NE_G ($P < 0.001$),and RFV ($P < 0.0001$) with lower NDF ($P < 0.0001$) than all other treatments. Austrian Winter Pea treatments had lower ADF than rye ($P < 0.01$), triticale/AWP ($P < 0.001$), and triticale ($P < 0.001$) treatments while control had less ADF than triticale/AWP ($P < 0.05$) and triticale ($P < 0.05$) treatments. Rye had the lowest percent Ash (7.5%, SE ±0.59, $P < 0.05$), with no difference amongst other treatments (Table 15).

Dry matter degradation (Table 17) had a treatment by *in situ* hour interaction (*P*< 0.0001). The AWP had the highest dry matter degradation (71.97%; *P*< 0.0001). The perennial grasses and forbs associated with the control treatment had a greater percent dry matter degradation at 24 and 96 hours (46.66 % ±1.89%; 68.68% ± 1.89%) than triticale (41.27% ± 1.59%; 60.34% ± 1.59%) and triticale/AWP (41.06% ± 1.59%; 59.33% ± 1.59%) (*P*< 0.01). Control also had a greater percent dry matter degradation than cereal rye at 96 hours (60.73% ± 1.64%) (*P*< 0.01). Cereal rye had a greater dry matter degradation at 24 hours (43.84% ± 1.64%) than triticale (41.27% ± 1.59%) and triticale/AWP (41.06% ± 1.59%)(*P*< 0.05).

The true *in situ* degradability and extended true *in situ* degradability was greatest for AWP (68.6% ± 1.5%) (74.4% ± 1.5%) (*P*< 0.001), with control treatments (50.4 ± 1.5; 72 ± 1.5) (*P*< 0.05) being intermediate. No differences occurred between rye, triticale, and triticale/AWP for true degradability.

The *in situ* disappearance of NDF (Table 18) (Figure 3) for AWP at 24 hours (24.25% ± 2.48%) was greater (*P*< 0.01) than cereal rye, triticale, and triticale/AWP, with control species having no significant difference between AWP and cereal rye. At 96 hours, control species had the greatest (*P*< 0.0001) NDF disappearance (55.72% ± 2.85%) with cereal rye, triticale and triticale/AWP being intermediate and AWP having the least amount of disappearance at 96 hours (38.51% ± 2.46%) (*P*< 0.05).

Discussion

In 2008, Idaho had 52.9%, or 1,758,277 acres of its 3,319,827 total irrigated acres, under center pivot irrigation (USDA-NASS, 2010). Other states in the region had lower percentages of irrigated acres under center pivot systems (Utah at 48.8%, Montana at 45.3%, and Wyoming at 23.5% of total irrigated acres under center pivot irrigation). Economic feasibility of extending irrigation to the dry corner areas of pivots is not present in all applications, therefore, there are dry corners associated with the use of center pivot irrigation.

In the present study, differences in moisture between the two years greatly affected forage results. Soil tillage the fall of 2009 immediately before planting resulted in a rough, powdery, dry seed bed for tilled treatments. Intensive tillage practices have been known to aggravate dry conditions (Dao, 1993). Salmon had a total of 137.2 mm precipitation (Sept. –May) at the KSRA weather station in 2009-10, but approximately half (50.9%) of that precipitation came in April and May (WRCC, 2013). Contrast that to 2010 when the KSRA station received 133.1 mm of precipitation from September through December. In 2009-10, January through May received 104.4 mm, in 2010-11 January through May received 85.9 mm. Fall precipitation at time of establishment was the greatest difference between the two seasons.

Forage yield of cereal rye, triticale and triticale/AWP did not differ significantly at a 99% confidence interval. Cash et al. (2007) reported forage yields ranging from 3295 to 8585 kg/ha of triticale raised under re-crop and fallow situations during 4 years of drought in Montana. Mut et al. (2006) reported that triticale produced more forage than wheat and barley, yielding 7058 kg/ha average across 12 genotypes at heading stage. In the present study, season 2 yields of triticale/AWP are higher than those reported by Welty (1984) examining forage yields of Barley + AWP and Oats + AWP in Kalispell, MT raised both under irrigation and as dryland crops.

Nutritional quality of triticale was not different than that of triticale/AWP. Redmon et al. (2008) showed that AWP increased the crude protein content of winter wheat sampled in May, but did not influence total biomass production. In the present study, triticale/AWP had similar crude protein levels compared to triticale alone. A possible reason for the failure of addition of AWP to triticale to increase CP content of the forage could be the exceptional growth of triticale plants in year two resulting in a change of weight of legume to weight of cereal ratio observed by Redmon et al. (2008). Forage composition between triticale and AWP was not quantified in this study.

Austrian winter pea, when planted in a monoculture, proved to be difficult to harvest and dry. However, the forage quality of the AWP (CP, ADF, NDF, NFC, TDN) was significantly greater than the cereals and cereal/AWP mixtures. The values for AWP are similar to those reported by Schultz (2010; ADF 34.0%, NDF 40.1%) for AWP in pre-bud. While AWP is of higher nutritive value than needed for a mid-gestation mature cows (NRC, 2000), stored AWP forage could be used as a supplement, or standing crop could be used as a green manure. Portable fences could be used to graze dry corners that are adjacent to non-forage crops. If seasonal moisture was sufficient to carry the crop to seed set, grain from AWP could be used as a supplement to wintering cows or as part of a ration for younger and/or lactating animals.

Cereal rye produced yields similar to triticale and triticale/AWP mixtures, with no difference in lab-analyzed nutritional qualities. While cereal rye is more cold tolerant than other domesticated cereals (Forage Information System, 2009), the difficulty of procuring seed prevented us from growing cereal rye in the first season when environmental conditions were more extreme. The difficulty of procuring the seed is due to the ability of cereal rye to become feral and infect other cereal crops (White et al., 2006). In areas that produce other cereals for grain crops (e.g. malt barley), growing cereal rye could be viewed unfavorably, especially in seed producing areas of Idaho (e.g. Grace, ID). Cereal rye can also cause physical damage to the mouths of cattle consuming mature forage from sharp awns (Hennessy and Clements, 2009). Due to cereal rye's unfavorable status, and the potential for harm to cattle, triticale appears to be the better option assuming it can continue to survive cold, dry winters.

Control treatments yielded similarly as AWP treatments, but had similar nutritional quality as triticale, triticale/AWP, and cereal rye. Plots were not fertilized and the high yields that the winter annuals experienced could be due in part to the nutrient release associated with the breakdown of the root structure of the perennial forages that were present before plot establishment. However, Cash et al. (2007) showed that annual forages had higher yields than perennial grasses and alfalfa during a drought. Uses of established perennial grasses or dry land alfalfa species could be advantageous in areas where risk of soil erosion on steep slopes necessitates constant cover. In this study, with a significant decrease in forage yield and no improvement in nutritional quality of the feed, control treatments were not advantageous.

Lab analysis of the nutritional quality of the feeds showed all forages to be adequate for protein and energy to meet the requirements of pregnant replacement heifers and non-lactating beef cows (52-55% TDN, 7-9% CP; NRC, 2000). The AWP was adequate to meet energy and protein requirements of mature beef cows during lactation (NRC, 2000). The protein levels of triticale, triticale/AWP, cereal rye, and control were high enough to meet protein requirements of late lactation, but were insufficient in energy. Triticale, triticale/AWP, and cereal rye could be useful in providing fiber for a total mixed ration used for growing steers or dairy animals due to its high levels of NDF and ADF.

In situ degradation observations had results similar to that which was expected from the proximate analysis. Austrian winter peas had a high water soluble content (0 hour) and were quickly degraded within the rumen typical of high protein, low fiber forages. Schultz (2010) found that some AWP samples were insufficient in fiber to maintain rumen function, and should be treated more as a concentrate than forage in rations. The low percent disappearance of the NDF fraction of AWP at 96 hours compared to grass species is expected due to the relatively low percent of hemicellulose found in legumes compared to grasses, and the higher proportion of lignin in legumes compared to grasses (Van Soest, 1982). Control species were intermediate in dry matter disappearance at 24 and 96 hours. Hoffman et. al (1993) reported ruminally degradable organic matter values for brome grass and quackgrass in boot phase at 55.5 and 43.3 percent. Observed 24 hour dry matter degradability of control species was 46.6 percent in the current study.

Triticale was initially developed as a cereal crop from the crossing of cereal rye and durum wheat. Because the two species are closely related, one would expect similar degradation kinetics between cereal rye and triticale. Cereal rye had higher dry matter disappearance at 24 hours, but no differences existed at 96 hours. In addition, no differences in percent NDF degradation existed at 24 hours between cereal rye and triticale. Because all treatments were hand washed it's possible that triticale and triticale/AWP had higher microbial protein residues remaining attached to samples. It has also been shown that *in situ* digestibility of starches have been found to vary with feeds, and the digestibility of specific feeds can vary depending upon whether concentrates are present in the ration (Cerneau and Michalet-Doreau, 1991). Another possibility is that differences in rate of ruminal degradation of protein existed between species. While AWP should have added nutritional quality to the triticale/AWP plantings, the *in situ* trial corroborated the lab analysis in that there were no significant nutritional differences between the triticale and the triticale/AWP.

Conclusion

When grown in dry pivot corners, triticale or rye in monoculture or with Austrian winter peas has the potential for excellent forage yields. However, yields appear to be highly dependent on the quantity of fall and winter moisture. The two winter cereals tested contained sufficient nutritional content to meet the requirements of cows in mid-gestation. There is little difference in nutritional content of triticale and rye as indicted by results from proximate analysis and *in situ* degradation. Addition of Austrian winter pea to the winter cereals may enhance nutrient content of forage. Selection of species should be tempered by the ability to control weeds in stands or the potential for the species to become a weed if it escapes pivot corners. Further research is needed to develop decision making tools for planting winter cereals in dry pivot corners.

Chapter 4: Winter Annual Production of Non-irrigated Farmland in High-Elevation Intermountain Valleys at Producer Co-operator Locations

Abstract

Producer trials were conducted at two locations. At location A, triticale and AWP were planted for two years in non-irrigated corners around a center pivot. At Location B, triticale was planted one year in a formerly cultivated field that had been abandoned due to high irrigation costs. Location One received 72.64 and 180.59 mm of precipitation from September – December in years one (2009) and two (2010) respectively. Location B received 92.20 mm of precipitation September – December. Location A had no difference in desired plant yield (3380 ± 330; 2280 ± 330 kg/ha) between treatments ($P = 0.11$), but experienced a difference between years ($P < 0.01$) and total yield ($P < 0.01$). Location B preliminary data had a yield average of 3280 ± 150.2 kg/ha.

Study Sites

Location A was 7.2 km southwest of Grace, Idaho (N 42°31 17” W 111°48’47”) at an elevation of 1570 m. Location B was located 10.5 km east of Carmen, Idaho (N 45°18’45” W 113°48’29”) at an elevation of 1530 m. Location A was located on the outer edge of a circular irrigation pivot. Location B consisted of approximately 2 hectares that had historically been farmed, but had been abandoned.

Materials and Methods, Location A

Year 1 - Fall 2009- Spring 2010

Three corners around a pivot (corners were not symmetrical in size due to physical obstructions) were placed into one of two treatments: triticale, or triticale /AWP. The southeast and southwest corners were planted to straight triticale (var. Beardless; Walton Feed, Montpelier, ID), making approximately 1.6 hectares combined. The northwest corner was planted to triticale/AWP and resulted in approximately 1.6 hectares. The fields were no-till planted into the previous crop's residue, utilizing a conventional grain drill. Corners were planted by the producer co-operator with triticale on 26 September, 2009, and AWP on 3 October, 2009. Planting rates were 18.4 kg/ha for triticale, and 12.9/5.5 kg/ha for triticale/AWP respectively.

Plant counts were conducted on 31 October, and again the following spring on 2 April, 2010. Counts were conducted by the producer co-operator. Plant counts were conducted in the same manner as done at the NMCREEC (Chapter 3), with 0.91 meter of row being measured and desired plant density determined, with plants/m^2 calculated (equation 4).

Plots were harvested on 28 June, 2010, when triticale reached bloom stage. Before cutting, six transects were randomly selected and run east to west in each treatment. Transects were 30.5 m long with samples taken at 10 m, 20 m, and 30 m. All biomass within a 0.5 m^2 circle was clipped at ground level, placed into plastic bags, and immediately transported to Salmon, ID to be weighed, sorted and dried. Samples were sorted based upon vegetation type (triticale, AWP, and weeds), and each group was weighed and dried at 38 °C to a constant weight.

Year 2 - Fall 2010 – Spring 2011

Corners were dragged with carpet harrows in an attempt to remove germinated winter annuals, primarily cheatgrass (*Bromus tectorum* L.). Corners were planted with beardless triticale and AWP on 9 October. Corners received opposite treatment from the year prior. Plant counts were conducted on 13 November, 2010 and again the following spring on 2 May, 2011, in the same manner as in the year prior.

Field samples were taken on 5 July, 2011, in the same manner as the year prior. Triticale was in bloom and the Austrian winter peas were blooming and just beginning to set pods. Samples were then weighed and dried at 30 °C in a forced-air oven until they reached a constant weight.

Forage Analysis

Samples were transported to Moscow, ID, in plastic totes. Long stem samples were ground through a Wiley mill fitted with a 6 mm screen, and 5 g sub-samples were dried at 100°C in a forced-air oven for 24 hours to calculate final dry matter. After drying, samples were placed in a desiccation chamber and allowed to thermally equilibrate to room temperature. Samples were pooled (transects 1 and 2, 3 and 4, and 5 and 6 were combined) and shipped for nutritional analysis of test species.

Nutritional analysis was conducted through wet chemistry by a commercial laboratory (Dairy One, Ithaca, NY). Samples were tested for moisture, dry matter (DM), crude protein (CP), adjusted CP, ADF, NDF, NFC, and ash. Values for TDN, NE_L, NE_M, NE_G and RFV were calculated.

Statistical Analysis

Yield, DM, CP, adjusted CP, ADF, NDF, NFC, ash, TDN, NE_L, NE_M, NE_G and RFV were analyzed using a mixed model procedure (SAS; proc mixed). Model included treatment, year and treatment x year. Least squared test (LSmeans) was used to test significance of treatment and year. Confidence interval was set at 95% interval.

Results

Location A received 72.64 and 180.59 mm (Figure 4) of precipitation from September -December in years one and two of the study (WRCC, 2013), respectively. Fall 2009 plant counts averaged 279.9 ± 15.1 and 381.1 ± 11.8 plants/m^2 for triticale and triticale/AWP, respectively. Spring 2010 plant counts averaged 212.1 ± 8.9 and 236.8 ± 13.4 plants/ft^2 for triticale and triticale/AWP, respectively. Fall 2010 plant counts averaged 42.0 ± 9.7 and 66.7 ± 32.3 plants/m^2 for triticale and triticale/AWP, respectively. Spring 2011 plant counts averaged 104.4 ± 9.7 and 115.2 ± 11.8 plants/m^2 for triticale and triticale/AWP, respectively.

Total plant yield differed between treatments and years ($P < 0.01$) while desired plant yield differed between years, but not treatments (P < 0.01) (Figure 5) due to weed infestation. Ash content varied between treatments with triticale averaging 8.84% ± 0.33% and triticale/AWP averaging 7.62% ± 0.33% (P< 0.05), with no other nutritional differences observed (P > 0.05; Table 16).

Materials and Methods Location B

Fall 2010 – Summer 2011

The field was disked and planted on 14 September, 2010 with Beardless triticale (var. VNS - Beardless; Walton Feed, Montpelier, ID) at the rate of 18.4 kg/ha with a Haybuster no-till grain drill (Haybuster model 1000, Jamestown, ND) with a row width of 17.78 cm. The field was grazed by cattle from October to November 2010. Plant counts were conducted on 16 November, 2010 and again the following spring on 14 May, 2011 (Equation 4). In addition, snow measurements were taken on 8 February, 2011 at ten random locations. Field was sprayed for broadleaf weeds the last week of May utilizing 1.183 L/ha of dichlorophenoxyaceticacid (2,4-D).

The field was harvested on 6 July, 2011. Because of the rectangular shape of the field, the perimeter was cut with a New Holland self-propelled swather conditioner, then three transects were cut length-wise through the field for sample collection: one in the lower portion of the field, one in the middle section, and one in the upper portion. The swather made a 3.81 m cut through the field. Sample collection starting points were staggered, with a random starting point and samples collected every 45 m after the first sample, for a collection of five samples from across the entire length of the field. Production data were collected by placing 2.44 m of windrow into a canvas tarp and weighing the samples with a Pesola PHS100 hanging scale with a precision of ±100 g. Three random samples were collected and bagged from each data point to comprise a sub-sample for dry matter calculation and nutritional analysis. Sub-samples were weighed and dried at 38 °C in a forced air oven to a constant weight and stored in plastic bags All forage present in the windrow (both desirable and undesirable species) was weighed, and no sorting of samples occurred.

Forage Analysis

Samples were transported to Moscow, ID, where the long stem samples were ground through a Wiley mill fitted with a 6-mm screen. A 5g sub-sample was dried at 100°C in a forced-air oven for 24 hours to determine dry matter content. After drying, samples were placed in a desiccation chamber and allowed to equilibrate to room temperature before being weighed. Samples were pooled by transect for nutritional analysis.

Nutritional analysis was conducted by wet chemistry by a commercial laboratory (Dairy One, Ithaca, NY). Samples were tested for moisture, dry matter (DM), crude protein (CP), adjusted crude protein, ADF, NDF, NFC, and ash. Values for TDN, NE_L, NE_M, NE_G and RFV were calculated.

Statistical Analysis

Due to small sample size, statistical analysis of Location B has not been conducted. Forage yield and nutritional analysis is reported as averages with standard error.

Results

Salmon received 92.20 mm (figure 1) of precipitation from September 2010 - December 2010 (WRCC, 2013). Fall plant counts showed 158.2 ± 11.8 plants/m^2 of triticale. Winter snow depth covering the plot measured 42.2 ± 0.8 cm. Spring plant counts had a survival rate of 46.3 ± 6.5 plants/m^2 with a snow mold being observed when the snow melted in the spring. Preliminary first year data had a triticale yield average of 3280.1 ± 150.2 kg/ha with nutritional averages reported in Table 16.

Discussion

In Location A, variation in total yield compared to desired crop yield was observed at the different corners for both years. Prior to being planted to triticale or triticale/AWP, the dry corners had different crops dependent upon the irrigated field the corners bordered. The northwest corner raised triticale the year prior, whereas the southeast and southwest corners had raised spring barley. This resulted in different degrees of infestation from cheatgrass between the two treatment groups. The corners that had been planted to spring barley were subjected to extensive spring tillage prior to planting the barley. Spring tillage is an effective means for controlling cheatgrass (Wicks, 1984). This variation of mechanical treatment prior to the initiation of the study resulted in a difference in weed pressure between the SE/SW and NE corners.

The weed pressure is also believed to have an effect on the AWP. Cheatgrass was the primary weed species found in the test plots. Cheatgrass has finely branched roots with many root hairs enabling it to quickly pull moisture from the soil and making it difficult for other species to compete (Morrow and Stahlman, 1984). Austrian winter peas were present in the triticale/AWP treatment at the beginning of the spring of 2010, but as the year progressed, appearance of AWP decreased. At harvest, no AWP was found in the samples collected. It is believed that the competition with triticale and cheatgrass resulted in the loss of AWP from the test plot that year. The following year when triticale/AWP was planted in the corner with less cheatgrass pressure, AWP persisted to sampling time.

Cheatgrass was a very serious problem in the test plots at location A. Cheatgrass matured before the test species were ready to harvest, and visual estimation of cheatgrass pressure increased from year one to year two. Mature cheatgrass decreases feed quality and is deficient in protein (≈ 6%) and can result in a negative energy balance for grazing animals (Cook and Harris, 1952) without protein supplementation. The sharp awns of cheatgrass have also been shown to result in agitation and injury to mouth, throat and eyes of animals consuming contaminated feed (Hulbert, 1955).

Location B had a strong cheatgrass presence before being grazed and going into the winter. The cattle grazed triticale and cheatgrass and pressure was maintained until a high level of utilization occurred. The heavy snow pack stayed on the field until the first part of April. When the snow pack receded, all remaining above ground vegetation had been consumed by a species of snow mold. Cheatgrass has been shown to facilitate the spread of snow mold amongst winter wheat (Miller et al., 2013), and cold hardening is important in the plants defense against snow mold (Nakajima and Abe, 1996). Damage to the crop from snow mold resulted in decreased yields at Location B.

Location A's yields in 2010-11 were less than those experienced at the NMCREEC in 2010-11. A possible reason for the variation in yields between the two locations is fertility and weed pressure. While the plots at the NMCREEC experience pressure from broadleaf, the cheatgrass pressure at Location A was extremely severe during that growing season. In addition, as mentioned in chapter 3, the plots at the NMCREEC had a full year for the roots and sod associated with the previous forage grown on the test plots to break down and return to the soil nutrient cycle. The test plots at Location A had been continually cropped with cereal annuals and no additional nitrogen inputs for two years prior to the 2010-11 growing seasons.

Triticale and triticale/AWP nutritional averages from Location A are very similar to those encountered at the NMCREEC center reported in Chapter 3. However, the nutritional quality from Carmen appears to be less. Due to the small sample size, statistical analysis was not done, but crude protein values were lower, with ADF and NDF being higher. Plants were cut at the same phenological time, and same batch of seed was used for plot establishment ruling out variation in cultivars. It's possible that sampling error due to small sample size or that stress induced by an environmental variable such as the snow mold resulted in accumulation of more structural carbohydrates in the plants.

Both test plots yielded a quality of forage that was acceptable for second trimester dry beef cattle. Triticale could be utilized in a total mixed ration as a source of fiber for dairy or feeder cattle, or supplemented with alfalfa or other protein sources for beef cattle in other stages of production. If a higher quality of forage is desired, triticale can be cut in boot phase, or more yield could be accomplished by allowing grain to reach a milky or soft dough phase.

Conclusion

Triticale can be a productive forage crop in higher elevation areas of the Intermountain West. However, it showed a susceptibility to impact of yields by snow mold and weeds. Cheatgrass was especially difficult to control in areas where winter annuals were grown for multiple years with no break in the crop cycle, and readily infested fields. Nutritional quality of triticale was adequate to meet the needs of a non-lactating mature beef cow.

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Tables

Table 1. Mineral element concentrations found in C_3 grasses, nutrient sufficiency concentrations found in C_4 grasses, and mineral requirements for mature gestating beef cows. Adapted from Mayland and Wilkinson 1996, Mathews et al. 2004, and NRC 2000.

Nutrient Class	C_3 Grasses	C_4 Grasses	Beef Cows	MTC*
Macronutrients				
P	2-4 g/kg	2.1 g/kg	13 g/d**	-
K	20-50 g/kg	18.7 g/kg	6 g/kg	30 g/kg
Ca	4 g/kg	2.5 g/kg	16 g/d**	-
Mg	1-3 g/kg	1.9 g/kg	1.2 g/kg	4 g/kg
S	1-3 g/kg	1.8 g/kg	1.5 g/kg	4 g/kg
Cl	1-5 g/kg	-	***	-
Na	<1-3 g/kg	-	.6-.8 g/kg	-
Micronutrients				
Fe	100 mg/kg	62 mg/kg	50 mg/kg	1,000 mg/kg
Mn	50 mg/kg	38 mg/kg	40 mg/kg	1,000 mg/kg
Zn	20 mg/kg	22 mg/kg	30 mg/kg	500 mg/kg
Cu	6 mg/kg	8 mg/kg	10 mg/kg	100 mg/kg
Mo	0.1 mg/kg	-	***	5 mg/kg
Ni	0.1 mg/kg	-	***	50 mg/kg
I	0.1 mg/kg	-	0.5 mg/kg	50 mg/kg
Co	0.2 mg/kg	-	0.1 mg/kg	10 mg/kg
Se	0.1 mg/kg	-	0.1 mg/kg	2 mg/kg
Cr	0.2 mg/kg	-	-	1,000 mg/kg

* Maximum Tolerable Concentration
** Maintenance Requirement
*** No NRC recommendations for beef cow requirements

Table 2. Summer annual seeding rates in kg/ha for six treatments of Teff, Sorghum x Sudangrass, German foxtail millet, corn, proso millet and pearl millet raised during the summers of 2008-2010 at the Nancy M. Cummings Research Extension and Education Center in Carmen, ID.

Treatment	Summer 2008	Summer 2009	Summer 2010
Tiffany Teff	10.13	10.13	6.73
Sorghum x sudangrass	20.18	20.18	30.61
German foxtail millet	39.24	20.18	26.8
Corn	-	36,000 seeds/acre	-
Proso millet	-	20.18	20.07
Pearl millet	22.42	-	-

Table 3. Irrigation dates and amounts for summer annual forage plot during the summers of 2008-2010 at the Nancy M. Cummings Research Extension and Education Center in Carmen, ID.

Summer 2008		Summer 2009		Summer 2010	
Date	Inches Applied	Date	Hours Watered	Date	Hours Watered
27-28 June	1.2”	3 July	12	7-8 July	24
2-3 July	3+”	19-20 July	24	22-23 July	12
14-15 July	3.5”	30-31 July	24	11-12 August	24
7 August*	2.5”	10-11 August	24	20-21 August	12
23 August	2.5”				

* Only 2/3rds of the plot was watered.

Table 4. Cattle grazing movements and grazing days from a summer annual forage study conducted at the Nancy M. Cummings Research Extension and Education Center in Carmen, ID starting on November 25, 2008 and ending January 5, 2009.

	Replicate 1		Replicate 2		Replicate 3	
Treatment	Date In	Date Out	Date In	Date Out	Date In	Date Out
Corn	25 November, 2008 P.M.	29 November, 2008 A.M.	29 November, 2008 A.M.	2 December, 2008 A.M.	2 December, 2008 A.M.	5 December, 2008 A.M.
Sorghum x sudangrass	25 November, 2008 P.M.	30 November, 2008 A.M.	30 November, 2008 A.M.	5 December, 2008 A.M.	-	-
German foxtail millet	5 December, 2008 P.M.	10 December, 2008	10 December, 2008	12 December, 2008	29 December, 2008	5 January, 2009
Pearl millet	5 December, 2008 P.M.	7 December, 2008	7 December, 2008	11 December, 2008	-	-
Teff	29 December, 2008	-	-	-	-	5 January, 2009

Table 5. Cattle grazing movements from warm season summer annual forage study conducted at the Nancy M. Cummings Research Extension and Education Center in Carmen, ID in 2010.

	Replicate 1			Replicate 2			Replicate 3		
Treatment	Group	Date In	Date Out	Group	Date In	Date Out	Group	Date In	Date Out
Corn	2	8 December	11 December	2	14 December	16 December	1	16 December	17 December
Sorghum x sudangrass	1	6 December	9 December	3	8 December	15 December	3	16 December	17 December
German foxtail millet	1	9 December	13 December	2	11 December	14 December	2	16 December	17 December
Proso millet	2	6 December	8 December	2	13 December	16 December	1	16 December	17 December
Teff	3	6 December	8 December	3	15 December	16 December	3	16 December	17 December

Table 6. Forage production in kg/ha from the summer annual test plots from 2008-2010 grown at the Nancy M. Cummings Research Extension and Education Center in Carmen, ID.

Year	Corn	German foxtail millet	Pearl/Proso millet	Sorghum x sudangrass	Teff
2008	4907.4 ± 826.5 ^{a}	4797.5 ± 826.5 ^{a}	3252.8± 982.1 ^{a}	6115.7 ± 982.1 ^{ab}	5368.6 ± 643.5 ^{a}
2009	9595.9 ± 826.5 ^{b}	5168.9 ± 826.5 ^{a}	3546.3± 826.5 ^{a}	6327.8 ± 826.5 ^{a}	-
2010	3074.5 ± 826.5 ^{a}	3379.9 ± 826.5 ^{a}	2684.7 ± 826.5 ^{a}	3822.2± 826.5 ^{b}	4888.9 ± 643.5 ^{a}

^{a,b,c} Within rows, effect of species $P < 0.05$

Table 7. Averages of nutrient analysis for warm season grass species (Corn, German foxtail millet and sorghum x sudangrass hybrid) grown 2008-2010 at the Nancy M. Cummings Research Extension and Education Center located near Carmen, ID.

Three year nutrient analysis average of warm season grasses						
	TDN %	CP %	Adj. CP %	DIP %	ADF %	NDF %
Corn	55.4 ± 0.38^{a}	10.4 ± 0.29^{a}	10.1 ± 0.30^{a}	63.3 ± 0.28^{a}	42.5 ± 0.43^{a}	67.2 ± 0.64^{a}
German foxtail millet	53.3 ± 0.38^{b}	11.1 ± 0.28^{a}	10.9 ± 0.29^{a}	64.1 ± 0.27^{ab}	42.9 ± 0.41^{a}	68 ± 0.64^{a}
Sorghum x sudangrass	54.9 ± 0.41^{ab}	10.3 ± 0.31^{a}	9.9 ± 0.32^{a}	65 ± 0.30^{b}	43.4 ± 0.46^{a}	67.5 ± 0.68^{a}
Yearly average of all three warm season grasses						
	TDN %	CP %	Adj, CP %	DIP %	ADF %	NDF %
2008	56.1 ± 0.41^{a}	12.1 ± 0.30^{a}	12.1 ± 0.31^{a}	68.3 ± 0.30^{a}	38.8 ± 0.45^{a}	62.6 ± 0.64^{a}
2009	52.6 ± 0.38^{b}	9.8 ± 0.29^{b}	9.4 ± 0.30^{b}	60 ± 0.28^{b}	47 ± 0.43^{b}	71.5 ± 0.59^{b}
2010	54.9 ± 0.38^{a}	9.9 ± 0.29^{b}	9.4 ± 0.30^{b}	64 ± 0.28^{c}	43.1 ± 0.43^{c}	68.5 ± 0.59^{c}

^{a,b,c} Within columns, effect of species $P < 0.05$

Table 8. Averages of mineral analysis for warm season grass species (Corn, German foxtail millet and sorghum x sudangrass hybrid) grown 2008-2010 at the Nancy M. Cummings Research Extension and Education Center located near Carmen, ID.

Three year mineral content average of warm season grasses									
	Ca %	P %	Mg %	K %	Na %	Fe ppm	Mn ppm	Zn ppm	Cu ppm
Corn	0.35 ± 0.03^{a}	0.27 ± 0.02^{a}	0.22 ± 0.02^{a}	2.35 ± 0.23^{a}	0.02 ± 0.002^{a}	160 ± 14.6^{a}	49 ± 3.4^{a}	40 ± 3.4^{a}	8 ± 0.54^{a}
German foxtail millet	0.49 ± 0.03^{a}	0.23 ± 0.02^{a}	0.27 ± 0.02^{a}	2.75 ± 0.23^{a}	0.02 ± 0.002^{a}	136 ± 14.6^{a}	41 ± 3.4^{a}	40 ± 3.2^{a}	9 ± 0.52^{a}
Sorghum x sudangrass	0.42 ± 0.03^{a}	0.25 ± 0.02^{a}	0.23 ± 0.02^{a}	2.41 ± 0.25^{a}	0.02 ± 0.002^{a}	129 ± 15.3^{a}	36 ± 3.6^{a}	32 ± 3.7^{a}	10 ± 0.58^{a}

^{a,b,c} Within columns, effect of species $P < 0.05$

Table 9. Nutrient analysis for corn, German foxtail millet, sorghum x sudangrass, pearl millet, and teff grass grown in 2008 at the Nancy M. Cummings Research Extension and Education Center located near Carmen, ID.

	TDN %	CP %	Adj. CP %	DIP %	ADF %	NDF %	Zn ppm
Corn	57.6 ± 0.58[ac]	10.5 ± 0.48[a]	10.4 ± 0.48[a]	67.5 ± 0.79[a]	38.4 ± 1.53[a]	60.9 ± 0.64[a]	39 ± 3.77[ab]
German foxtail millet	54.6 ± 0.55[b]	13.7 ± 0.42[bc]	13.7 ± 0.42[bc]	69.2 ± 0.79[a]	37.8 ± 1.45[ab]	61.7 ± 0.63[ab]	44 ± 3.27[b]
Sorghum x sudangrass	56.0 ± 0.71[ab]	12.1 ± 0.60[ab]	12.0 ± 0.59[ab]	68.3 ± 0.97[a]	40.2 ± 1.84[a]	65.2 ± 0.78[c]	38 ± 4.62[b]
Pearl millet	56.1 ± 0.71[ab]	14.7 ± 0.60[c]	14.7 ± 0.59[c]	70.3 ± 0.97[a]	32.9 ± 1.84[b]	65.6 ± 0.78[c]	27 ± 4.62[ac]
Teff	58.3 ± 0.58[c]	12.0 ± 0.48[a]	12.0 ± 0.48[a]	67.8 ± 0.79[a]	37.5 ± 1.53[ab]	63.3 ± 0.64[bc]	31 ± 3.77[ac]

[a,b,c] Within columns, effect of species $P < 0.05$

Table 10. Nutrient analysis for corn, German foxtail millet, sorghum x sudangrass, proso and teff grasses grown in 2009 at the Nancy M. Cummings Research Extension and Education Center located near Carmen, ID.

	TDN %	CP %	Adj. CP %	DIP %	ADF %	NDF %	Ca %	P %	Mg %	K %	Na %	Mn ppm	Zn ppm	Cu ppm
Corn	52.9^{a}	11.1^{a}	10.8^{a}	58.9^{a}	46.6^{ab}	72.7^{a}	.30^{a}	.30^{a}	.20^{a}	1.8^{a}	0.02^{ab}	48^{a}	60^{a}	7^{a}
German foxtail millet	54.1^{a}	8.8^{b}	8.5^{b}	59.5^{ac}	45.9^{a}	69.9^{a}	.52^{b}	.19^{b}	.21^{ab}	2.1^{a}	0.02^{ab}	34^{b}	48^{ab}	7^{a}
Sorghum x sudangrass	50.8^{a}	9.4^{b}	8.9^{b}	61.7^{b}	48.4^{b}	71.8^{a}	.42^{ab}	.26^{a}	.21^{a}	2.5^{b}	0.02^{a}	29^{b}	33^{b}	12^{b}
Proso millet	53.2^{a}	8.7^{b}	8.3^{b}	60.7^{bc}	45.9^{a}	69.7^{a}	.35^{a}	.25^{a}	.26^{b}	1.9^{a}	0.03^{b}	42^{a}	22^{b}	7^{a}
Teff	-	-	-	-	-	-	-	-	-	-	-	-	-	-

^{a,b,c} Within columns, effect of species $P < 0.05$

Pooled SE for data; TDN ± 1.01, CP ± 0.46, Adj. CP ± 0.47, DIP ± 0.35, ADF ± 0.54, NDF ± 0.89, Ca ± 0.056, P ± 0.021, Mg ± 0.016, K ± 0.23, Na ± 0.003, Mn ± 2.13, Zn ± 7.68, Cu ± 0.53

Table 11. Nutrient analysis for corn, German foxtail millet, sorghum x sudangrass, proso millet and teff grass species grown in 2010 at the Nancy M. Cummings Research Extension and Education Center located near Carmen, ID.

	TDN %	CP %	Adj. CP %	DIP %	ADF %	NDF %	Ca %	P %	Mg %	K %	Na %	Mn ppm	Zn ppm	Cu ppm
Corn	55.8^{a}	9.5^{a}	9.2^{a}	63.3^{a}	42.6^{a}	67.9^{a}	$.34^{a}$	$.23^{a}$	$.18^{a}$	1.2^{a}	0.01^{a}	55^{a}	22^{ab}	6^{a}
German foxtail millet	51.3^{b}	10.8^{a}	10.4^{a}	63.7^{ab}	45.0^{b}	72.3^{b}	$.51^{a}$	$.18^{a}$	$.31^{bc}$	1.9^{b}	0.01^{a}	42^{ab}	27^{a}	8^{a}
Sorghum x sudangrass	58.0^{ac}	9.5^{a}	8.8^{a}	64.9^{abc}	41.7^{a}	65.4^{ac}	$.39^{a}$	$.20^{a}$	$.20^{a}$	1.4^{a}	0.01^{a}	26^{b}	27^{a}	8^{a}
Proso millet	52.1^{b}	9.7^{a}	9.0^{a}	65.9^{bcd}	45.5^{b}	73.0^{b}	$.45^{a}$	$.21^{a}$	$.32^{b}$	2.0^{bc}	0.01^{a}	35^{b}	12^{b}	7^{a}
Teff	59.2^{c}	13.9^{b}	13.9^{b}	68.3^{d}	36.6^{c}	62.1^{c}	$.57^{a}$	$.32^{b}$	$.21^{ac}$	2.5^{c}	0.03^{b}	44^{ab}	28^{a}	13^{b}

^{a,b,c} Within columns, effect of species $P < 0.05$

Pooled SE for data; TDN ± 0.79, CP ± 0.69, Adj. CP ± 0.69, DIP ± 0.77, ADF ± 0.71, NDF ± 1.16, Ca ± 0.071, P ± 0.023, Mg ± 0.032, K ± 0.16, Na ± 0.002, Mn ± 5.93, Zn ± 3.21, Cu ± 0.91

Table 12. Winter annual seeding rates for triticale, Austrian winter pea, triticale/Austrian winter pea, and cereal rye for 3 different locations within Idaho during the growing seasons of 2009-2010 and 2010-2011. Weights denoted by ≈ are approximations based off of machine recommendations.

Location	Treatment	Fall 2009 kg/ha	Fall 2010 kg/ha
NMCREEC	Triticale	≈90	99
	Triticale/AWP	≈90/56	84/67
	AWP	≈56	115
	Cereal Rye	-	126
Grace, ID	Triticale	≈112	≈ 112
	Triticale/AWP	≈78/34	≈78/34
Carmen, ID	Triticale	-	≈112

Table 13. Average annual forage production in kg/ha from the NMCREEC winter annual test plots 2010-2011. TDN and CP yield were calculated from averaged lab values.

	Triticale	AWP	Triticale/AWP	Rye	Control
Total Yield	8400 ± 602[a]	3359 ± 625[b]	10680 ± 602[a]	8247 ± 632[a]	3442 ± 884[b]
TDN	4662	2059	5938	4734	1928
CP	1000	813	1314	990	399

[a,b,c] Within row effect of species $P < 0.05$

Table 14. Forage nutrient analysis of winter annuals grown during the 2009-2010 growing season at the Nancy M. Cummings Research Extension and Education Center near Carmen, ID.

Treatment	% CP	%ADF	%NDF	%NFC	%Ash	%TDN	NE_L Mcal/lb.	NE_M Mcal/lb.	NE_G Mcal/lb.	RFV
AWP	20.9	34.1	45.7	26.7	8.4	62	0.63	0.6	0.34	127
Control	10.0	40.9	66.5	13.9	10.6	54	0.45	0.46	0.21	80
Triticale	13.9	38.5	62.8	11.6	13.4	52	0.46	0.43	0.19	87

*Data was limited, no statistical analysis has been performed

Table 15. Forage nutrient analysis of winter annuals grown during the 2010-2011 growing season at the Nancy M. Cummings Research Extension and Education Center near Carmen, ID.

	CP%	ADF%	NDF%	NFC%	Ash%	TDN%	NE_L Mcal/lb.	NE_M Mcal/lb.	NE_G Mcal/lb.	RFV
AWP	24.2 ± 0.52^{a}	31.4 ± 1.46^{a}	41.8 ± 1.34^{a}	26.1± 1.59^{a}	10.2 ± 0.59^{a}	61.3 ± 0.87^{a}	0.64 ± 0.016^{a}	0.60 ± 0.014^{a}	0.34 ± 0.013^{a}	144.6 ± 4.01^{a}
Control	11.6 ± 0.73^{b}	34.8 ± 1.93^{ab}	62.1 ± 1.76^{b}	17.7 ± 2.14^{b}	9.4 ± 0.80^{a}	56.0 ± 1.19^{b}	0.50 ± 0.021^{b}	0.49 ± 0.018^{b}	0.24 ± 0.017^{b}	92.5 ± 5.40^{b}
Rye	12.0 ± 0.52^{b}	38.6 ± 1.46^{bc}	64.6 ± 1.34^{b}	17.4 ± 1.59^{b}	7.5 ± 0.59^{b}	57.4 ± 0.87^{b}	0.49 ± 0.016^{b}	0.51 ± 0.014^{b}	0.26 ± 0.013^{b}	84.9 ± 4.02^{b}
Triticale	11.9 ± 0.52^{b}	40.3 ± 1.43^{c}	65.8 ± 1.29^{b}	14.8 ± 1.55^{b}	9.1 ± 0.58^{a}	55.5 ± 0.86^{b}	0.46 ± 0.016^{b}	0.48 ± 0.014^{b}	0.23 ± 0.013^{b}	81.7 ± 3.93^{b}
Triticale/AWP	12.3 ± 0.52^{b}	40.2 ± 1.43^{c}	65.3 ± 1.29^{b}	14.9 ± 1.55^{b}	9.1 ± 0.58^{a}	55.6 ± 0.86^{b}	0.47 ± 0.016^{b}	0.49 ± 0.014^{b}	0.23 ± 0.013^{b}	82.2 ± 3.93^{b}

[a,b,c] Within columns, effect of species $P < 0.05$

Table 16. Forage nutrient analysis of winter annuals grown from fall 2009-spring 2011 at producer co-operators located near Grace, ID and near Carmen, ID.

	CP%	Adjusted CP%	ADF%	NDF%	NFC%	Ash%	TDN%	NE_L Mcal/lb.	NE_M Mcal/lb.	NE_G Mcal/lb.	RFV
Location A Triticale	12.8^{a}	12.8^{a}	38.3^{a}	62.9^{a}	17.0^{a}	8.8^{a}	56.6^{a}	0.49^{a}	0.50^{a}	0.25^{a}	89^{a}
Location A triticale/AWP	11.6^{a}	11.6^{a}	37.7^{a}	61.5^{a}	20.2^{a}	7.6^{b}	58.1^{a}	0.52^{a}	0.53^{a}	0.27^{a}	92^{a}
Location B triticale	9.3	9.3	42.5	67.5	14.0	10.1	54.0	0.44	0.46	0.21	77

^{a,b,c} Within columns, effect of species $P < 0.05$

Pooled SE data for Location A; CP ± 1.4, Adjusted CP ± 1.4, ADF ± 1.4, NDF ± 3.2, NFC ± 2.0, Ash ± 0.33, TDN ± 1.02, NE_L ± 0.03, NE_M ± 0.02, NE_G ± 0.02

Location A is located near Grace, ID with location B located near Carmen, ID.

Averages for location A are two year averages while location B is averaged from the 2010-2011 growing season.

Table 17. *In situ* Forage trial results for percent dry matter degradation from study conducted at the Nancy M. Cummings Research Extension and Education Center. *In situ* degradation test forages were from winter annual forages grown at the research center located near Carmen, ID in 2010.

	AWP %	Control %	Rye %	Triticale %	Triticale/AWP %
0 Hour	43.6 ± 1.64^{a}	30.0 ± 1.89^{b}	29.6 ± 1.64^{b}	28.3 ± 1.59^{b}	28.2 ± 1.59^{b}
24 Hour	66.1 ± 1.64^{a}	46.7 ± 1.89^{b}	43.8 ± 1.64^{b}	41.3 ± 1.59^{c}	41.1 ± 1.59^{c}
96 Hour	72.0 ± 1.64^{a}	68.7 ± 1.89^{b}	60.7 ± 1.64^{c}	60.3 ± 1.59^{c}	59.3 ± 1.59^{c}

^{a,b,c} Within rows effect of species $P < 0.05$

Table 18. In situ forage trial results for percent NDF degradation from study conducted at the Nancy M. Cummings Research Extension and Education Center. In situ degradation test forages were from winter annual forages grown at the research center located near Carmen, ID in 2010.

	AWP %	Control %	Rye %	Triticale %	Triticale/AWP %
0 Hour	-2.59	1.24	-0.07	-0.76	-1.28
24 Hour	24.25 ± 1.52^{a}	21.62 ± 1.76^{ab}	18.40 ± 1.51^{bc}	16.40 ± 1.45^{c}	15.36 ± 1.45^{c}
96 Hour	38.51 ± 1.51^{a}	55.72 ± 1.76^{b}	43.68 ± 1.56^{c}	45.54 ± 1.45^{c}	42.91 ± 1.45^{c}

^{a,b,c} Within rows effect of species $P < 0.05$

Figures

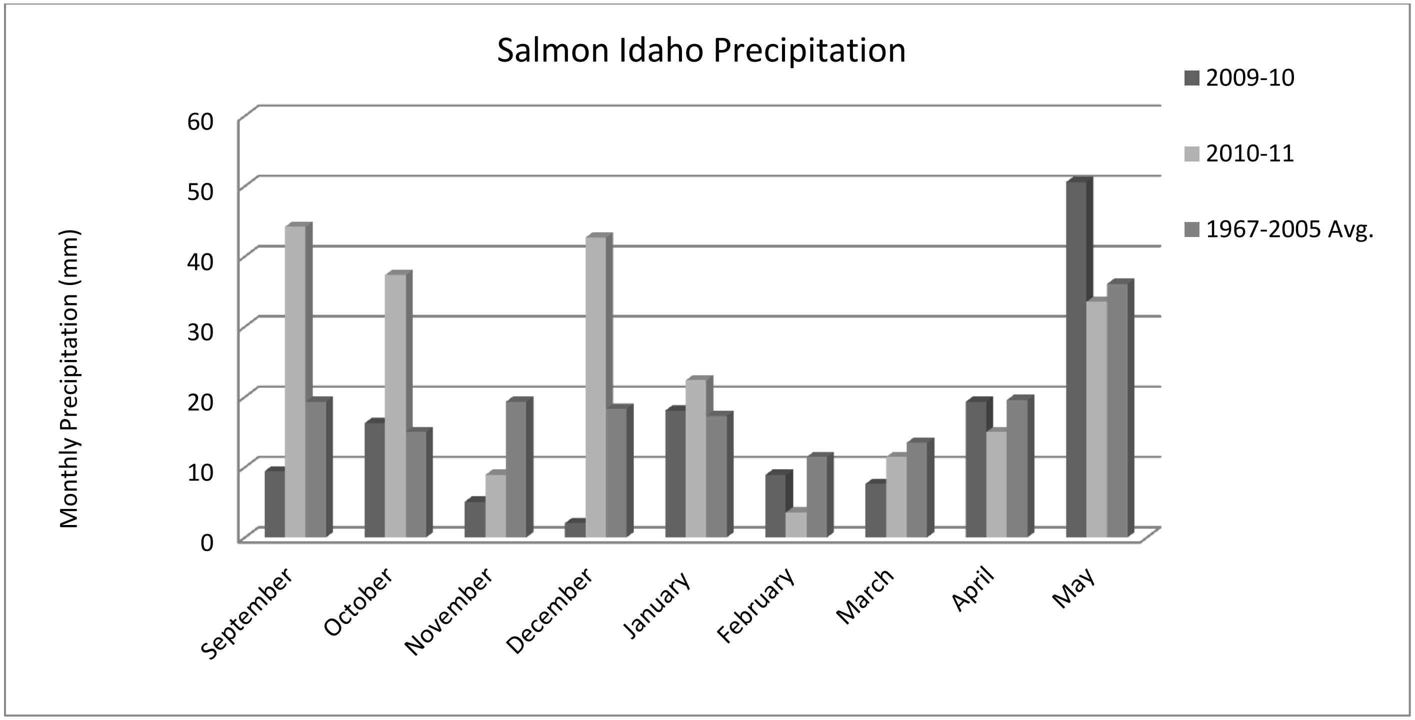

Figure 1. September to May monthly precipitation averages for Salmon, ID as recorded from the KSRA weather station of the Western Region Climate Center (WRCC, 2013).

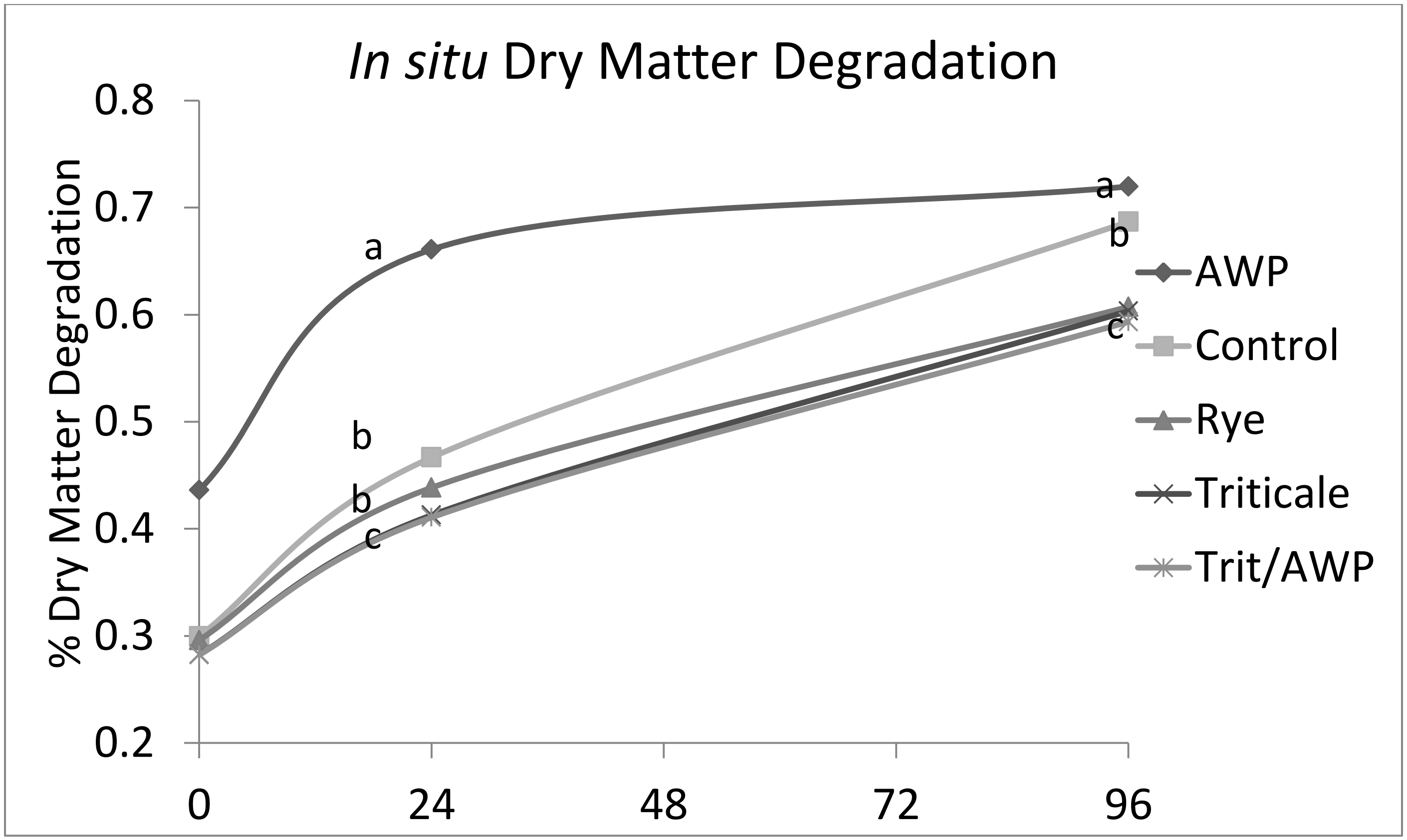

Figure 2. Percent dry matter degradation from *In situ* study conducted at the Nancy M. Cummings Research Extension and Education Center near Carmen, ID.
*Pooled SE data; AWP ± 1.45, Control ± 1.55, Rye ± 1.45, Triticale ± 1.43, Triticale/AWP ± 1.43
$P < 0.05$

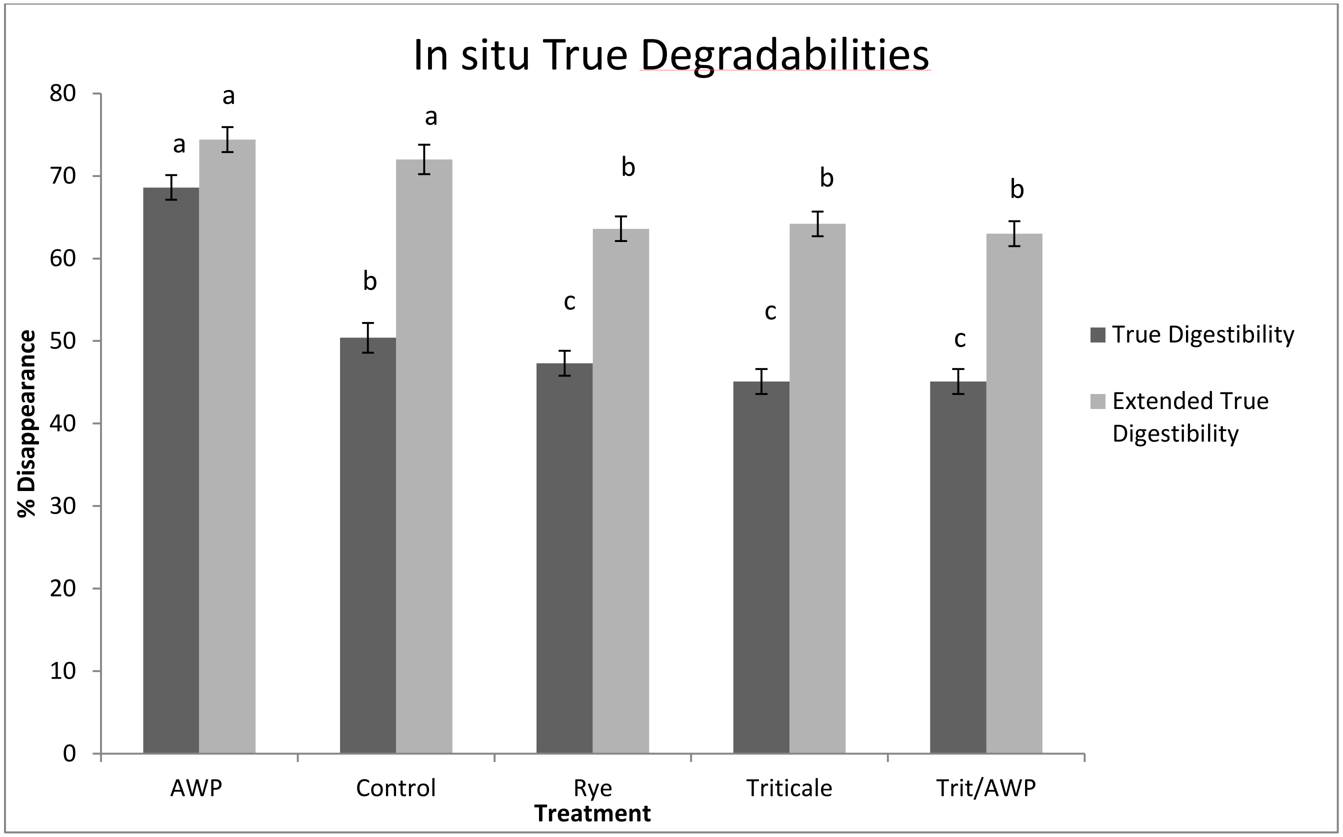

Figure 3. *In situ* true degradability and extended true degradability for winter annual species grown at the Nancy M. Cummings Research Extension and Education Center in Salmon, ID for the growing season of 2010-11. $P < 0.05$

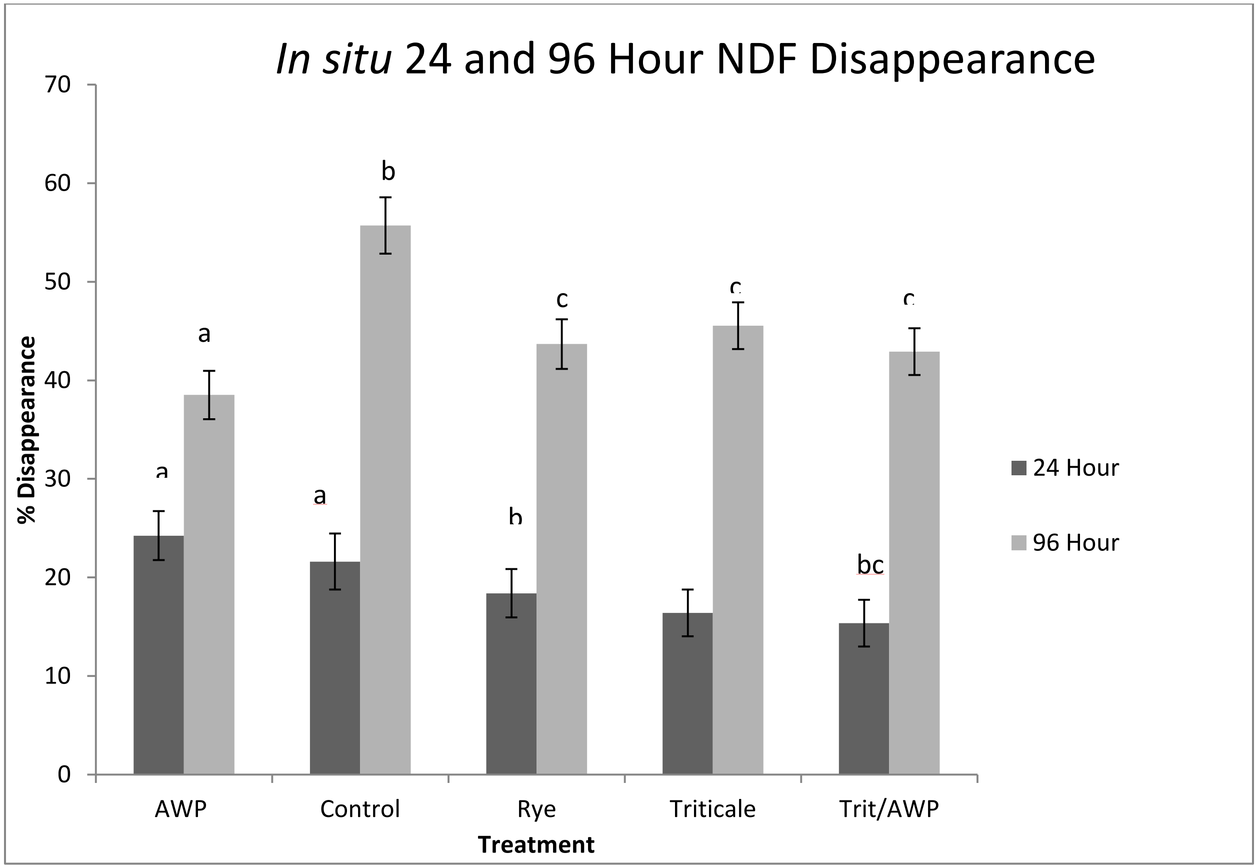

Figure 4. *In situ* NDF disappearance for winter annual species grown at the Nancy M. Cummings Research Extension and Education Center near Carmen, ID for the growing season of 2010-11. $P < 0.05$

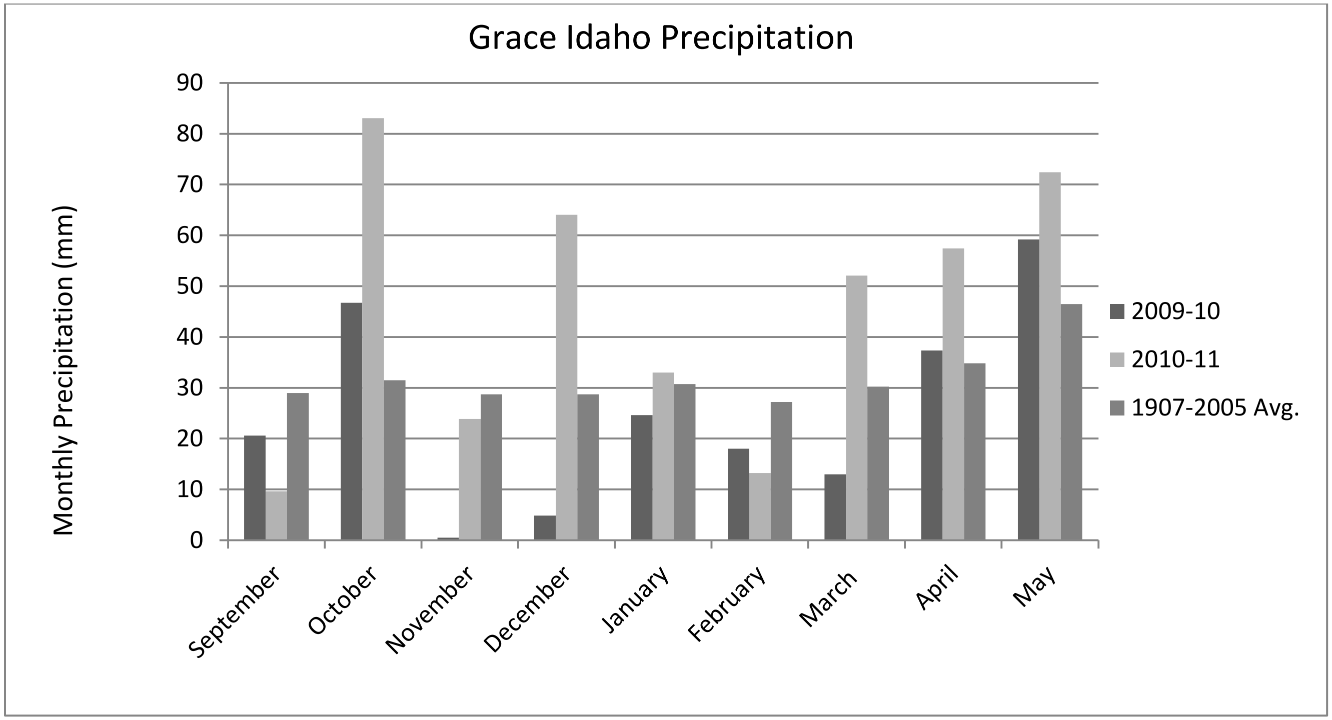

Figure 5. Monthly precipitation for Grace, Idaho as recorded by the Western Region Climate Center (WRCC, 2013).

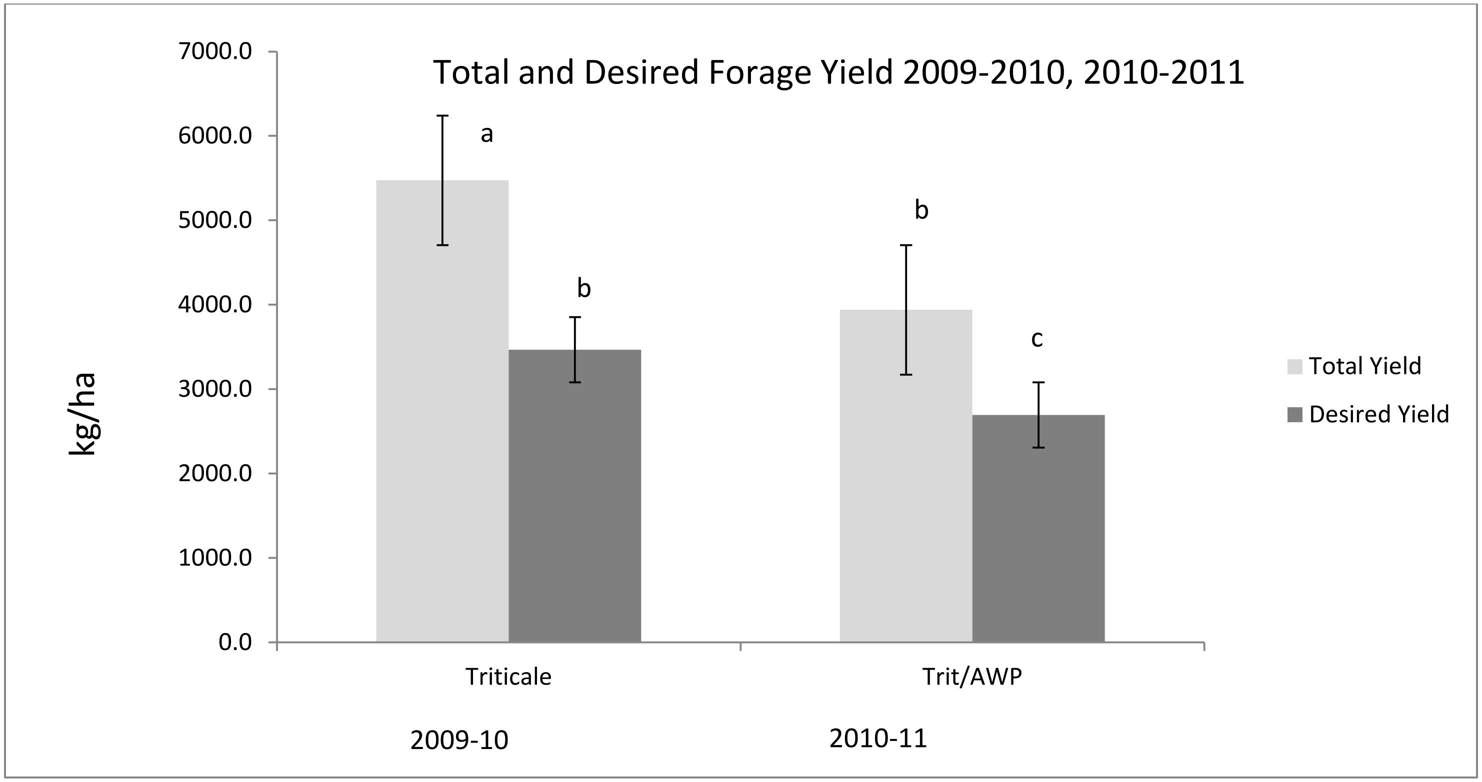

Figure 6. Total and desired forage yield from Grace, Idaho for 2009-2010 and 2010-2011 growing seasons. Total yield represents biomass from all plants that grew during the given season, including weed species. Desired forage is the biomass from only triticale and Austrian winter peas. $P < 0.01$

Appendix A

University of Idaho
Animal Care and Use Committee

Date: Friday, February 08, 2013
To: John Hall
From: University of Idaho
Re: Protocol 2013-2
In situ digestibility of cool season forages raised on dry pivot corners

Your animal care and use protocol for the project shown above was reviewed and approved by the University of Idaho on Friday, February 08, 2013.

This protocol was originally submitted for review on: Tuesday, January 15, 2013
The original approval date for this protocol is: Friday, February 08, 2013
This approval will remain in affect until: Saturday, February 08, 2014
The protocol may be continued by annual updates until: Monday, February 08, 2016

Federal laws and guidelines require that institutional animal care and use committees review ongoing projects annually. For the first two years after initial approval of the protocol you will be asked to submit an annual update form describing any changes in procedures or personnel. The committee may, at its discretion, extend approval for the project in yearly increments until the third anniversary of the original approval of the project. At that time, the protocol must be replaced by an entirely new submission.

Brad Williams, DVM
Campus Veterinarian
University of Idaho
208-885-8958