GRAZING COOL-SEASON PERENNIAL GRASSES AND CHANGES IN NUTRITIVE VALUE OF THREE FORAGE TYPES IN THE SOUTHERN GREAT PLAINS

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Bachelor of Science

Oklahoma State University

Stillwater, Oklahoma

1998

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
July, 2000

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ACKNOWLEDGEMENTS

Hopefully, this is the only section of this document where you will find my thoughts independent of scientific analysis and referenced literature. Therefore, this part is a reflection of me personally, and the remainder is a reflection of me professionally.

First and foremost, I want to thank the good Lord for the unimaginable blessing that is my life, and for the perseverance (Philippians 4:12) to accomplish the things that He has set in front of me. May I never forget where all of this truly came from.

Thanks are in order to Dr. Gerald Horn and Dr. Hebbie Purvis for their support of my graduate program, both financially and personally. The breadth of experience and excellence of education that I received in the Animal Science department was due in large part to these men.

I wish to thank Dr. Bill Phillips for his service on my committee and his constant encouragement before and during my graduate education. Dr. David Buchanan was always a great source of insight to me.

Some of the most important people to me while in graduate school were my peers. Dr. Brett Gardner and Dr. Callan Ackerman always challenged me intellectually, but both served a deeper purpose to me as friends and mentors. Shon Rupert and Mark McGee have been long-time friends and made the pressures of graduate school much easier for me to handle. Many other fellow graduate students have provided much needed and appreciated camaraderie while I was in school.

Many university employees deserve recognition. Without the continued service of people like Ken Poling, Jim Kountz, David Cox, Tim Bodine, Carolyn Lunsford, Donna Perry, and Carol Bradley, the research produced by this department would not be possible.

A heartfelt thanks is extended to all of my family, especially Mom and Dad, for your understanding and support during this time of my life. Fred, thanks for your wise counsel and cowboy attitude; it always lifted my spirits.

I began this section with the person that helped me the most, and I'll end it with the people that run a close second. Hadley and Mallie, you are the light of my life and the reason that I get up every morning and keep trying. Julie, only you know the true ups and downs that I go through. Only you will listen when I can't sleep for being excited or worried. You were the only one who has had to forgive me for most of the mistakes I have made. And I know that even if everybody else is against me, you will still be with me. That has made all the difference.

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NOMENCLATURE

ADF	acid detergent fiber
ADG	average daily gain
BW	body weight
cm	centimeters
CP	crude protein
d	day
DIP	degradable intake protein
DM	dry matter
DMD	dry matter digestibility
DMI	dry matter intake
EBG	empty body gain
g	grams
h	hour
ha	hectare
IVDMD	in vitro dry matter digestibility
IVOMD	in vitro organic matter digestibility
kg	kilograms
ME	metabolizable energy
mg	milligrams

mm	millimeters
NDF	neutral detergent fiber
NRC	National Research Council
ppm	parts per million
TDN	total digestible nutrients
OM	organic matter
°C	degrees Celsius
UIP	undegradable intake protein
U.S.	United States
USDA	United States Department of Agriculture
yr	year

CHAPTER I

INTRODUCTION

The economics of the beef cattle industry force producers to focus attention on production and financial efficiency. Producers seek out grazing systems that can maintain or increase production while reducing costs. For example, using complementary grazing systems to combine the advantages of two or more forages to help increase efficiency. Wheat pasture is one of the main forage resources in the southern Great Plains, and a complementary grazing system involving wheat pasture could have wide application in this region.

Winter wheat is traditionally grown as a dual-purpose crop in the southern Great Plains. Wheat can be used as a forage for grazing until late winter when it reaches the "first hollow stem" stage of maturity (Krenzer, 1997). If animals are removed from the pasture at this time, grain yield is not reduced and a grain crop can be harvested in June. Instead, producers may choose to allow the animals to continue grazing the wheat into the spring ("graze out"). This allows for increased animal weight gain, but removes the possibility of harvesting grain.

This dual-purpose aspect of winter wheat creates a somewhat unique opportunity to institute a complementary grazing system. Both the grain crop and the increased production of cattle from the graze-out period have significant value. If the cattle could be grown on a complementary forage, the grain crop could be harvested from the wheat, and overall production would be increased.

Cool-season perennial grasses may provide this complementary forage (Redmon, 1997; Schuster and Garcia de Leon, 1973).

In the southern Great Plains, forage production of cool-season perennial grasses is bimodal, with production periods in the fall and spring, and relative dormant periods in the summer and the coldest part of the winter (Burns and Bagley, 1996). Wheat produces forage from mid-fall to late winter or early-spring. Therefore, cattle could possibly graze wheat until first hollow stem when they could be moved to cool-season perennial grass pasture, leaving the grain crop available for harvest.

Three cool-season perennial grass species were selected for study in the present experiments, and were chosen because of their success in other areas of the U.S. Smooth bromegrass, pubescent wheatgrass, and orchardgrass are popular cool-season forage grasses, and represent a range of drought and heat tolerance. Our experiments were conducted to determine the timing of grazable forage production and performance of stocker cattle grazing these cool-season perennial grasses. Inference may then be drawn as to their suitability as complementary forages to wheat pasture in the southern Great Plains.

A separate experiment was conducted in relation to the application of the 1996 NRC model for grazing cattle. Extensive data exist on the effects of advancing maturity on digestibility and crude protein of many forages. However, relatively little data exists as to how ruminal degradability of crude protein of grazed forages changes as forages mature. An experiment was designed to collect monthly forage samples from three different forages common to the southern Great Plains during the summer grazing season. The samples were collected by rumen evacuation in an attempt to accurately portray the diet of grazing cattle. These data were then used in the Level I Model of the 1996 Beef Cattle NRC to determine limiting nutrients for stocker cattle grazing these forages. This information could increase our understanding of nutrient supplementation needs of stocker cattle in the southern Great Plains.

CHAPTER II

REVIEW OF LITERATURE

Introduction of Cool-Season Perennial Grasses

Cool-season grasses are generally defined as having the C3 photosynthetic pathway. The designation 'C3' comes from the first product of carbon dioxide reduction in cool-season plants, a three-carbon acid: 3-phosphoglyceric acid. Warm-season grasses, or C4 grasses, use a more biochemically and anatomically complicated method of reducing carbon dioxide that begins with formation of the four carbon acid oxaloacetate (Nelson, 1996). Cool-season grasses are also referred to as temperate grasses, because they are more often found in temperate geography. Warm-season grasses are sometimes referred to as tropical grasses (Nelson, 1994).

Examples of some cool-season grasses are: timothy, orchardgrass, the bromegrasses, reed canarygrass, the wheatgrasses, tall fescue, Kentucky bluegrass, perennial and annual ryegrass, and the cereal grains; wheat, oat, rye, triticale, and barley. Some common warm-season grasses are: big bluestem, little bluestem, Old World bluestem, switchgrass, indiangrass, buffalograss, the gramas, bermudagrass, corn, sorghum, and sudangrass (Ball et al., 1996). Grass species exist that have the C3 photosynthetic pathway but are not considered cool-season grasses due to the locations where they occur. Bamboo is an example of this type of grass (Nelson, 1996). Additionally, grasses with a photosynthetic pathway intermediate to the C3 and C4 types exist (Wilson et al., 1983).

Cool-season grasses have about one-half of the maximum photosynthetic capacity of warm-season grasses. Put another way, cool-season grasses are about 3% efficient in converting absorbed solar energy into biomass. Warm-season grasses can be 5-6% efficient in this process (Ball et al., 1996).

Cool-season grasses require significantly more water than warm-season grasses to produce equal amounts of biomass (Ball et al., 1996). Some estimates are as high as two to three times the water requirement for cool-season grasses (Nelson, 1996). Additionally, warm-season grasses use water more efficiently during periods of high heat and low precipitation, which would tend to decrease the amount of water available for plants. Differences in plant physiology and biochemistry are responsible for the majority of variance, but it should be noted that cool-season grasses generally contain shorter roots than warm-season grasses. Root mass may be similar, but the longer roots of warm-season species may enable these plants to tap soil water that would be unavailable for cool-season grasses (Ball et al., 1996).

Optimum growth for cool-season grasses occurs in the range of temperatures from 15.5°C to 26.5°C. This range is lower and wider as compared with the optimum range for warm-season grasses, which is 29.5°C to 32°C (Ball et al., 1996). Cool-season grasses are generally most adapted to areas between 30° and 60° latitude. Under environments to which they are adapted, cool-season grasses are not at a disadvantage to warm-season grasses and can be very productive. In hotter, drier regions, warm-season grasses produce significantly more forage (Moser and Hoveland, 1996).

Forages "on the edge" of their adaptation zone are stressed more by environmental factors than the same forage grown at the center of its adaptation zone. This leaves the forage plant more susceptible to other stresses, such as over-grazing. Sixty-one percent on the grass species in Oklahoma are C4 species, whereas this percentage declines to 52% and 40% in Kansas and Nebraska, respectively. This highlights the importance of increased grazing management required to maintain successful stands of cool-season perennial grass in locations where they are only marginally adapted (Nelson and Moser, 1994).

Cool-season grasses are generally capable of less dry matter production, but of higher nutritive value, than warm-season grasses (Nelson, 1995). Cool-season grasses have a major advantage over warm-season grasses in that the sward typically has a much higher leaf:stem ratio. Fisher et al. (1991) reported that a grazed tall fescue sward contained 78% leaf and 7% stem as compared with a grazed bermudagrass sward that was 37% leaf and 47% stem. Greater leaf concentration allows animals to select the most nutritious and palatable portion of the plant, and reduces the amount of time and energy expended while grazing (Burns and Bagley, 1996). Additionally, weight gain of grazing ruminants is more closely correlated with amount of green, vegetative forage than of total forage mass (Bird et al., 1989).

Cool-season grasses have a period of growth in the spring that culminates in flowering (Leasure, 1952). Spring growth usually accounts for about two-thirds of the annual dry matter production (Burns and Bagley, 1996). This spring period is followed by a relatively dormant summer season and then a period of vegetative growth in the fall. Limited growth may occur in the winter season at soil temperatures above 4.4°C (Leasure, 1952).

Mixed swards of cool- and warm-season species (orchardgrass and either big bluestem or switchgrass) were effectively maintained under grazing or haying treatments in Pennsylvania. However, grazing management was designed to favor warm-season species in this environment where cool-season species are more traditionally grown (Jung et al., 1985). In areas where warm-season grasses are more typical, grazing management designed to favor cool-season species will be required to achieve a mixed stand. However, Decker et al., (1974) reported that the increased yield of cool-season annual grasses seeded into bermudagrass as compared with cool-season perennial grasses and bermudagrass established together more than offset the cost of reseeding the annual. The proportion of each type of grass in a mixed sward can be highly dependent on yearly variation in precipitation as well (Ball et al., 1996).

Cool-season perennial grasses are more adapted to be grown with legumes than warm-season grasses. Most legumes are C3, and therefore stages of maturity are more closely matched and management is more simple (Burns and Bagley, 1996).

Barnett and Posler (1983) studied the performance of cool-season perennial grasses, both alone and mixed with legumes, in eastern Kansas. Smooth bromegrass, Turkish bromegrass, tall fescue, and reed canarygrass were evaluated in pure stands and in mixtures with alfalfa, red clover, birdsfoot trefoil, and crownvetch. Over four years, results were inconsistent in ranking of grass species in terms of dry matter production. Grass-legume mixtures consistently out-produced fertilized pure grass stands in both dry matter production and crude protein content. The grass component of the mixed plots produced more dry matter and was higher in crude protein than grass from fertilized pure grass plots. This would indicate that grasses grown in association with legumes appear to benefit from the legume's ability to harvest atmospheric nitrogen. Presumably, increased rates of fertilizer may have a similar effect. No environmental adaptability issues were noted in this research.

There has long been interest in cool-season perennial grasses in the southern Great Plains. Klages (1929) reported that orchardgrass and smooth bromegrass both rated highly in production yield trials of perennial grasses in central Oklahoma. Climatic conditions appear to limit the range and seasonal dry matter production for cool-season grasses, and are the major factor limiting their use as forages (Burns and Bagley, 1996).

Schuster and De Leon Garcia (1973) conducted a study near Amarillo, TX comparing several cool-season grasses for use in the southern Great Plains. Precipitation at this site averaged 508 mm/yr. Intermediate wheatgrass appeared to be able to better tolerate defoliation than tall wheatgrass in this trial.

However, one of the weaknesses of intermediate wheatgrass has traditionally been little resistance to grazing (Dahl et al., 1967; Assay and Jensen, 1996). The five varieties of intermediate wheatgrass tested produced similar amounts of forage, averaging 725 to 816 kg/ha. Production of intermediate wheatgrass was significantly greater than western wheatgrass under irrigation. Orchardgrass was very productive under irrigation, but produced less dry matter than many of the wheatgrasses under dryland conditions. No species survived under dryland conditions after the fifth growing season following establishment. However, orchardgrass and tall fescue died out even under limited irrigation, while the wheatgrasses survived. 'Luna' pubescent wheatgrass appeared to be one of the more drought resistant grasses in the study.

A study comparing long-term survival of grass species near Dalhart, TX (430 mm precipitation/yr) revealed that careful management is necessary to maintain stands of cool-season perennial grasses in this area. After 36-yr, Old World bluestem and Caucasian bluestem, both warm-season species, dominated most of the plots originally established to one of 25 different species, including western wheatgrass (Eck and Sims, 1984). Sustained production of cool-season perennial grasses may not be possible without irrigation in areas receiving minimal precipitation. Stand persistence is probably more economically important than other traits when selecting forage species for establishment (Miller and Stritzke, 1995).

Griggs and Matches (1991) successfully grazed crested, tall, and pubescent wheatgrass, alone and in combination with sainfoin, near Lubbock, TX. The researchers concluded that these cool-season perennial grasses and legumes can make important contributions in April and May to grazing continuity in the warm-season grass and cereal grain pasture dominated region of the southern High Plains. Similar conclusions were reached by Holechek et al. (1989) when comparing several wheatgrasses in the big sagebrush range of New Mexico.

Tall fescue appears to be the most tolerant of more stressful conditions associated with the southern region of the cool-season perennial grass range (Burns and Bagley, 1996). However, the tall fescue varieties most adapted to this region are infected with the endophytic fungus *Acermonium coenophialum* (Ball et al., 1996). Ruminants grazing infected tall fescue during periods of high fungal concentration typically have reduced performance (Sleper and Buckner, 1995).

Smooth bromegrass is a leafy, sod-forming, cool-season perennial grass that exhibits excellent seedling vigor, vigorous rhizomes, and exceptional persistence in its area of adaptation. Smooth bromegrass is generally more winter and drought tolerant than orchardgrass and ryegrasses, but less than the wheatgrasses. Smooth bromegrass may tolerate higher temperatures than some cool-season perennial grasses (Baker and Jung, 1968). Bromegrasses are most adapted to areas east of longitude 100°W, whereas wheatgrasses are more favorably grown in locations west of this mark. Southern types of smooth bromegrass maintain the winter-hardiness and forage yields of northern types, but appear to be more drought and heat tolerant in stressful environments.

'Lincoln' smooth bromegrass is an early variety of the southern type released by the USDA and the Nebraska Agricultural Experiment Station noted for its large area of adaptation and high forage yield (Vogel et al., 1996).

Asay and Jensen (1996) describe intermediate wheatgrass as a moderately rhizomatous cool-season perennial grass used for hay and pasture in areas of greater than 350 mm of annual precipitation. Drought tolerance is reported to be between that of crested wheatgrass and smooth bromegrass, and matures to the flowering stage approximately 10 to 14 days later than these two grasses. Intermediate wheatgrass is sensitive to intense defoliation (Dahl et al., 1967). The variety 'Manska' is a recent release developed by the USDA-Agricultural Research Service, USDA-Soil Conservation Service, and the Universities of North Dakota and Nebraska. Manska was derived from an earlier release of pubescent wheatgrass, with selection emphasis on forage nutritive value (Asay and Jensen, 1996).

Orchardgrass is a popular cool-season perennial grass in areas of North America with greater than 500 mm of annual precipitation. It is described as a highly productive bunchgrass that is highly responsive to nitrogen fertilization and is well adapted to be grown in mixtures with legumes (Van Santen and Sleper, 1996). Casler (1988) reported that orchardgrass was more adapted to being grown with alfalfa than smooth bromegrass. Orchardgrass was shown to contain more energy reserves for growth than either smooth bromegrass, bluegrass, or timothy (Baker and Jung, 1968). 'Pauite' orchardgrass is a late-maturing variety with improved drought tolerance released from the U.S. Forest Service (Van Santen and Sleper, 1996).

Performance of Animals Grazing Cool-Season Perennial Grasses

Burns and Bagley (1996) published a review of performance of animals grazing cool-season perennial grass pastures. Liveweight gain, expressed on an area basis, generally ranged from 250 to 350 kg/ha, while ADG varied from .44 to .76 kg/d (average of .59 kg/d) on cool-season perennial grasses. An adapted legume in the pasture mix increased animal gain by about .05 to .1 kg/d.

Heifers grazing irrigated smooth bromegrass in Kansas gained .88 and .55 kg/d for the first and second halves, respectively, of a 150-d grazing period. Stocking rate was 2016 kg BW/ha during the first period and was reduced by half for the second period, reflecting the reduced summer production characteristic of cool-season perennial grasses. The first half of the grazing season produced over three times more gain/ha than the second half (Blasi et al., 1997).

Cool-season perennial grasses produced ADG and gain/ha of approximately .95 kg/d and 280 kg/ha in central Oklahoma. Stocking rate was 1365 kg BW/ha, and the grazing season was limited to the months of April and May. No differences were observed in cattle performance among smooth bromegrass, orchardgrass, and intermediate wheatgrass (Reuter et al., 1999).

A trial in Nebraska compared spring grazing of bromegrass with either spring grazing of bromegrass followed by summer grazing of warm-season pasture or full season grazing of Sandhills native range (principally warm-season species). Steers grazing smooth bromegrass for 55-d in early spring averaged 1.06 kg/d. Gain was not different between the other two treatments, and 130-d ADG was .86 and .91 kg/d, respectively. Steers were followed through the finishing phase, where the short-grazed, bromegrass-only treatment was fed significantly more days. This treatment also had lower ADG and DMI, and higher gain/feed and yield grade than the steers on the long-grazed programs, most likely due to the lower initial weights of the short-grazed group. Finishing performance was not different between the two full-summer grazing treatments, and economic analysis showed that amount of summer gain was the best indicator of slaughter break-even (Jordon et al., 1999).

Steers grazing smooth bromegrass through a full summer season (May 7 to September 13) gained .73 kg/d in Nebraska. Performance was not influenced by either continuos or rotational grazing methods. Full-season bromegrass grazing produced lower ADG than either full-season (summer) Sandhills range, bromegrass followed by Sandhills range, or bromegrass followed by warm-season grass treatments, which averaged near .91 kg/d (Shain et al., 1996). A similar experiment was conducted the following year with similar results. Cattle grazing some combination of cool-season perennial grass and warm-season perennial grass achieved higher ADG on pasture than cattle grazing only cool-season perennial grass. Economic analysis after the finishing phase again indicated amount of pasture gain to be the single largest factor influencing feedlot break-even (Shain et al., 1997).

The Nebraska experiments suggest that using complementary forage systems can increase animal performance in summer stocker programs. Following the cattle through the feedlot confirms that amount of gain on low-cost pasture is the major factor in determining slaughter break-even (Jordan et al., 1999; Hayden et al., 1997; Shain et al., 1997; Shain et al., 1996). McLaren et al. (1983) also reported increased beef production with a combination of cool-season and warm-season grass as compared with several other systems.

Reid et al. (1978) found that lambs grazing smooth bromegrass gained faster than those grazing orchardgrass, tall fescue, or perennial ryegrass in West Virginia. Orchardgrass lambs performed better than tall fescue lambs, but were not different from perennial ryegrass lambs. Perennial ryegrass lambs gained quickly during the initial phases of the experiment, but gain declined later in the grazing season as forage decreased in quality, probably due to crown rust. However, tall fescue was observed to be capable of supporting about 150% of the stocking rate of the other grasses.

Lechtenburg et al. (1973) reported that beef production was unaffected by source of nitrogen fertilizer on smooth bromegrass. Animal gain exhibited a curvilinear response to rate of fertilizer with 224 kg N/ha and 448 kg N/ha producing 339 and 363 kg BW/ha, as compared with non-fertilized pastures, which produced 234 kg BW/ha.

Turner et al. (1996) used small plots of cool-season perennial grass to test differences in canopy management on forage mass, nutritive value, and predicted animal performance. Results suggest that more grazing days, which results in more animal gain per year, was attained by removing roughly 75% of the height of a "tall" sward (20 cm down to 5 cm). Conversely, highest calculated ADG (for 250-kg steers) was attained by removal of 50% of the tall sward (20 cm down to 10 cm).

More precise grazing management may be required to optimize performance of cool-season grasses in locations where they are only moderately adapted. Introducing cool-season grasses into a system that makes use of warm-season grasses generally increases flexibility in the enterprise, which tends to improve animal productivity and financial stability (Burns and Bagley, 1996). As with most forage systems, management factors appear to have a larger impact on animal performance than the species of cool-season grass (Turner et al., 1996).

Differences in Quality Between Cool- and Warm-Season Grasses

General

Cool-season grasses tend to be intermediate to legumes and warm-season grasses in most nutritive value components. A rule of thumb is that cool-season species are of higher nutritive value than warm-season species, legumes are of higher nutritive value than grasses, and annuals are of higher nutritive value than perennials (Ball et al., 1996).

Intake is the largest single factor determining performance of animals (Buxton et al., 1995; Allison, 1985; Wilson et al., 1989; Minson, 1990), and dry matter intake explains roughly 70% of the differences observed in energy intake by animals grazing forages (Buxton et al., 1996). A two phase model of intake regulation is generally accepted for ruminants. Intake of low energy diets is generally controlled by reticulo-rumen capacity and disappearance rate. Disappearance rate is influenced by physical and(or) chemical characteristics of the diet, and represents the sum of digestion and passage. Intake of high-energy feeds is controlled by physiological mechanisms, and is influenced by energy demand. In other words, control of intake can be described as being limited by gut fill until nutrient intake balances nutrient demand of the animal, at which point intake is controlled by physiological responses from the animal. Intake of forages is most often regulated by physical restraints (Buxton et al., 1995; VanSoest, 1982; McDonald et al., 1995). The objective of this review is to compare the compositional differences between cool-season and warm-season grasses that can impact intake and animal performance.

Intake

Minson (1990) reported a voluntary intake of ruminants of 61 g/kg $BW^{0.75}$ for temperate forages as compared with 50 g/kg $BW^{0.75}$ for tropical forages. However, Reid et al. (1988) analyzed data from 170 digestibility trials with cattle fed both classes of forage and concluded that intake, which averaged 89.7 g/kg $BW^{0.75,}$ was not different between cool-season and warm-season hays over a wide range of qualities. Similar data with sheep did indicate higher intake of cool-season grass than warm-season grass (Reid et al., 1988). Linear regression of DMI on DMD for cattle resulted in an R^2 of .02 for cool-season grasses and .53 for warm-season grasses (Reid et al., 1988), indicating that digestibility may play a larger role in regulation of intake of warm-season grasses than cool-season grasses in cattle.

Intake, passage rate and digestibility of forages are interrelated, especially at low digestibilities. Relationships between digestibility and intake may be different for different forage types (Minson, 1981; Reid et al., 1988). For example, cattle consume substantially more legume hay than grass hay, even when digestibility is approximately equal (Thomson et al., 1991; Thornton and Minson, 1973; Grenet, 1989).

Increasing maturity decreases voluntary intake. Minson (1990) reported a decrease in DMI of 3.9%/d ($BW^{0.75}$-basis) for cool-season grasses. This decreased intake would presumably be due to increased gut fill and decreased rate of passage as these forages mature and become less digestible. Cool-season grasses generally decrease in voluntary intake faster than warm-season grasses (Minson, 1990), possibly due to the greater difference in composition of immature *versus* mature cool-season grass (Galyean and Goetsch, 1993). Reid et al. (1988) reported a slope from the regression of DMI on NDF for warm-season grasses that was twice the magnitude of the slope for cool-season grasses (CSG > DMI g/kg $BW^{.75}$ = 169 – 1.22(NDF); WSG g/kg $BW^{.75}$ > DMI = 282 - 2.58(NDF)). Intake of spring growth of cool-season perennial grasses has been observed to be higher than fall growth, but the reasons for this are not clear (Jamison and Hodgson, 1979).

There is little evidence to rank species in terms of DMI, but tall fescue does appear to have lower voluntary intake than other grasses, especially perennial ryegrass (Minson, 1990).

Another way to consider intake of grazed forages is to consider intake to be a function of grazing behavior. Amount of dry matter consumed per bite, number of bites per hour, and hours spent grazing per day can be multiplied to calculate DMI (McDonald et al., 1995). Bite size would appear to be the primary variable controlling intake, with the animal increasing grazing time to partially compensate for decreases in bite size (Forbes, 1988). These measures can be significantly influenced by structure of the forage sward.

Differences exist in sward structure of cool-season and warm-season grasses (Fisher et al., 1991). Twidwell et al. (1988) reported that total concentration of stems in standing herbage is often greater for warm-season grasses than cool-season grasses. Animals consume more leaves than stems (Poppi et al., 1981a), and this may explain part of the differences in animal performance observed between cool-season and warm-season pastures. Leaves of all forages are eaten in greater quantity than stems (Minson, 1990). This is observed even at similar digestibilities, indicating that passage rates of leaves are higher (Poppi et al., 1981a), and that leaves are less resistant to breakdown by chewing than stems.

Forage mass greater than 2000 kg/ha of vegetative material does not restrict bite size (Minson, 1990). Bite size declines when forage mass is below this level, and increased number of bites do not fully compensate, resulting in decreased forage intake. Daily forage allowance of 90 g DM/kg BW appeared to maximize intake and selectivity for calves grazing perennial ryegrass. Reducing forage allowance to 30 g DM/kg BW resulted in an 18% decrease in forage intake (Jamison and Hodgson, 1979). These animals had increased bite size and grazing time when first allowed into a new pasture, indicating that grazing behavior and not gut fill was limiting intake on the low forage allowance.

Higher levels of available forage may be required in warm-season pastures to optimize intake per bite. A forage mass of 3400 kg/ha of Old World bluestem maximized bite size, but only 2000 kg/ha of cool-season grass resulted in maximum bite size (Nelson and Moser, 1994). Comparing studies may be risky, however, as there tend to be other differences in the pastures or animals that confound comparisons of grazing behavior.

In temperate grass pastures, height of forage is the major factor regulating bite size. However, density of leaves and concentration of leaves relative to stems seems to be more important in tropical grasses (Forbes, 1988). This could reflect the overall higher proportion of leaves in cool-season swards (Fisher et al., 1991) and the greater selectivity observed by animals grazing warm-season swards (Grovum, 1988). As both types of grass mature, bite size is reduced. In temperate pastures, leaves are less dense in the surface horizon, causing the animal to be more selective. In tropical grasses, leaves make up a smaller proportion of the dry matter, also causing more intense selection with each bite (Forbes, 1988).

Digestibility

Digestibility of cool-season grasses is generally higher than warm-season grasses (Buxton et al., 1996; Jung and Vogel, 1986; Brake et al., 1989). Minson (1990) stated that temperate grasses are 13% more digestible than tropical grasses. Tropical grasses average about 55% digestible dry matter while temperate grasses average 68% (Minson, 1990). This is due to both the difference in anatomy of the grasses and also to the higher temperature at which tropical forages are often grown (Minson, 1990; Galyean and Goetsch, 1993.). Anatomical differences accounted for an 8% difference in cool- *versus* warm-season species of the same genus grown in the same environment (Wilson et al., 1983).

The temperature at which these grasses are normally grown may account for the remaining portion of the difference in digestibility (Minson, 1990). Higher temperature causes a reduction in soluble carbohydrate in these grasses (Wilson and Ford, 1973), and an increase in lignin content (Ford et al., 1979). High temperatures may decrease digestibility of cool-season grasses more than warm-season grasses (Ford et al., 1979), but digestibility of cool-season grass remained higher than warm-season grass, even at elevated temperatures (Wilson and Ford, 1971).

Wilson et al. (1983) conducted a greenhouse experiment using 28 C3 and C4 species of *Panicum*. Average digestibility of leaves of cool-season species was 7% higher, and NDF concentration was 17% lower, than the average of leaves of the warm-season species. In a field study conducted by Kephart and

Buxton (1993), however, the differences between cool-season and warm-season grass leaves were much smaller. Tall fescue, deertongue grass, and reed canarygrass leaf NDF averaged 4.5% lower than switchgrass and big bluestem. Stems of the two grass types were similar in digestibility. Jung and Vogel (1986) reported that cool-season grasses contained less NDF, and that the NDF was somewhat lower in lignin and somewhat higher in digestibility, than warm-season grasses.

Reid et al. (1988) reported an average of 67% DMD *versus* 60% DMD for cool-season and warm-season grasses, respectively. Neutral detergent fiber concentration was 65% and 74% for cool-season and warm-season grasses, respectively, while ADF concentration averaged 38% and 43%. Both NDF and ADF were negatively correlated with digestibility, DMI, and digestible DMI. However, NDF intake increased as NDF increased in the forage. These researchers postulated that animals can adapt to higher cell wall concentration of forages by increasing gut fill, and do not consume a constant amount of cell-wall over a range of cell-wall concentrations. Greater gut fill was found for steers consuming orchardgrass silage as compared with alfalfa silage, even though intake of alfalfa was higher (Thomson, 1991). If animals maintain intake of a forage as the cell wall content of that forage increases, it may be assumed that animals can adapt to higher cell wall concentrations by increasing fill limits and(or) passage rates. This may explain the higher than expected intake of animals fed warm-season grasses (Reid et al., 1988). Performance usually suffers as a result, however, due to the overall lower availability of energy in diets that are high in cell wall (Buxton et al., 1996; Thomson, 1991).

Maturity decreases digestibility of forages. Wheatgrass and tall fescue both decreased in IVOMD as they matured, although other responses were different (Park et al., 1994; McCracken et al., 1993). Rate and extent of NDF digestion also generally decline as plants mature (Park et al., 1994). Cool-season species decline in digestibility faster than warm-season species. Minson (1990) reported that cool-season grasses fall 0.47% in DMD per day, as compared with 0.26% for warm-season grasses.

Leaves of cool-season grasses are typically higher in TDN, a measure of digestibility, than stems, because of the greater concentration of cell walls in stems. However, the difference in energy content between leaves and stems in cool-season grasses is not as large as the difference in legumes. Stems decline in TDN at a faster rate than leaves as plants mature (Buxton et al., 1996). Cool-season grasses typically have a higher percentage of leaf than warm-season grasses (Fisher et al., 1991), which may amount to a further advantage in digestibility separate from anatomical and temperature effects.

In vitro dry matter digestibility averaged 69.8% for bromegrass and 67.3% for orchardgrass from April to October in West Virginia. Tall fescue IVDMD was significantly lower than these at 66%. In vitro dry matter digestibility exhibited a cubic response to time, reflecting the spring and fall lush growth periods separated by a summer dormancy that is characteristic of temperature forages (Burns and Bagley, 1996). Significant species effects on IVDMD were observed in the spring period, but the grasses were not different in the summer period from June to September. Tall fescue was higher in cell-wall content than smooth bromegrass and perennial ryegrass. No difference was found in lignin content, which was shown by regression analysis to explain 80% of the variation in IVDMD (Powell et al., 1978). In another experiment (Collins and Casler, 1990), smooth bromegrass was more digestible and contained less NDF and ADF than orchardgrass. However, protein content of these two grasses was not different. Additionally, smooth bromegrass and orchardgrass declined in quality at a slower rate than tall fescue and reed canarygrass during May and June. Intermediate wheatgrass has been observed to be higher in digestibility than smooth bromegrass at similar stages of maturity (Buxton et al., 1995). Differences also exist in digestion of cell wall among species, as evidenced by low digestibility of tall fescue even though it was low in NDF (Collins and Casler, 1990).

Lignin is a good predictor of cell-wall digestibility, but its relationships are complex (Jung and Vogel, 1986). Buxton and Russell (1988) reported regression equations that support the concept than if lignin was non-existent, eventual cell wall digestibility would be 100%. Cell wall and lignin content of stems is greater than that of leaves (Buxton and Russell, 1988; Jung and Vogel, 1986). Lignin affects cell wall digestibility more than dry matter digestibility (Jung and Vogel, 1986).

Legume stems contain more lignin than grass stems (Buxton and Russel, 1988), but legume lignin is more digestible than grass lignin (Warren et al., 1974). Grasses increase in lignin at a much faster rate as they mature than legumes. Grass lignin appears to inhibit cell wall digestion more so than legume lignin, possibly due to different components of the lignin matrix or increased concentration of p-coumaric acid in grass lignin. P-coumaric acid is toxic to rumen bacteria (Buxton and Russell, 1988). Additionally, p-coumaric acid associated with the lignin in cell walls is known to be in much lower concentration in mature cool-season grasses than in mature warm-season grasses (Buxton et al., 1996).

Generally, warm-season grass contains more lignin, and that lignin is less apparently digestible, than cool-season grass (Jung and Vogel, 1986). However, no difference was observed in lignin concentration or digestibility of lignin of *leaves* between cool-season and warm-season grasses (Kephart and Buxton, 1993). This may indicate that lignin relationships would play a larger role in the stem fraction of forage. The proportion of hemicellulose and cellulose to cell wall is about the same for cool- and warm-season grass (Ford et al., 1979). As the cell wall content of plants increase, hemicellulose and cellulose components decrease in proportion linearly and lignin increases exponentially. However, lignin appears to lose some of its digestibility inhibitory action at higher lignin concentrations, possibly due to changes in its chemical makeup (Jung and Vogel, 1986).

Chemical Composition

Compositional differences in the chemical makeup of forage from cool-season and warm-season grasses influence intake and performance of grazing animals. Water content of forages does not appear to limit intake when water content is less than 78% of the forage when fed to penned animals. Wheat forage intakes were pooled across levels of dry matter from 19.1% to 28.1%, indicating that water content of this forage was not limiting intake (Mader and Horn, 1986). Free water in the rumen would be expected to be absorbed or passed out of the rumen relatively quickly. However, greater cell-wall content of warm-season grasses, especially at maturity, may absorb and hold more free water, which could increase bulk in the rumen and decrease intake slightly (Allison, 1985).

Buxton et al. (1996) noted that cool-season grasses typically have a higher cell wall concentration than legumes but lower than that of warm-season grasses. Brake et al. (1996) reported that NDF digestion was higher for orchardgrass hay as compared with bermudagrass hay. This would indicate that cool-season grasses would be higher in digestibility compared with warm-season grasses. Cell-wall concentration, digestibility of cell-walls, and rate of passage may be the most important factors controlling intake within a forage type (Buxton et al., 1996).

Reid et al. (1988) reported an average of 65% and 74% NDF for cool-season and warm-season grasses, respectively, while ADF concentration averaged 38% and 43%. Collins and Casler (1990) reported that smooth bromegrass was lower in NDF than other cool-season perennial grasses. Tall fescue was low in NDF as well, but it was also low in digestibility, indicating that variation in extent of cell-wall digestibility exists among species.

NDF may be inversely related to intake, in that animals may consume a constant amount of NDF over a range of NDF values in forage by modulating dry matter intake (Buxton et al., 1996). However, VanSoest (1982) reported a correlation of DMI to NDF of only 58%. Additionally, Reid et al. (1988) observed higher intakes of NDF as NDF concentration increased. The effect was more pronounced for cattle than sheep.

Intake was highly correlated with NDF and ADF of temperate grass (r^2=.89 and .90) (Jones and Walters, 1975). However, intake was not as highly correlated with lignin (r^2 = .69). Intake was more highly correlated with ADF than NDF for tropical grasses (Abrams et al., 1983) with r^2 of .54 *versus* .38, with lignin being intermediate (r^2 = .45). Reid et al., (1988) found that intake was more closely correlated with ADF for cool-season than warm-season grasses, but intake was correlated with NDF about equally for the two grass types. These effects are difficult to interpret, but it would appear that while cell wall content most assuredly influences intake, other factors are important as well.

Leaves of cool-season grasses can be lower in NDF than leaves from warm-season species (Kephart and Buxton, 1993; Wilson et al., 1983). Voluntary intake of leaves is higher than stems, even at similar digestibilities (Poppi et al. 1983a). However, the difference may be larger for warm-season grasses than cool-season grasses (Laredo and Minson, 1975).

Cool-season grasses are generally intermediate to legumes and warm-season grasses in crude protein concentration. Average values of 17%, 12.9%, 10% crude protein have been reported for cool-season legumes, cool-season grasses, warm-season grasses, respectively (Buxton et al. 1996; Minson 1990). One-fifth of the warm-season samples compared by Minson were below 6% CP, the minimum required for maintenance of rumen bacteria. Several researchers have reported higher concentration of crude protein for cool-season grasses (Mullahey et al., 1992; Wilson and Ford, 1973). Crude protein of orchardgrass hay was 2 percent higher than bermudagrass even though the two hays had equal NDF (Brake et al., 1989).

Ribulose-1,5-bisphosphate, the CO_2-fixing enzyme, can account for as much as 70% of the true protein in cool-season grasses (Buxton et al., 1996), whereas this enzyme is only about 8-23% of protein in warm-season grass (Mullahey et al., 1992). Nitrogen associated with the NDF fraction of cool-season grasses is typically about 10% to 12% of total forage nitrogen (Buxton et al. 1996).

Chemical analysis indicated that tall fescue was lower in nitrogen concentration than smooth bromegrass and orchardgrass in West Virginia (Powell et al., 1978). Several species of wheatgrasses and orchardgrass exhibited similar patterns of protein content throughout the year on the southern High Plains. Additionally, no difference was observed in protein content between a short stubble-height treatment (heavy grazing pressure) and a moderate height treatment (Schuster and De Leon Garcia, 1973).

Protein in forages declines at an average rate of .22%/d (Minson, 1990). Protein content of cool-season forage declines more in response to maturity than warm-season forage. This is likely due to the overall higher quality of cool-season grasses, in that cool-season grass has a relatively broad range of protein from early growth to mature forage, leaving it a greater range in which to decline (Galyean and Goetsch, 1993). This decline occurs due to decreased nitrogen concentration of both leaves and stems and to an increased percentage of stems in the forage dry matter (Buxton et al., 1996).

Crude protein below 7% may limit microbial production in the rumen of ruminants grazing forage (Allison, 1985). This would therefore decrease rate of digestion, and result in lower intake of forage (Minson, 1990). For example, providing late-season protein supplementation to stocker cattle on low quality warm-season pasture remedies their protein deficiency, resulting in increased intake (Arelovich et al., 1983) and performance (Lusby and Horn, 1983). However, protein supplementation can add expense to grazing programs (McCollum and Horn, 1990). Additionally, younger, lighter animals can require more than 13% crude protein in the diet to achieve high rates of gain (NRC, 1996). The higher protein content of cool-season perennial grasses could enable them to support high stocker cattle gains with less protein supplementation.

Protein in forages can be broken down into two basic fractions. Protein degraded in the rumen that can potentially be used for microbial protein synthesis is termed degradable intake protein (DIP). Nitrogen released from DIP can be either incorporated into microbial protein or lost as simple nitrogen containing compounds like ammonia. The fraction of crude protein that is not DIP is termed undegradable intake protein (UIP). This protein passes from the rumen into the lower gastro-intestinal tract where it may be digested in the small intestine. Microbial protein and UIP comprise metabolizable protein, which is the protein the animal can actually digest and absorb as amino acids in the small intestine (NRC, 1996). Flow of non-ammonia nitrogen to the small intestine often is 80% microbial protein (Buxton et al. 1996).

The DIP content of fresh forages is about 75% of CP on average (Buxton et al. 1996; Minson, 1990). DIP as a percentage of crude protein in cool-season grasses is generally higher than in warm-season grasses (Moser and Hoveland, 1996). Nelson and Moser (1994) further stated that protein digestible in the rumen is about 50-60% for warm-season grasses, whereas it is typically 80% or higher for cool-season grasses. This is presumably due to the decreased rate and extent of digestion of warm-season *versus* cool-season bundle sheath cells (Nelson and Moser, 1994; Akin, 1983).

Mullahey et al. (1992) reported differences in DIP for different photosynthetic types. Crude protein of smooth bromegrass was 80% DIP, while switchgrass had about 50% of the crude protein as DIP. DIP remained relatively constant to maturity for the cool-season grass, but increased as the warm-season grass matured. These researchers found a positive relationship between CP and DIP for both forages, indicating that a lower percentage of CP is ruminally degradable when the forage is lower in nutritive value. This was especially true for switchgrass. These researchers concluded that more of the protein in warm-season grasses is physically protected from microbial degradation by parenchyma bundle sheath cells. Vaughn et al. (1998) came to similar conclusions.

DIP can only be efficiently converted to microbial protein in the presence of available carbohydrate. Buxton et al. (1996) calculated that for forages containing 40% and 80% digestible dry matter, 7% and 14% crude protein, respectively, was the upper limit for efficient capture of nitrogen by ruminal bacteria. Nitrogen degraded in the rumen above that level is susceptible to being lost as ammonia. Minson (1990) reported that ruminal degradation of protein can increase net non-ammonia nitrogen flow to the small intestine in forages less than 13% CP. However, ruminal degradation of nitrogen results in a net loss of non-ammonia nitrogen at protein levels higher than this, due to loss of nitrogen as ammonia. Therefore, a significant portion of the DIP in many high-quality forages, such as vegetative cool-season perennial grass, may not be efficiently used by the animal. This could lead to a metabolizable protein deficiency on a forage that is actually quite high in overall protein concentration. Escape protein supplementation (80% UIP) of calves grazing fairly good quality forage (13% CP) resulted in increased performance, indicating an MP deficiency (Lardy et al., 1998b).

Blood urea nitrogen concentration has been proposed as a measure of both intake and utilization of nitrogen for ruminants (Carver et al., 1978). Plasma urea nitrogen levels of cattle grazing cool-season perennial grass and legume mixtures remained above the level required for moderate gain throughout the grazing season, whereas urea concentrations fell below this level approximately 45-75 days into the grazing season for cattle grazing warm-season grass (Carver et al., 1978).

Digestive Kinetics

Rate of disappearance of reticulo-ruminal contents can have large effects on intake. Positive correlations between organic matter intake and particulate disappearance rate have been observed (Allison, 1985; Park et al., 1994; McCracken et al., 1993, Thornton and Minson, 1973). Disappearance from the rumen can occur by either digestion or passage. Indigestible fractions must be eliminated by passage, whereas digestible fractions may either be broken down and the nutrients absorbed into the bloodstream or into microbial cells, or they may be reduced to a size small enough (1-2 mm, Minson, 1990; Grenet, 1989) to pass through the rumino-reticular orifice. Particles can be reduced in size by chewing and(or) microbial digestion, but chewing is the more important (Grenet, 1989; Minson, 1990). Intake potential of a forage is inversely related to its resistance to breakdown by mastication (Minson, 1990).

Greater intake of legume hays than cool-season perennial grass hays has been reported, even at similar digestibilities (Thompson et al., 1991; Goering et al., 1991). Additionally, gut fill of cattle consuming legumes is less than that of cattle consuming cool-season grass hay, despite higher intakes of legumes. This would indicate legumes have a higher rate of disappearance that is not associated with digestibility.

Similarly, rate of disappearance from the rumen of grass leaf particles is higher than stem particles, even at similar digestibilities (Poppi et al., 1981a; Laredo and Minson, 1975). Since cool-season grass swards generally contain a higher percentage of leaf than warm-season grass swards (Burns and Bagley, 1996; Fisher et al., 1991), greater intake of cool-season grass may be possible, even at similar digestibilities.

Researchers from Australia (Wilson et al., 1989a) discovered differences in the chewing and rate of digestion characteristics between cool-season and warm-season grasses. Mastication reduced warm-season grass leaf particles more so than cool-season grass leaf particles. Other research has shown that ingestive mastication is greater for warm-season grasses (Pond et al., 1984; Fisher et al., 1991). Grenet (1989) found greater mastication for ryegrass than alfalfa, which would be consistent with greater mastication of lower quality forage. However, average particle size of fecal material was greater for bermudagrass as compared with orchardgrass, indicating that rumination may reduce particle size more evenly (Brake et al., 1989).

Wilson et al. (1989a) proposed that warm-season grass may exhibit both a "brittleness" that enable easier fracturing and a "toughness" that contributes to a tactile sensation causing the animals to chew more to aid comfortable swallowing. In situ digestion of cool-season grass leaves was more rapid from 0 to 6 h than warm-season grass leaves. Rate of digestion from 6 to 96 h was not different, indicating no major difference in the rate of digestion of cell walls between the two species. Therefore, rate of digestion differences appear to be due to the higher content of cell wall of warm-season species. Indigestible cell wall was not different between the two forage types, averaging 47% of the cell wall fraction. More rapid digestion of cool-season *versus* warm-season grass leaves may contribute to increased rate of passage from the rumen, which would allow for greater intake of cool-season grasses when in vitro digestibility is similar for the two types.

Light microscopy revealed differences in the extent of leaf blade parenchyma bundle sheath tissue digestion between C3 and C4 species of *Panicum*. Bacterial degradation of these cells in cool-season species were 90 to 100% digestible whereas warm-season parenchyma was only about 50% digestible (Akin, 1983). In a later paper (Wilson et al., 1989b), the researchers investigated differences in anatomical structure and its relationship with the process of particle size reduction of the two grass types. Substantial differences were observed between the two types, with warm-season species generally exhibiting a leaf structure that was much more resistant to physical separation. Warm-season grass leaf contained twice the amount of thick walled-tissues and contained more vascular bundles per area of leaf tissue. Resistance to ruminal digestion is highest for vascular tissue, followed by sclerenchyma and parenchyma sheath. Mesophyll cells have the least resistance to ruminal degradation (Minson, 1990). Cool-season leaves contained a larger amount of mesophyll tissue, and it was less densely packed. Additionally, the intercostal cells in the epidermis of the cool-season leaf were more easily split, resulting in more rapid reduction of the width of the leaf. The epidermis of the cool-season leaf was also more easily detached from the vascular bundles around the cell walls, again resulting in more rapid fragmentation of the tissues. These characteristics would all aid in allowing ruminal microbes access to the digestible material (Pond et al., 1984). Finally, particles of cool-season grass leaf were smooth and rounded after initial mastication, as opposed to the rough, jagged particles of the warm-season leaf. This could allow digested cool-season particles to more easily separate from the mass of particles in the rumen and flow out with the liquid fraction (Wilson et al., 1989b).

Stem particles from similar forages were examined and no apparent histological or in vitro digestibility differences could be attributed to photosynthetic type (Akin, 1984). Differences in mastication and digestion kinetics between cool-season and warm-season grasses may principally be due to differences in the leaves, and therefore differences between the two forage types may be reduced at more mature stages when stem tissue constitutes a larger fraction of the total forage mass.

Brake et al. (1989) observed higher fluid passage rates with orchardgrass hay as compared with bermudagrass hay when fed to cows, even though the hays had similar NDF and ADF values. Reasons for this are not clear, but Prigge et al. (1984) found a similar relationship with ryegrass hay *versus* switchgrass hay. Total tract NDF digestibility of orchardgrass was 12 percentage points greater than that of bermudagrass. Microbial efficiency although not statistically different, was 14.1 and 10.8% for orchardgrass and bermudagrass, respectively (Brake et al., 1989). Galyean and Goetsch (1993) suggested that higher microbial efficiency with cool-season grass diets may result from greater synchrony of nutrient supply with potential rate of utilization by microbes.

Other Factors

Palatability of forages may have a large role in controlling intake of forages. Palatability of a feed refers to some quality that can be sensed by the animal, such as taste or texture, that is not related to its post-ingestive characteristics (Grovum, 1988). Differences in palatability of grasses has been reported (Burns et al., 1988; Minson & Bray, 1986) but the results of the experiments are usually confounded by differences in chemical composition that may also affect intake. Differences in intake of 'acceptable' and 'unacceptable' strains of reed canarygrass were quite large, however (O'Donovan et al., 1967). Arnold (1966) also reported large differences in intake due to palatability, primarily either taste, touch, or smell of forages. Burns et al. (1988) found large difference in preference among varieties of switchgrass that were unrelated to chemical or sward characteristics. Greater diet selection has been observed in tropical grass pastures than in temperate grass pastures (Grovum, 1988), probably reflecting the higher overall nutritive value of temperate grasses. If animals are only offered one species to graze, palatability effects on intake may become less important that other factors. Palatability effects on intake, and intake control in general, needs more investigation (Allison, 1985; Grovum, 1988).

Powell et al. (1978) fed cut herbage of four cool-season perennial grasses at two maturities to estimate mineral absorption rates. Calcium, phosphorus, potassium, and sulfur concentration and apparent absorption tended to decrease with increasing plant maturity. Magnesium concentration, however, was not affected by plant age, while apparent absorption of magnesium increased as the forage matured. Smooth bromegrass was reported to have consistently lower concentrations of magnesium than the other grasses. Cool-season grasses generally contain less calcium than legumes, and less magnesium than both cool-season legumes and warm-season grasses. (Buxton et al. 1996). Sulfur content of these grasses averaged 0.22%, and its apparent absorption was about 65% (Powell et al., 1978). Sulfur is important for production of the sulfur containing amino acids cysteine and methionine. A nitrogen to sulfur ratio of about 10 is needed for optimum production.

Magnesium supplementation may be required on some cool-season forages. A deficiency of absorbed magnesium can lead to hypomagnesemic tetany, also known as grass tetany. Grass tetany is most often observed in lactating cows (Buxton et al., 1996). Magnesium absorption can be reduced by high levels of forage potassium and protein. Magnesium is rarely required above 0.1% of diet DM by growing animals (Spears, 1994; Minson, 1990) and 0.2% of diet DM by lactating cows (Sleper and Buckner, 1996). However, magnesium supplementation has resulted in increased intake and fiber digestibility on forage that is higher than 0.1% magnesium (Spears, 1994). Temperate grasses averaged 0.18% Mg where as warm-season grasses averaged 0.36%. Sixty-five percent of temperate species were under 0.2% while only 15% of tropical species were below this level. Grass tetany usually occurs early in the spring when cool-season grasses are making active growth and are low in magnesium content (Sleper and Buckner, 1996). Wheat pasture that was 31% CP, 3.4% potassium, and 0.15% magnesium was referred to as “highly tetanigenic”, and grass tetany was a possible cause of high mortality (10-20%) of calves grazing this pasture (Mayland, 1988). Grass tetany has not been observed on warm-season forages (Minson, 1990).

The energy contained in cool-season grasses may be used more efficiently for tissue gain than the energy in warm-season grasses, especially by younger animals (Buxton et al., 1995). Evidence exists that legumes are used more efficiently for gain than grasses when fed at similar intakes (Thomson et al., 1991; Huntington, 1988; Rattray and Joyce; 1974). This may be due to the higher protein content of legumes, which could result in more protein absorbed as amino acids. These amino acids could then be used as precursors for converting acetate into fat, increasing the efficiency of use of acetate (Buxton et al., 1995). Cool-season grasses are generally intermediate to warm-season grasses and legumes in cell wall concentration. Therefore, metabolic relationships known to exist between grasses and legumes could also exist between cool-season grasses and warm-season grasses (Buxton et al., 1996). Alternatively, the greater cell wall concentration of grasses can cause a shift in the volatile fatty acid profile produced in the rumen (Buxton et al., 1995). Increased fiber digestion will produce more acetate and less propionate (Dove, 1996; Van Soest, 1982; McCollum et al., 1985). Propionate is a more efficient fatty acid than acetate for metabolism into tissue gain (Minson, 1990). However, Minson (1990) also stated that VFA proportions may only affect efficiency of ME use in protein deficient forages.

Finally, the higher cell-wall concentration of warm-season grasses can increase the amount of indigestible material processed by the gut. Maintenance requirements of visceral organs may be increased with bulky, high cell wall forages (Galyean and Goetsch, 1993). Additionally, increased energy spent grazing (Stobbs, 1974) and ruminating (Coleman et al., 1989) for warm-season grass could decrease the total efficiency of energy use by ruminants grazing these forages.

Cool-season grasses have many benefits for animal performance as compared with warm-season grasses. The benefits include increased digestibility, increased ease of particle breakdown, higher protein content and possibly greater intake apart from digestibility and passage rate. High quality forages with low cell wall content may be metabolized more efficiently than lower quality forage. Anatomical differences between photosynthetic types are the main reason for most of the differences in quality. Other factors, such a temperature and sward characteristics, are important as well. Perhaps the most important advantage for cool-season grasses in the southern Great Plains is their ability to provide nutritious forage at a time of the year that warm-season grasses cannot. Complementary grazing of cool- and warm-season grasses can increase animal performance and overall financial stability.

Changes in Forage Nutritive Value with Maturity

Forages decline in quality as they mature. In fact, plant maturity is the major determinant of forage quality, usually more important that species (Nelson and Moser, 1994; Dabo et al., 1988, Myran and Nichols, 1987). Maturation of forage is typified by decreasing proportion of leaf in relation to stem and by a decline in quality of the stem fraction (Twidwell et al., 1988). Early vegetative warm-season grasses may produce twice as much leaf dry matter as stem, but at maturity the stem fraction will be twice as large as the leaf fraction (Neslon and Moser, 1994). Increasing maturity of rangeland vegetation has been shown to reduce intake (McCollum and Galyean, 1985), digestibility (McCollum et al., 1985) and ruminal volatile fatty acid and ammonia nitrogen production (Adams, 1987). Yearly variation in quality of grazed forages due to environmental factors can be high (Cochran and Vanzant, 1991; Dabo et al., 1998; Gunter et al., 1991).

In his review, Ackerman (1999) asserted that Old World bluestem would appear to be of higher nutritive value than native tallgrass prairie. Old World bluestem decreases in crude protein and increases in cell wall content more quickly at the beginning of the growing season as compared with the end of the season. Old World bluestem fell below the protein level required for maintenance of mature cows about the middle of July (Dabo et al., 1988). In other studies (Horn and Taliaferro, 1979), Old World bluestem digestibility remained relatively constant until August, when it declined more rapidly. This emphasizes the need to manage these grasses so that a vegetative state of growth is maintained.

Nichols et al. (1993) recently studied the effects of advancing maturity on individual species in subirrigated meadows in Nebraska. Both cool-season and warm-season grasses decreased linearly in IVOMD from June to September. Crude protein of these grasses exhibited a somewhat curvilinear response in that protein decreased more rapidly from June to July than from July to September. These responses would be considered typical for changes in forage nutritive value over the summer (Collins and Casler, 1990.; Dabo et al., 1988, Myran and Nichols, 1987).

DIP content of forages averages about 75% of CP (Buxton et al. 1996). However, different types of forage may have different DIP profiles. Mullahey et al. (1992) reported 80% of smooth bromegrass CP was DIP, while switchgrass was only about 50% DIP. Degradable intake protein remained relatively constant to maturity for the cool-season grass, but decreased as the warm-season grass matured. Degradable intake protein as a percent of DM was closely correlated to CP, with a slope of .74 for bromegrass and .57 for switchgrass. Ackerman (1999) also noticed a decrease in DIP of Old World bluestem from June to August. Thus, forages tend to decrease in the percentage of crude protein that is ruminally degradable as they mature (Buxton et al., 1995).

As discussed previously, DIP as a percentage of crude protein in cool-season grasses is generally higher than in warm-season grasses (Moser and Hoveland, 1996). Nelson and Moser (1994) reported that absolute protein digestible in the rumen is about 50-60% for warm-season grasses, whereas it is typically 80% or higher for cool-season grasses. McCollum et al. (1985) suggested that crude protein may not be an acceptable measure of protein supply on ranges with diverse forage types.

Any factor, such as supplementation, that will change intake and(or) passage rate will also affect degradability of forage crude protein (Minson, 1990). Increasing intake of alfalfa hay by 50% doubled the amount of forage protein that escaped the rumen undegraded (Ulyatt et al., 1984; Merchen et al., 1986). Additionally, cold stress (2-5°C vs. 18-21°C for 20 d) reduces the amount of smooth bromegrass CP degraded in the rumen of closely shorn sheep, most likely due to the increased passage rate associated with cold temperatures (Kennedy and Milligan, 1978). Processing forages (grinding, pelleting) actually decreased the amount of CP degraded in the rumen due to changes in other digesta kinetics, such as increased passage rate (Minson, 1990).

In situ degradation of forage crude protein of bromegrass hay (57%) was higher than for bermudagrass (50.4%) or prairie hay (36.4%). Prairie hay contained less rapidly soluble protein (a component of DIP) and more insoluble protein than either of the other hays (Mathis et al., 1997.)

Old World bluestem and native midgrass prairie (sideouts grama, blue grama, buffalograss) masticate samples were collected in southwestern Oklahoma during May, June, August, and October by Gunter et al. (1991). Old World bluestem was significantly higher than midgrass prairie in crude protein and in vitro organic matter digestibility at all sampling dates. Insoluble crude protein was higher for midgrass prairie during June and August. Crude protein content of midgrass prairie was highest in May and lowest in June, with August and October being intermediate. In vitro organic matter digestibility was highest in May, and then decreased in June where it remained through the end of the season. Old World bluestem followed similar trends, with August and October crude protein values being greater than or equal to June values. In vitro organic matter digestibility did not change from June to October. Clearly, nutritive value can be influenced greatly by yearly variation in climatic conditions (Cochran and VanZant, 1991; Ackerman, 1999).

Sixteen and 24-h in situ ruminal disappearance of organic matter and crude protein was consistently higher for Old World bluestem than midgrass prairie. Disappearance of organic matter and crude protein tended to reflect changes in overall concentration of these characteristics across the sampling dates. For example, August disappearance of Old World bluestem OM and CP was higher than either June or October, corresponding to an overall increase in CP of the forage at this time. Rumen degradable CP ranged from 19.5 to 13.7 g/100 g rumen degradable OM for the Old World bluestem samples. Similar measurements for midgrass prairie samples ranged from 13.1 to 6.4 across the sampling periods. Gunter et al. (1992) used 16.3 g/100 g as the optimal DIP level required for microbial protein production in the rumen, indicating that a DIP supplement may have been beneficial to cattle grazing Old World bluestem and midgrass prairie in the summer (Gunter et al., 1992).

Tallgrass prairie decreased in protein and digestibility and increased in cell wall concentration from May to September (McCollum, 1992). Additionally, the ratio of ruminally degradable nitrogen to ruminally degradable OM was below the estimated optimum level in May and decreased across the grazing season. This would indicate that cattle grazing tallgrass prairie were DIP deficient (McCollum, 1992). Although concentration of nitrogen in blue grama rangeland declined with the decrease in digestibility, proportion of soluble and insoluble nitrogen to total nitrogen remained relatively constant (McCollum et al., 1985).

Precipitation patterns may interact with maturity affects (Buxton et al., 1995; Bittman et al., 1988; Cochran and Vanzant, 1991). Summer drought has been shown to increase leaf senesce, and therefore increase the rate of decline of protein, of cool-season grasses (Bittman et al., 1988). However, digestibility decline was actually slowed due to slower accumulation of lignin and ADF (Wilson, 1983; Mislevy and Evertt, 1981; Bittman et al., 1988). Thus, drought conditions may exaggerate DIP deficits.

Researchers in Nebraska collected samples from upland range and subirrigated meadow using esophageally-fistulated cows. Upland range sites, primarily native warm-season grasses, had elevated crude protein levels in the spring and summer. Increased IVOMD was also observed during the same period. Meadow pastures consisted of cool-season perennial grasses, and nutritive value characteristics showed similar relationships with time. Spring growth, and the associated protein and digestibility increases, began about one month earlier for these grasses. March, April and May CP was 14.1, 25.3 and

15.3 percent of DM; while IVDMD was 61.3, 71.9 and 67.9, respectively. Both CP and digestibility gradually decreased to a low of about 7% and 50%, respectively, by mid-winter (Lardy et al., 1997).

Protein degradability was estimated by an in situ method using nitrogen associated with the NDF fraction as a measure of degradability. Degradable intake protein as a percent of CP for both forage types remained relatively constant across the year, averaging about 85% for warm-season and slightly higher for cool-season forages when determined by the NDF method (Lardy et al., 1997). Degradable intake protein as a percent of DM was elevated during the growing season, but mostly reflected changes in CP concentration.

Lardy et al. (1998a) reviewed the use of the most recent NRC calculations for nutrient requirements of cattle on pasture using DIP fractions of 82% for summer native range, 85% for winter native range, and 87% for subirrigated meadow regrowth. Standard deviations are relatively small, averaging about 2.5%. These values were determined using the NDF-N method, and indicate that DIP levels of these forages may be relatively constant across the year, and even more so across a typical grazing season. However, Lardy et al. (1997a) also determined that both DIP and UIP appear to be limiting performance of summer calving cows on native range during the late summer and fall. This is the time when protein content and digestibility are declining in response to maturity of the forage. Providing a small amount of a protein supplement that contained both DIP and UIP during this period resulted in greater cow weight gain during the breeding season than either a DIP-only supplement or an iso-energetic control supplement that provided no additional protein. Degradable intake protein supplementation, alone or with UIP, increased calf weight gain during the breeding season as compared with the iso-energetic control supplement. No significant difference was found among the treatments during the late lactation phase.

Undegradable intake protein supplementation was shown to increase weight gains of calves grazing high quality meadow regrowth that was about 20% UIP (Lardy et al., 1998b). This pasture was of relatively high quality (13% CP) but was deficient in MP for these calves. This emphasizes the need to understand ruminal degradability of protein for grazing ruminants.

The DIP content of cool-season forages appears to be higher than that for warm-season forages. There are conflicting reports regarding the relative change in DIP of forages as the mature, but there is evidence to suggest than forages may decline in DIP with maturity. There is also disparity with regard to estimation of DIP by different methods, making interpretation even more difficult.

Use of the 1996 NRC Modeling Software

The 1996 edition of the Nutrient Requirements of Beef Cattle (NRC) incorporates a metabolizable protein (MP) system in its nutritional guidelines for beef cattle and modeling of cattle performance. This system replaces the old CP system by addressing nitrogen requirements of the ruminal microbes and the animal separately. Crude protein in feedstuffs must be divided into the portion that is potentially available to the microbes for microbial protein synthesis (DIP) and the portion that will escape ruminal degradation (UIP). Protein that is available for digestion in the small intestine (MP) is the sum of microbial protein and the UIP fraction of feed protein (NRC 1996).

Digestibility of UIP is assumed to be 80%, and is included in MP supply. Microbial crude protein (MCP) is assumed to be 80% true protein, which is assumed 80% digestible, therefore MCP multiplied by 64% yields the contribution of MCP to MP supply. Total MP requirements are calculated for both maintenance and the requirement to achieve the metabolizable energy-allowable gain from the feedstuff. Calculated MP requirements are therefore quite sensitive to energy content of the feed (NRC 1996).

Lardy et al. (1998a) recommend cautious use of the "On Pasture" feature and the environmental options of the model, as they can produce unrealistic increases for estimates of energy requirements in some situations. These researchers also asserted the importance of the microbial efficiency input of the model. Microbial efficiency is the amount of digestible OM that the rumen microbes will convert into microbial protein, and is an estimate of both DIP requirements and bacterial CP. They recommend 8% microbial efficiency for dormant pasture, and 13% for high-quality, vegetative pasture.

The Level I model of the NRC allows the user to input values for nutrient concentrations of feeds unique to their individual situation, such as forages during different seasons. After specifying animal type and weight, the model estimates a DMI based on the TDN content of the forage. This intake can be adjusted by the user if so desired. The model then calculates intake of individual nutrients based on the concentration and DMI. These are compared with the estimated requirements of the animal set forth in the text of the NRC. Nutrient balances are then reported for energy, DIP and MP. This allows the user to see which nutrients might be limiting performance for different classes of animals on different feeds, which allows more precise estimation of supplement needs. The model also calculates an ADG that is allowed by the metabolizable energy and protein supply independently of each other, allowing the user to compare estimated performance increases if the nutrient deficiency is alleviated.

The 1996 NRC Level 1 Model provides a useful tool for analyzing nutrient balances of cattle grazing forages. However, accurate values must be established for nutrient concentration of forages before this model can be used successfully. Additionally, caution should be exercised when using the model as nutrient supply can be influenced heavily by DMI and microbial efficiency.

LITERATURE CITED

Ackerman, C.J. 1999. Performance of light *vs.* heavy weight steers grazing plains Old World bluestem at three stocking rates. Ph.D. Dissertation. Oklahoma State University.

Adams, D.C., R.C. Cochran and P.O. Currie. 1987. Forage maturity effects on rumen fermentation, fluid flow, and intake in grazing steers. J. Range Mangmt. 40(5):404-408.

Akin, D.E., R.H. Brown and L.L. Rigsby. 1984. Digestion of stem tissues in *Panicum* species. Crop Sci. 24:769-773.

Akin, D.E., J.R. Wilson, and W.R. Windham. 1983. Site and rate of tissue digestion in leaves of C3, C4 and C3/C4 intermediate *Panicum* species. Crop Sci. 23:147-155.

Allison, C.D. 1985. Factors affecting forage intake by range ruminants: A review. J. Range Mangmt. 38(4):305-311.

Arelovich, J.M., D.G. Wagner and C.A. Hibberd. 1983. Effect of supplementation on intake and utilization of low quality prairie hay by steers. p. 232-234. Okla. State Univ. Animal Science Research Report. MP-114.

Arnold, G.W. 1966. The special senses in grazing animals. I. Sight and dietary habits in sheep. Aust J. Agric. Res. 17:521-529.

Asay, K.H. and K.B. Jensen. 1996. Wheatgrasses. p. 691-724. *In.* Moser, L.E., D.R. Buxton, and M.D. Casler (ed.) Cool-Season Forage Grasses. Monograph #34. ASA, CSSA, SSSA. Madison, WI.

Baker, B.S. and G.A. Jung. 1968. Effect of environmental conditions of the growth of four perennial grasses. I. Response to controlled temperature. Agron. J. 60:155-158.

Ball, D.M., C.S. Hoveland and G.D. Lacefield. 1996. Southern Forages. Potash and Phosphate Institute. Norcross, GA.

Barnett, F.L. and G.F. Posler. 1983. Performance of cool-season perennial grasses in pure stands and in mixtures with legumes. Agron. J. 75:582-586.

Bird, P.R., M.J. Watson, and J.W.D. Cayley. 1989. Effect of stocking rate, season, and pasture characteristics on liveweight gain of beef steers grazing perennial pastures. Aust. J. Agric. Res. 40:1277-1291.

Bittman, S., G.M. Simpson, and Z. Mir. 1988. Leaf senescence and season decline in nutritional quality of three temperature forage grasses as influenced by drought. Crop. Sci. 28:546-552.

Blasi, D.A., G.L. Kuhl, M.D. Reynolds, and R.T. Brandt, Jr. 1997. Effect of revalor-G on the performance of stocker heifers grazing irrigated smooth bromegrass pasture for a full season. Report of Progress 783. AES Kansas St. Univ. Manhattan. p. 44-45.

Brake, A.C., A.L. Goetsch, L.A. Forster, Jr., and K.M. Landis. 1989. Feed intake, digestion and digesta characteristics of cattle fed bermudagrass or orchardgrass alone or with ground barley or corn. J. Anim. Sci. 67:3425-3436.

Burns, J.C. and C.P. Bagley. 1996. Cool-Season Grasses for Pasture. p. 321-356. *In*. Moser, L.E., D.R. Buxton, and M.D. Casler (ed.) Cool-Season Forage Grasses. Monograph #34. ASA, CSSA, SSSA. Madison, WI.

Burns, J.C., D.H. Timothy, R.D. Mochrie, and D.S. Fisher. 1988. Relative grazing preferences of *Panicum* germplasm from three taxa. Agron J. 80:574-579.

Buxton, D.R. and J.R. Russell. 1988. Lignin constituents and cell-wall digestibility of grass and legume stems. Crop. Sci. 28:553-558.

Buxton, D.R. D. R. Mertens and D.S. Fisher. 1996. Forage Quality and Ruminant Utilization. p. 229-266. *In*. Moser, L.E., D.R. Buxton, and M.D. Casler (ed.) Cool-Season Forage Grasses. Monograph #34. ASA, CSSA, SSSA. Madison, WI.

Buxton, D.R. D. R. Mertens and K.J. Moore. 1995. Forage quality for ruminants: plant and animal considerations. Prof. Anim. Sci. 11:121-131.

Carver, L.A., K.M. Barth, J.B. McLaren, H.A. Fribourg, J.T. Connel and J.M. Bryan. 1978. Plasma urea nitrogen levels in beef steers grazing nitrogen-fertilized bermudagrass and orchardgrass-ladino clover pastures. J. Anim. Sci. 47: 927-934.

Casler, M.D. 1988. Performance of orchardgrass, smooth bromegrass, and ryegrass in binary mixtures with alfalfa. Agron. J. 80:509-514.

Cochran, R.C. and E.S. Vanzant. 1991. Seasonal variation in quality of grazed forage during a drought year. p. 45-47. Cattlemen's Day. Report of Progress 623. AES, Kansas State Univ., Manhattan.

Coleman, S.W., T.D.A. Forbes, and J.W. Stuth. 1989. Measurement of the plant-animal interface in grazing research. p. 37-52. *In* Grazing Research: Design, methodology, and analysis. CSSA Spec. Publ. 16. CSSA and ASA, Madison WI.

Collins, M. and M.D. Casler. 1990. Forage quality of five cool-season grasses. II. Species effects. Anim. Feed Sci. Tech. 27:209-218.

Dabo, S.M., C.M. Taliaferro, S.W. Coleman, F.P. Horn and P.L. Claypool. 1988. Chemical composition of Old World bluestem grasses as affected by cultivar and maturity. J. Range Mangt. 41(1):40-47.

Dahl, B.E., A.C. Everson, J.J. Norris, and A.H. Denham. 1967. Grass-alfalfa mixtures for grazing in Eastern Colorado. Colorado Agr. Exp. Sta. Bull. 529-S, p. 25.

Decker, A.M., H.J. Retzer and F.R. Dudley. 1974. Cool-season perennials *vs.* cool-season annuals sod seeded into a bermudagrass sward. Agron. J. 66:381-383.

Dove, H. 1996. The ruminant, the rumen, and the pasture resource: nutrient interactions in the grazing animal. p. 219-246. In Hodgson, J. and A.W. Illius (ed.) The Ecology and Management of Grazing Systems. CAB International.

Eck, H.V. and P.L. Sims. 1984. Grass species adaptability in the southern high plains – a 36-year assessment. J. Range Mgt. 37:211-217.

Fisher, D.S., J.C. Burns, K.R. Pond, R.D. Mochrie, and D.H. Timothy. 1991. Effects of grass species on grazing steers. I. Diet composition and ingestive mastication. J. Anim. Sci. 69:1188-1198.

Forbes, T.D.A. 1988. Researching the plant-animal interface: The investigation of ingestive behavior in grazing animals. J. Anim. Sci. 66:2369-2379.

Ford, C.W., I.M. Morrison and J.R. Wilson. 1979. Temperature effects on lignin, hemicellulose and cellulose in tropical and temperate grasses. Aust. J. Agric. Res. 30:621.

Galyean, M.L. and A.L. Goetsch. 1993. Utilization of Forage Fiber by Ruminants. p. 33-72. *In* Jung, H.D., D.R. Buxton, R.D. Hatfiled, and J. Ralph. (ed.) Forage Cell Wall Structure and Digestibility. ASA, CSSA, and SSSA, Madison, WI.

Goering, H.K., D.R. Waldo, H.F. Tyrrell and D.J. Thomson. 1991. Composition of fomaldehyde- and formic acid-treated alfalfa and orchardgrass silages harvested at two maturities and their effects on intake and growth by Holstein heifers. J. Anim. Sci. 69:4634-4643.

Grenet, E. 1989. A comparison of the digestion and reduction in particle size of lucerne hay (*Medicago sativa)* and Italian ryegrass hay (*Lolium italicum*) in the ovine digestive tract. Br. J. Nutrition. 62:493-507.

Griggs, T.C. and A.G. Matches. 1991. Productivity and consumption of wheatgrasses and wheatgrass-sainfoin mixtures grazed by sheep. Crop Sci. 31:1267-1273.

Grovum, W.L. 1988. Appetite, palatability, and control of feed intake. In Church, D.C. (ed) The Ruminant Animal: Digestive Physiology and Nutrition. p. 202-216. Waveland Press, Prospect Heights, IL.

Gunter, S.A., F.T. McCollum, and R.L. Gillen. 1991. Chemical composition of diets consumed by cattle grazing native range or plains bluestem pasture. Okla. State Univ. Animal Science Research Report. MP-134.

Gunter, S.A., F.T. McCollum, and R.L. Gillen. 1992. Midgrass prairie range *vs.* plains bluestem pasture for stocker cattle. Okla. State Univ. Animal Science Research Report. MP-136.

Hayden, C., I. Rush, B. Weichenthal, and B. VanPelt. 1997. Evaluating breakeven for various management systems for different breed types from weaning to slaughter. Nebraska Beef Report MP 67-A. Univ. of Nebraska-Lincoln. p. 52-55.

Holechek, J.L., R.E. Estell, C.B. Kuykendall, R. Valdez, M. Cardenas, and G. Nunez-Hernandez. 1989. Seeded wheatgrass yield and nutritive quality on New Mexico big sagebrush range. J. Range Mangmt. 42(2):118-122.

Huntington, G. B., G. A. Varga, B.P. Glenn, and D.R. Waldo. 1988. Net nutrient absorption and oxygen consumption by Holstein steers fed alfalfa or orchardgrass silage at equalized intakes. J. Anim. Sci. 66:1292-1303.

Horn, F.P. and C.M. Taliaferro. 1979. Seasonal changes in the nutritive value of five “Old World Bluestems”. p. 108-110. Okla. State Univ. Animal Science Research Report. MP-104.

Jamison, W.S. and J. Hodgson. 1979. The effect of daily herbage allowance and sward characteristics upon the ingestive behavior and herbage intake of calves under strip grazing management. Grass Forage Sci. 34:261-267.

Jones, D.I.H. and R.J.K. Walters. 1975. Structural constituents of grasses in relation to digestibility and voluntary intake. J. Sci. Food Agr. 26:1436-1437.

Jordon, D.J., G. Erickson, T. Klopfenstein, D. Adams, T. Milton, and R. Cooper. 1999. Steer performance within summer grazing systems. Nebraska Beef Report MP 71. Univ. of Nebraska-Lincoln.

Jung, G.A., J.L. Griffin, R.E. Kocher, J.A. Shaffer, and C.F. Gross. 1985. Performance of switchgrass and bluestem cultivars mixed with cool-season species. Agron. J. 77:846-850.

Jung, H.G., and K.P. Vogel. 1986. Influence of lignin on digestibility of forage cell wall material. J. Anim. Sci. 62:1703-1712.

Kennedy, P.M., and L.P. Milligan. 1978. Effects of cold exposure on digestion, microbial synthesis and nitrogen transformations in sheep. Br. J. Nutr. 39:105-117.

Kephart, K. D. and D. R. Buxton. 1993. Forage quality responses of C3 and C4 perennial grasses to shade. Crop Sci. 33:831-837.

Klages, K. H. 1929. Comparative ranges of adaptation of species of cultivated grasses and legumes in Oklahoma. J. Amer. Soc. Agron. p. 201-223.

Krenzer, G., Jr. 1997. Wheat for Pasture. Okla. Coop. Ext. Serv. F-2586.

Lardy, G., D. Adams, T. Klopfenstein, and D. Brink. 1998a. Use of the NRC model for evaluating nutrient balances of grazing beef cattle. Nebraska Beef Report MP 69-A. Univ. of Nebraska-Lincoln. p. 7-11.

Lardy, G., D. Adams, T. Klopfenstein, Ueckert, J. and R. Clark. 1998b. Escape protein supplementation and weaning effects on calves grazing meadow regrowth. Nebraska Beef Report MP 69-A. Univ. of Nebraska-Lincoln. p. 14-16.

Lardy, G., D. Adams, T. Klopfenstein, J. Lamb and D. Clark. 1997a. First limiting nutrient of native range for summer calving cows during the breeding season and late lactation. Nebraska Beef Report MP 67-A. Univ. of Nebraska-Lincoln. p. 6-8.

Lardy, G., D. Adams, T. Klopfenstein, D. Clark and J. Lamb. 1997b. Seasonal changes in protein degradabilities of Sandhills native range and subirrigated meadow diets and application of a metabolizable protein system. Nebraska Beef Report MP 67-A. Univ. of Nebraska-Lincoln. p. 3-5.

Laredo, M.A. and D.J. Minson. 1975. The voluntary intake and digestibility by sheep of leaf and stem fractions of *Lolium perenne*. J. Br. Grassld. Soc. 30:73-77.

Leasure, J.K. 1952. The growth pattern of mixtures of orchardgrass and tall fescue with ladino clover in relation to temperature. Proc. Assoc. South. Agric. Workers. 49:177-178.

Lechtenberg, V.L., C.L. Rhykerd, G.O. Mott, and D.A. Huber. 1974. Beef production on bromegrass (*Bromus inermis* Leyss) pastures fertilized with anhydrous ammonia. Agron. J. 66:47-50.

Lusby, K.S. and G.W. Horn. 1983. Energy *vs.* protein supplementation of steers grazing native range in late summer. p. 209-211. Okla. State Univ. Animal Science Research Report. MP-114.

Mader, T.L. and G.W. Horn. 1986. Low quality roughages for steers grazing wheat pasture. II. Effect of wheat forage intake and utilization. J. Anim. Sci. 62:1113.

Mathis, C.P., I.E.O. Abdelgadir, R.C. Cochran, J.S. Heldt, K.C. Olson, B.C. Woods, E.C. Titgemeyer, and E.S. Vanzant. 1997. Evaluation of the protein characteristics of four diverse grasses. p. 58-59. Cattlemen's Day. Report of Progress 783, AES Kansas St. Univ., Manhattan.

Mayland, H..F. 1988. Grass tetany. In Church, D.C. (ed) The Ruminant Animal: Digestive Physiology and Nutrition. p. 511-523. Waveland Press, Prospect Heights, IL.

McCollum, F.T. 1992. Chemical composition of cattle diets on tallgrass prairie. p. 25-26. In Range Research Highlights. Circular E-905. CES, Okla. State Univ.

McCollum, F.T. III, and G.W. Horn. 1990. Protein supplementation of grazing livestock: A review. Prof. Anim. Sci. 6(2):1-16.

McCollum, F.T. and M.L:. Galyean. 1985. Cattle grazing blue grama rangeland II. Season forage intake and digesta kinetics. J. Range Mangt. 38(6):543-546.

McCollum, F.T., M.L:. Galyean, L.J Krysl, and J.D. Wallace. 1985. Cattle grazing blue grama rangeland I. Season diets and rumen fermentation. J. Range Mangt. 38(6):539-543.

McCracken, B.A., L.J. Krysl, K.K. Park, D.W. Holcombe, and M.B. Judkins. 1993. Steers grazing endophyte-free tall fescue: seasonal changes in nutrient quality, forage intake, digesta kinetics, ruminal fermentation, and serum hormones and metabolites. J. Anim. Sci. June 1993:1588-1595.

McDonald, P., R.A. Edwards, J.F.D. Greenhalgh and C.A. Morgan. 1995. Animal Nutrition. Longman Scientific and Technical, Essex, England.

McLaren, J.B., R.J. Carlisle, H.A. Fribourg and J.M. Bryan. 1983. Bermudagrass, tall fescue, and orchardgrass pasture combinations with clover or N fertilization for grazing steers. I. Forage growth and consumption, and animal performance. Agron. J. 75:587-592.

Merchen, N.R., J.L. Firkins and L.L. Berger. 1986. Effect of intake and forage level on ruminal turnover rates, bacterial protein synthesis and duodenal amino acid flows in sheep. J. Anim. Sci. 62:216.

Miller, D. A. and J. F. Stritzke. 1995. Forage Establishment and Weed Management. p. 89-104. *In* Forages Vol. I: An Introduction to Grassland Agriculture. Barnes, R.F., D.A. Miller, and C.J. Nelson (ed.). Iowa State University Press. Ames, IA.

Minson, D.J. 1981. Effects of chemical and physical composition of herbage eaten upon intake. p. 167-182. *In* J.B. Hacker (ed.) Nutritional limits to animal production from pastures. Proc. Int. Symp., St. Lucia, Australia. 14-18 August. Commonw. Agric. Bur., Farnham Royal, England.

Minson, D.J. 1990. Forage in ruminant nutrition. Acad. Press, Inc, New York.

Minson, D.J., and R.A. Bray. 1986. Voluntary intake and in vivo digestibility by sheep of five lines of *Cenchrus ciliaris* selected on the basis of preference rating. Grass Forage Sci. 41:47-52.

Mislevy, P., and H.P. Everett. 1981. Subtropical grass species response to different irrigation and harvest regimes. Agron. J. 73:601-604.

Moser, L.E. and C.S. Hoveland. 1996. Cool-season grass overview. p. 1-14. *In*. Moser, L.E., D.R. Buxton, and M.D. Casler (ed.) Cool-Season Forage Grasses. Monograph #34. ASA, CSSA, SSSA. Madison, WI.

Mullahey, J.J., S. S. Waller, K. J. Moore, L. E. Moser and T. J. Klopfenstein. 1992. In situ ruminal protein digestion of switchgrass and smooth bromegrass. Agron J. 84:183-188.

Myran, D. and J. Nichols. 1987. Forage quality of Sandhills vegetation. p. 58-61. Beef Cattle Report, MP 52. Univ. of Nebraska-Lincoln.

Nelson, C.J. 1995. Photosynthesis and carbon metabolism. p. 31-44. *In* Forages Vol. I: An Introduction to Grassland Agriculture. Barnes, R.F., D.A. Miller, and C.J. Nelson (ed.). Iowa State University Press. Ames, IA.

Nelson, C.J. 1996. Physiology and developmental morphology. p. 87-126. *In*. Moser, L.E., D.R. Buxton, and M.D. Casler (ed.) Cool-Season Forage Grasses. Monograph #34. ASA, CSSA, SSSA. Madison, WI.

Nelson, C.J. and L.E. Moser. 1994. Plant factors affecting forage quality. p. 115-154. *In* Fahey, G.C. Jr. (ed) Forage Quality, Evaluation, and Utilization. ASA, CSSA, SSSA, Madison, WI.

Nichols, J.T., P.A. Duncan, and D.C. Clanton. 1993. Seasonal trends in forage quality of plants in subirrigated meadows of the Nebraska Sandhills. Transactions of the Nebraska Academy of Sciences, XX:25-32.

NRC. 1996. Nutrient requirements of beef cattle. (7th Ed.). National Academy Press, Washington, D.C.

O'Donovan, P.B., R.F. Barnes, M.P. Plumlee, G.O. Mott, and L.V. Packett. 1967. *Ad libitum* intake and digestibility of selected reed canarygrass (*Phalaris arundinacea* L.) clones as measured by the fecal index method. J. Anim. Sci. 26:1144-1151.

Olson, K.C. 1991. Diet sample collection by esophageal fistula and rumen evacuation techniques. J. Range Mangmt. 44(5):515-519.

Park, K.K, L.J. Krysl, B.A. McCracken, M.B. Judkins, and D.W. Holcombe. 1994. Steers grazing intermediate wheatgrass at various stages of maturity: effects on nutrient quality, forage intake, digesta kinetics, ruminal fermentation, and serum hormones and metabolites. J. Anim. Sci. 72:478-486.

Pond, K.R., W.C. Ellis and D.E. Akin. 1984. Ingestive mastication and fragmentation of forages. J. Anim. Sci. 58:1567.

Poppi, D.P., D.J. Minson, and J.H. Ternouth. 1981a. Studies of cattle and sheep eating leaf and stem fractions of grasses. I. The voluntary intake, digestibility retention time in the reticulo-rumen. Aust. J. Agric. Res. 32:99-108.

Poppi, D.P., D.J. Minson, and J.H. Ternouth. 1981b. Studies of cattle and sheep eating leaf and stem fractions of grasses. II. Factors controlling the retention of feed in the reticulo-rumen. Aust. J. Agric. Res. 32:109-121.

Poppi, D.P., D.J. Minson, and J.H. Ternouth. 1981c. Studies of cattle and sheep eating leaf and stem fractions of grasses. III. The retention time in the rumen of large feed particles. Aust. J. Agric. Res. 32:123-137.

Powell, K., R.L. Reid and J.A. Balasko. 1978. Performance of lambs on perennial ryegrass, smooth bromegrass, orchardgrass and tall fescue pastures. II. Mineral utilization, in vitro digestibility and chemical composition of herbage. J. Anim. Sci. 46:1503-1514.

Prigge, E.C., M.J. Baker and G.A. Varga. 1984. Comparative digestion, rumen fermentation and kinetics of forage diets by steers and wethers. J. Anim. Sci. 59:237.

Rattray, P.V. and J.P. Joyce. 1974. Nutritive value of white clover and perennial ryegrass. IV. Utilization of dietary energy. N.Z. J. Agric. Res. 17:401-406.

Redmon, L.A. 1997. Cool-Season Perennial Grass Update. Production Technology Report. PT 97:42. Oklahoma State University.

Reid, R. L. , G.A. Jung, and W. V. Thayne. 1988. Relationships between nutritive quality and fiber components of cool-season and warm-season forages: A retrospective study. J. Anim. Sci. 66:1275-1291.

Reid, R.L., K. Powell, J.A. Balasko and C.C. McCormick. 1978. Performance of lambs on perennial ryegrass, smooth bromegrass, orchardgrass and tall fescue pastures. I. Live weight changes, digestibility, and intake of herbage. J. Anim. Sci. 46:1493-1502.

Reuter, R.R., G.W. Horn, C.J. Ackerman and J.N. Carter. 1999. Performance of steers grazing cool-season perennial grasses. Okla. State Univ. Animal Science Research Report. P-973.

Schuster, J.L. and R. C. De Leon Garcia. 1973. Phenology and forage production of cool-season grasses in the Southern Plains. J. Range Mgt. 26:336-339.

Shain, D., T. Klopfenstein, R. Stock, and M. Klemesrud. 1996. Grazing systems utilizing forage combinations. Nebraska Beef Report MP 66-A. Univ. of Nebraska-Lincoln. p. 48-51.

Shain, D., T. Klopfenstein, R. Stock, and M. Klemesrud. 1997. Forage combinations for summer and fall grazing. Nebraska Beef Report MP 67-A. Univ. of Nebraska-Lincoln. p. 56-59.

Sleper, D.A. and R.C. Buckner. 1995. The Fescues. p. 345-356. *In* Forages Vol. I: An Introduction to Grassland Agriculture. Barnes, R.F., D.A. Miller, and C.J. Nelson (ed.). Iowa State University Press. Ames, IA.

Spears, J.W. 1994. Minerals in forages. p. 281-317. *In* Fahey, G.C. Jr. (ed) Forage Quality, Evaluation, and Utilization. ASA, CSSA, SSSA, Madison, WI.

Stobbs, T.H. 1974. Components of grazing behavior of dairy cows on some tropical and temperate pastures. Proc. Aust. Soc. Anim. Prod. 10:299-302.

Thomson, D. J., D. R. Waldo, H. K. Goering, and H. F. Tyrrell. 1991. Voluntary intake, growth rate, and tissue retention by Holstein steers fed formaldehyde- and formic acid-treated alfalfa and orchardgrass silages. J. Anim. Sci. 69:4644-4659.

Thornton, R.F and D.J. Minson. 1973. The relationship between apparent retention time in the rumen, voluntary intake, and apparent digestibility of legume and grass diets in sheep. Aust. J. Agric. Res. 24:889-898.

Turner, K.E., D.P. Belesky, J.M. Fedders and E. B. Rayburn. 1996. Canopy management influences on cool-season grass quality and simulated livestock performance. Agron. J. 88:199-205.

Twidwell, E.K., K.D. Johnson, J.H. Cherney, and J.J Volenec. 1988. Forage quality and digestion kinetics of switchgrass herbage and morphological components. Crop Sci. 25:772-782.

Ulyatt, M.J., G.C. Waghorn, A. John, C.S.W. Reid and J. Monro. 1984. Effects of intake and feeding frequency on feeding behavior and quantitative aspects of digestion of in sheep fed chaffed lucerne hay. J. Agric. Sci. 102:645-657.

Van Santen, E., and D.A. Sleper. 1996. Orchardgrass. p. 503-534. *In*. Moser, L.E., D.R. Buxton, and M.D. Casler (ed.) Cool-Season Forage Grasses. Monograph #34. ASA, CSSA, SSSA. Madison, WI.

Van Soest, P.J. 1982. Nutritional ecology of the ruminant. O & B Books, Inc. Corvallis, OR.

Vaughn, D., W. Schacht, L. Moser, R. Graybosch, and T. Klopfenstein. 1998. Ruminal degradation of rubisco by beef cattle grazing switchgrass and big bluestem. Nebraska Beef Report MP 69-A. Univ. of Nebraska-Lincoln. p. 21-23.

Vogel, K.P., K.J. Moore, and L.E. Moser. 1996. Bromegrasses. p. 534-568. *In*. Moser, L.E., D.R. Buxton, and M.D. Casler (ed.) Cool-Season Forage Grasses. Monograph #34. ASA, CSSA, SSSA. Madison, WI.

Warren, W. P., F.A. Martz, K.H. Asay, E.S. Hilderbrand, C.G. Payne and J.R. Vogt. 1974. Digestibility and rate of passage by steers fed tall fescue, alfalfa and orchardgrass hay in 18 and 32 C ambient temperatures. J. Anim. Sci. 39:93-96.

Wilson, J.R., D.E. Akin, M.N. McLeod, and D.J. Minson. 1989a. Particle size reduction of the leaves of a tropical and a temperate grass by cattle. I. Effect of chewing during eating and varying times of digestion. Grass Forage Sci. 44:55-63.

Wilson, J.R., D.E. Akin, M.N. McLeod, and D.J. Minson. 1989b. Particle size reduction of the leaves of a tropical and a temperate grass by cattle. II. Relation of anatomical structure to the process of leaf breakdown through chewing and digestion. Grass Forage Sci. 44:65-75.

Wilson, J.R. 1983. Effects of water stress on in vitro dry matter digestibility and chemical composition of herbage of tropical pasture species. Aust. J. Agric. Res. 34:377-390.

Wilson, J.R. and C.W. Ford. 1971. Temperature influences on the growth, digestibility, and carbohydrate composition of two tropical grasses, *Panicum maximum* var. Trichoglume and *Sertaria sphacelata*, and two cultivars of the temperate grass *Lolium perenne*. Aust J. Agric. Res. 22:563-571.

Wilson, J.R. and C.W. Ford. 1973. Temperature influences on the in vitro digestibility and soluble carbohydrate accumulation of tropical and temperate grasses. Aust J. Agric. Res. 24:187-198.

Wilson, J.R., R.H. Brown, and W.R. Windham. 1983. Influence of leaf anatomy on the dry matter digestibility of C3, C4, and C3/C4 intermediate types of *Panicum* species. Crop Sci. 30:141-146.

CHAPTER III

COOL-SEASON PERENNIAL GRASSES AS COMPLEMENTARY FORAGES TO WHEAT PASTURE

Abstract

Three grazing trials were conducted to evaluate three cool-season perennial grasses, Manska pubescent wheatgrass, Lincoln smooth bromegrass, and Paiute orchardgrass, as complementary forages for winter wheat pasture. Cattle should be removed from wheat pasture at the first hollow stem stage of maturity in late winter to avoid reductions in grain yield. Stocking rate averaged 1408 kg BW/ha for approximately 60 d in the spring trials (April and May) and 857 kg BW/ha for 40 d in the fall trial (late September and October). Average daily gain and gain/ha averaged .86 kg/d and 287 kg/ha, and .50 kg/d and 59 kg/ha, for the spring and fall trials, respectively. Generally, neither animal performance nor production per hectare was different among the three grasses. However, organic matter of wheatgrass was more digestible, and its crude protein was more ruminally degradable than the other grasses. A poor fit between timing of forage production from these grasses and the first hollow stem stage of maturity of wheat pasture was observed.

Key Words: Cool-season perennial grass, Wheat pasture, Complementary forage

Introduction

Winter wheat (*Triticum aestivum*) pasture is an important forage resource for stocker cattle producers in the southern Great Plains, and winter wheat can serve a dual purpose by producing both forage for grazing and a grain crop in late spring. However, cattle must be removed from wheat pasture at the "first hollow stem" stage of maturity if reductions in grain yield are to be avoided. Grazing wheat beyond the first hollow stem stage of maturity has been shown to decrease grain yields by approximately 83 $\text{kg}\cdot\text{ha}^{-1}\cdot\text{d}^{-1}$ (Redmon et al., 1996). First hollow stem is defined as the time at which a hollow stem can first be identified above the crown in ungrazed wheat plants. This stage usually occurs in late winter, approximately March 1 to March 20 (Krenzer, 1997). Warm-season perennial grasses, such as Old World bluestem, bermudagrass, or native grasses, are generally not ready for grazing until approximately May 15, and a forage resource that could "fill the gap" between the time of first hollow stem of wheat pasture and grazing of warm-season perennials in southern Great Plains could be valuable to stocker cattle producers. Several cool-season perennial grasses have been shown to produce adequate quantities of forage of high nutritive value in Oklahoma (Redmon, 1997) and may have potential to fill this gap.

In order to use these forages most efficiently, information about their nutrient profiles is valuable. The 1996 edition of the Nutrient Requirements of Beef Cattle utilizes a metabolizable protein (MP) system to express protein requirements of cattle. This system partitions crude protein (CP) of feeds and forages into two fractions based on ruminal degradability of protein. Degradable intake protein (DIP) is available to the rumen microbes for incorporation into microbial protein, while undegradable intake protein (UIP), or escape protein, by-passes the rumen and is potentially available for digestion in the small intestine. Estimates of the degradability of CP of these cool-season perennial grasses are needed to fully evaluate nutrient balance and possible supplementation strategies. Typically, either energy or protein is the first-limiting nutrient for gain of forage fed ruminants. However, forage types can vary in their concentration and availability of other nutrients, minerals for example, that can affect animal performance. Therefore, this study was conducted to evaluate growth performance of steers grazing three cool-season perennial grasses, as well as quantify forage nutritive value and degradability of CP. This information could then be used to evaluate management of these grasses as complementary forages to wheat pasture.

Materials and Methods

Research Site

The study was conducted at the Wheat Pasture Research Unit southeast of Marshall, OK. The primary soil type is Kirkland silt loam. Long-term (30-yr) mean annual precipitation was 805 mm. Three cool-season perennial grasses that had been shown to produce adequate quantities of forage in this environment, and that represented a range of drought and heat tolerance were selected for establishment (Redmon, 1997). Manska pubescent wheatgrass (*Thinopyrum intermedium* Host), Lincoln smooth bromegrass (*Bromus inermis* Leyss.), and Paiute orchardgrass (*Dactylis glomerata* L.) were established in each of two locations. Location 1, established on September 5, 1996, included six pastures of 2.8 ha each, with two pastures for each of the three grasses. Location 2, established on September 3, 1997, also included six pastures but of 4 ha in size. Nitrogen fertilizer was applied before grazing at the rate of 39 kg/ha in the spring of 1998, 58 kg/ha in the spring of 1999, and 59 kg/ha in the fall of 1999. Complete agronomic management of these pastures is presented in Appendix C.

Animals

Trial 1. Ninety crossbred steers (initial BW 258 ±(SD) 24 kg) that had previously grazed native range were allocated to the six pastures at Location 1 at the rate of 5.3 steers/ha (1365 kg BW/ha). Initial weights of the steers were calculated as the average of two full weights recorded on consecutive days minus a 2% mathematical shrink. Final weights were recorded after a 16-h fast without feed or water. The pastures were grazed for 56 d (April 3 to May 29, 1998).

Trial 2. Two-hundred and nine crossbred heifers (initial BW 233 ±(SD) 20 kg) were used in this trial. These heifers had previously undergone a 42-d receiving period in which they were fed a 14% CP diet that was 32.5% soybean hulls, 25% corn, 10% cottonseed hulls, and the balance of the ration was a supplement containing wheat midds, cottonseed meal, soybean meal, vitamins, minerals, and monensin (Stovall et al., 1999). Receiving period ADG was 1.07 kg/d. Initial and final weights were recorded after a 16-h fast without feed or water. In an effort to equalize fill at the end of the trial, all heifers grazed a common, dormant native grass pasture for two days before final weights were recorded. Heifers were randomly allocated to all six pastures of Location 2, and 2 pastures each of wheatgrass and bromegrass at Location 1. The orchardgrass pastures at Location 1 were not used because the stand did not survive the drought during the previous summer. Grazing began on March 31, 1999 and terminated on June 9, 1999.

Six forage samples were clipped in each pasture nine d (March 22) before the trial began to determine initial forage mass. Stocking rate was adjusted to provide an equal initial forage allowance of 547 ± 28 kg of forage DM per heifer at the initiation of the trial. To fully utilize the available forage in each pasture, heifers were not removed from a pasture until the stubble height of the forage in that pasture was reduced to approximately 15 cm. This necessitated removing heifers from five pastures at d 54 of the trial. These heifers were weighed and some were reassigned to the remaining pastures as put-and-take grazers to more quickly utilize the available forage. Cattle were removed from the remaining five pastures on d 70 of the trial. Average daily gain was calculated as gain/heifer divided by the appropriate number of days, either 54 or 70. Gain/ha was calculated as gain/heifer multiplied by a weighted average stocking rate that reflected the increased stocking rate from d 54 to d 70.

Trial 3. Seventy two crossbred heifers (initial BW 289 ±(SD) 16 kg) that had previously undergone a 42-d receiving period were used in this trial. The receiving diet was similar to the diet described for Trial 2, and ADG was .79 kg/d. Heifers were weighed on September 23, 1999 after a 16-h fast without feed or water and allotted to one of the six pastures at Location 2 at the rate of 2.96 heifers/ha (844 kg BW/ha). Final weights were recorded after a 16-h fast without feed or water on November 3, 1999.

Forage Sampling Procedure

Four nutritive value samples were clipped by hand from each pasture at the initiation, midpoint, and termination of each trial. An attempt was made by the sample collector to mimic selection of the cattle by clipping only the portion that the cattle were consuming. Samples were dried at 55°C until dry (approximately 24 h) and composited by pasture within sampling time in preparation for chemical analysis.

Additionally, forage samples were clipped from the six pastures at Location 1 on October 3, 1997 and October 30, 1997. These samples, and the samples from the spring of 1998, were composited into one fall and one spring sample for each grass, and were then analyzed for mineral concentrations.

Forage mass was determined by clipping all forage matter to ground level inside a 0.19 m^2 quadrat. Six samples per pasture were taken in conjunction with the nutritive value samples, were dried at 55°C for 24 h, and then weighed to calculate forage DM/ha.

Chemical Analysis

Oven dried (55°C) samples for nutritive value were ground in a Wiley mill to pass through a 2-mm screen. Percent ash was determined by exposing the samples to 500°C for 6 h in a muffle furnace. Organic matter (OM) was calculated as dry weight of the sample less the ash content. A combustion technique (LECO NS-2000, St. Joseph MI: AOAC, 1996), utilizing a combustion catalyst (COM-CAT: LECO, St. Joseph MI) was used for nitrogen and sulfur analysis. Crude protein (CP) was calculated as nitrogen * 6.25. Degradable intake protein (DIP) was determined by measuring nitrogen disappearance during a 48-h incubation in a borate-phosphate buffer containing protease type XIV from *Streptomyces greises*. This procedure was similar to that described in Roe et al. (1991) except that the pH of the buffer in the present procedure was 7.8 rather than 6.7. A 48-h in vitro procedure, described by Goering and Van Soest (1970), was used to estimate digestible organic matter (IVOMD).

Composited samples from the fall of 1997 and spring of 1998 were microwave digested to a total pressure of 1.035 x 10^6 pascal. An inductively coupled plasma spectrophotometer (Spectro SpectroFlame; Fitchburg, MA), calibrated with high purity standards, was used to determine concentrations of calcium, phosphorus, magnesium, sodium, potassium, and copper.

Statistical Analysis

Forage mass, animal performance and beef production per hectare were analyzed within trial by analysis of variance as a completely randomized design. Grass species was the only source of variation included in the model. Least squares means of dependent variables were separated by least significant difference.

An additional analysis was performed to evaluate the change in forage nutritive value over the grazing periods. In this analysis, nutritive value data from each sampling time in all three trials were analyzed by analysis of variance as a split plot design. Trial and grass species were the whole-plot variables and time of sampling was the split-plot variable. Sources of variation included in the model were trial, grass species, time of sampling (beginning, middle, or end of each trial), all of the two-way interactions and the three way interaction. Pasture (nested within trial and grass) was used as the error term for the whole-plot variables, while the residual was used to test terms involving the split-plot variable. Interaction terms were considered significant if their P-value was less than .05, and were removed from the model if their P-value was greater than .30. However, the interaction of time and grass species remained in the model regardless of significance because it was part of the error term testing the whole-plot factors. Nutritive value components were analyzed separately.

Sulfur and CP data were pooled across trial, time, and grass species to determine the relationship of sulfur to crude protein with simple linear regression. The hypothesis was that sulfur content of the forages would reflect crude protein content, as the major source of sulfur in plants is sulfur amino acids (Spears, 1994).

In vitro organic matter digestibility (%DM), CP, and DIP values for each forage at each sampling time were inserted into the Feed Library of the Level 1 model of the 1996 NRC. Also, NDF (50%) and % effective NDF (50%) values were inserted so that the model would not reduce intake and microbial yield because of low pH. Other inputs were 227 kg Angus X Hereford, 8 mo. old steer. Environmental factors were left as default values, the option of "no implant or ionophore" was selected, and microbial efficiency was set at 12%. Dry matter intake, DIP, and metabolizable protein (MP) balance, as well as average daily gain allowed by metabolizable energy (ME) and MP intake, was predicted by the model for each grass and time of sampling combination. First limiting nutrient was determined by the following rationale. Negative DIP balance precludes full utilization of the ME in the feed (forage), therefore DIP is limiting if DIP balance is negative. If DIP balance is positive, MP balance determines the first limiting nutrient. The requirement listed for MP by the model is the amount of MP required to achieve the gain allowed by ME. Therefore, if MP balance is positive, excess MP is present for the amount of ME, and energy is first limiting. These guidelines were applied regardless of magnitude of differences. However, small negative or positive balances may not be biologically significant. Fifty grams of DIP is supplied by only 154 g of soybean meal (49% CP, 65% of CP as DIP).

Results and Discussion

Animal Performance

Animal performance and gain/ha was not different among grass species in Trial 1 (Table 1). However, ADG was lower ($P < .05$) for orchardgrass than either of the other grasses in Trial 2 (Table 2). In order to equalize initial forage allowance, stocking rate was numerically highest for wheatgrass, followed by bromegrass and then orchardgrass. Gain/ha was calculated as gain/heifer multiplied by stocking rate. Although gain/heifer was similar among the grasses, stocking rate was not the same, therefore, gain/ha was about 55 kg/ha higher for wheatgrass and bromegrass as compared with orchardgrass (Table 2). No difference was observed among the grasses during Trial 3 (Table 3).

In Trial 1, cattle grazing orchardgrass gained only 6 kg less than cattle on the other pastures. In Trial 2, both of the orchardgrass pastures produced more forage than expected late in the season, necessitating that they be grazed for 70 d. Cattle were removed from approximately half of the wheatgrass and bromegrass pastures on d 54. The cattle most likely did not gain weight as rapidly during the last 16 d of the trial as compared with the first 54 d, due to lower forage nutritive value. Average daily gain was calculated by dividing gain/heifer by number of days on pasture, without adjustment for this lower performance during the later part of the trial. Thus, methodology of calculating ADG in Trial 2 may have under-estimated cattle performance from orchardgrass pastures. However, smooth bromegrass has been shown to produce higher ADG in lambs than orchardgrass (Reid et al., 1978).

Animal performance in the spring trials (Trial 1 and 2) was numerically greater than in the fall trial (Trial 3). Average daily gain averaged .86 kg/d for the two spring trials as compared with .50 kg/d for the fall trial. Dry matter production of these grasses is lower in the fall than in the spring. Stubble height of the pastures were reduced to approximately 15 cm more quickly in the fall trial than the spring trials, necessitating the shorter, 40-d grazing period. Additionally, the pastures were able to support a higher average stocking rate in the spring (1402 kg initial BW/ha for 63 d) than in the fall (857 kg initial BW/ha for 40 d), reflecting increased forage production in the spring. Increased ADG and stocking rate in the spring resulted in much greater gain/ha for the spring trials, averaging 287 kg/ha, as compared with 59 kg/ha observed in the fall trial. Cool-season perennial grasses typically produce two-thirds of the yearly forage production in the spring (Burns and Bagley, 1996). However, in these trials, beef production in the spring was 80% of the total yearly production. These responses were not able to be tested statistically due to our inability to graze the pastures in the fall of 1998 because of drought the previous summer. This resulted in only one fall grazing trial, with no replication of season of grazing for statistical analysis. However, the responses we observed are similar to those observed in other grazing trials. Smooth bromegrass pastures in Kansas produced threefold more gain/ha in the first half (spring) of a 150 d grazing season as compared with the second half (summer/fall) (Blasi et al., 1997). Increased weight gain early in the season was due to both decreased ADG and stocking rate in the second half.

Burns and Bagley (1996) reported that the average ADG of cattle grazing cool-season perennial grasses such as bromegrass, orchardgrass, timothy (*Phleum pratense* L.), and Kentucky bluegrass (*Poa pratensis* L.) was .59 kg/d, but performance in the present trial was higher. This could be due to the relatively short grazing season used in the present study. Several trials in Nebraska with smooth bromegrass have reported ADG of near .9 kg/d in the early part of the grazing season (Jordon et al., 1999; Blasi et al., 1997; Shain et al., 1996).

Neither initial nor final herbage mass differed among grass species (Tables 1, 2, and 3). Orchardgrass was very productive under irrigation, but produced less DM than wheatgrass under dryland conditions in the Texas panhandle (Schuster and De Leon Garcia, 1973). Central Oklahoma receives about 800 mm of precipitation, which is higher than the 500 mm minimum required by orchardgrass (Van Santen and Sleper, 1996).

Forage Nutritive Value

The interaction of grass x time was significant ($P < .05$) for OM, IVOMD and S, and data are presented by grass and time (Table 4). In vitro organic matter digestibility was greater ($P < .05$) for wheatgrass than either of the other grasses at all sampling times. The Manska variety of wheatgrass used in this trial was produced by genetic selection emphasis on increased nutritive value (Asay and Jensen, 1996). Additionally, pubescent wheatgrass is slower to mature than some other cool-season perennial grasses (Asay and Jensen, 1996), and may be more digestible than smooth bromegrass even at similar maturities (Buxton et al., 1995). Bromegrass was more ($P < .05$) digestible than orchardgrass at the initial sampling time. Increased digestibility of bromegrass as compared with orchardgrass has been reported (Collins and Casler, 1990), but the effect may be less pronounced later in the season (Powell et al., 1978). Each grass declined ($P < .05$) in digestibility at each sampling time in all three trials (Table 4).

Sulfur was highly related to CP, and the equation $y = 0.05114 + 0.00857(CP)$ ($R^2 = .907$; $S_{y \cdot x} = .0152$) explained 90.7% of the variation in sulfur content of these forages. Spears (1994) reported that the major location of sulfur in plants is in the sulfur-containing amino acids methionine and cysteine. Minson (1990) reported that S and N are closely related in all proteins and that there is no apparent reason to consider them separately.

The interaction of trial x grass x time was significant ($P < .05$) for CP, therefore data were presented by trial, grass, time (Table 5). Crude protein content of all three grasses decreased ($P < .05$) from the initial to the final sampling time in each trial except for wheatgrass and orchardgrass in Trial 1. In Trial 1, orchardgrass was lower ($P < .05$) in CP than bromegrass and wheatgrass except at the final sampling time. In Trial 2, grasses were not different at the initiation of the trial, but bromegrass was lower ($P < .05$) than the other grasses at the midpoint, and wheatgrass was lower ($P < .05$) than the other grasses at the end of the trial. Orchardgrass was lower ($P < .05$) than the other grasses at each sampling time during Trial 3. Wheatgrass was lower ($P < .05$) than bromegrass at the initial and final sampling time in Trial 3.

The interactions of trial x grass x time, grass x time and trial x grass were not significant ($P > .05$) for DIP, therefore the main effect of grass was presented. Wheatgrass was highest ($P < .05$) in DIP (69.1% of CP), followed by bromegrass (62.3%) and then orchardgrass (57.3%) (Table 6).

In vitro digestibility declined at a rate of approximately .25%/d over these trials, which is slower than .47%/d decline reported by Minson (1990). Crude protein declined more dramatically than IVOMD as these plants matured. Minson (1990) reported .22%/d as the average rate of decline in CP of cool-season grasses, but in this trial forages declined at the rate of .56%/d. However, CP concentration remained above 12.7%, which would meet the requirements of a 274-kg steer with 1.3 kg/d ADG (NRC 1996). Degradable intake protein was generally more stable than CP across the grazing season. However, average DIP of these grasses (63% of CP) was lower than the average reported for cool-season grasses (80% of CP) by Nelson and Moser (1994).

Concentrations of calcium, phosphorus and sodium of these grasses were generally below the requirement for a 227-kg steer gaining .91 kg/d (Table 6). Potassium, magnesium, and copper were adequate. Caution should be exercised when considering magnesium levels of cool-season grasses, as grasses high in crude protein and potassium and marginal in magnesium could cause grass tetany (Sleper and Buckner, 1996).

The Level 1 Model of the 1996 NRC indicated that metabolizable energy intake was generally first limiting to gain of cattle grazing these grasses (Appendix D, Tables 1, 2, and 3). Protein content of these high-quality forages appears adequate to support relatively high rates of gain by stocker cattle, and metabolizable energy intake is most likely limiting gain.

Management Considerations

Wheat pasture adjacent to the study site reached the first hollow stem stage of maturity in late February in both 1998 and 1999. However, cool-season perennial grasses were not ready for grazing until early April. Therefore cattle could not be moved directly from wheat pasture to cool-season perennial grass. The grazing season of cool-season perennial grasses lasted until late May, which is well into the traditional grazing season of warm-season perennial grass (Gillen et al., 1992; McCollum et al., 1992). Cool-season perennial grasses were also grazed successfully by sheep in April and May in the Texas Panhandle (Griggs and Matches, 1991). Complementary forage systems may aid in increasing the financial stability of stocker operations. Smooth bromegrass grazing followed by grazing native range has successfully reduced feedyard breakeven as compared with grazing smooth bromegrass alone (Shain et al., 1997). The single fall trial (Trial 3) began in late September and lasted through early November. If this timing of forage production holds true in other years, cool-season perennial grasses could provide grazing during the fall to fill the gap between traditional warm-season native range grazing and wheat pasture availability. However, stocking rate may somewhat limit the acceptance of these forage types, due to the cost of establishing a relatively large percentage of land to cool-season perennial grasses which provide a relatively short grazing season. Assuming an average stocking rate of .81 ha of wheat pasture/animal, approximately 20% of the land area would need to be established to cool-season perennial grasses to provide spring grazing for all of the cattle that are removed from wheat pasture. This increases to approximately 30% of the land area if complementary fall grazing is desired. Because lower stocking rates are used in native range grazing programs, a smaller percentage of the land area would need to be established to cool-season perennial grasses in a native range-based operation. Incorporating cool-season perennial grasses in this way will increase the potential for total weight gain of each animal, but will decrease the total number of animals that can be stocked.

The summer of 1998 was one of the most severe droughts on record for most of Oklahoma (Appendix E, Figure 1). The drought provided the opportunity to evaluate the grasses on an observational, rather than experimental, basis. While the pubescent wheatgrass and the smooth bromegrass survived the drought with minimal loss, orchardgrass did not survive on the upland sites at Location 1. However, some orchardgrass survived in the lower, wetter areas of the pastures. This may indicate that the extreme lack of precipitation or a combination of low precipitation and high temperature determined the survival of orchardgrass. Other orchardgrass stands in Oklahoma also suffered during the drought (Phillips, 1998; Redmon, 1999). Wheatgrass and bromegrass stands appeared thinned by the drought, but recovered well in the fall. Wheatgrass species were more drought tolerant than orchardgrass under dryland and limited irrigation conditions in the panhandle of Texas (Shuster and De Leon Garcia, 1973). Environmental adaptability and persistence is one of the most important characteristics to consider when selecting forages for establishment (Miller and Stritzke, 1995). The observations in this experiment appear to favor pubescent wheatgrass and smooth bromegrass over orchardgrass in terms of drought tolerance. However, it is important to remember that this was not a controlled experiment, but rather simple observation.

For optimum production and stand life, grazing and fertility management of cool-season perennial grasses requires more attention than traditional wheat pasture. Management factors, such as grazing management, generally have a larger impact on animal performance than species of forage (Turner et al., 1996). Growth of cool-season perennial grasses is very rapid and dynamic, and a grazing plan should be developed prior to the spring grazing season. Delaying grazing can result in forage maturation and quality deterioration earlier in the grazing season.

Implications

No consistent difference in growth performance was found among stocker cattle grazing either pubescent wheatgrass, smooth bromegrass, or orchardgrass. Pubescent wheatgrass was higher in DIP and digestibility than the other grasses. Orchardgrass appears to be the least resistant to summer drought. These grasses did not produce enough forage in late February and March to provide a pasture resource for cattle removed from dual-purpose wheat pasture. However, these grasses may complement warm-season perennial grass programs fairly well.

Literature Cited

AOAC. 1996. Official Methods of Analysis (14th ed.). Association of Official Analytical Chemists, Washington, D. C.

Asay, K.H. and K.B. Jensen. 1996. Wheatgrasses. p. 691-724. *In*. Moser, L.E., D.R. Buxton, and M.D. Casler (ed.) Cool-Season Forage Grasses. Monograph #34. ASA, CSSA, SSSA. Madison, WI.

Blasi, D.A., G.L. Kuhl, M.D. Reynolds, and R.T. Brandt, Jr. 1997. Effect of revalor-G on the performance of stocker heifers grazing irrigated smooth bromegrass pasture for a full season. Report of Progress 783. AES Kansas St. Univ. Manhattan. p. 44-45.

Burns, J.C. and C.P. Bagley. 1996. Cool-Season Grasses for Pasture. p. 321-356. *In*. Moser, L.E., D.R. Buxton, and M.D. Casler (ed.) Cool-Season Forage Grasses. Monograph #34. ASA, CSSA, SSSA. Madison, WI.

Buxton, D.R. D. R. Mertens and K.J. Moore. 1995. Forage quality for ruminants: plant and animal considerations. Prof. Anim. Sci. 11:121-131.

Collins, M. and M.D. Casler. 1990. Forage quality of five cool-season grasses. II. Species effects. Anim. Feed Sci. Tech. 27:209-218.

Gillen, R. L., F.T. McCollum, M.E. Hodges, and K.W. Tate. 1992. Livestock response to grazing systems and stocking rate on tallgrass prairie. Okla. State Univ. Animal Science Research Report. MP-136.

Goering and Van Soest. 1970. Forage Fiber Analysis: Apparatus, Reagents, Procedures, and Some Applications. USDA-ARS Washington, D. C. Handbook No. 379.

Griggs, T.C. and A.G. Matches. 1991. Productivity and consumption of wheatgrasses and wheatgrass-sainfoin mixtures grazed by sheep. Crop Sci. 31:1267-1273.

Jordon, D.J., G. Erickson, T. Klopfenstein, D. Adams, T. Milton, and R. Cooper. 1999. Steer performance within summer grazing systems. Nebraska Beef Report MP 71. Univ. of Nebraska-Lincoln.

Krenzer, G., Jr. 1997. Wheat for Pasture. Okla. Coop. Ext. Serv. F-2586.

McCollum, F.T., D.M. Engle, and J.F. Stritzke. 1992. Cattle performance following prescribed burning of rangeland in north-central Oklahoma. Okla. State Univ. Animal Science Research Report. MP-136.

Miller, D. A. and J. F. Stritzke. 1995. Forage Establishment and Weed Management. Forages. *In* Forages Vol. I. Barnes et al. (ed.). Iowa State University Press. Ames, IA.

Minson, D.J. 1990. Forage in ruminant nutrition. Acad. Press, Inc, New York.

Nelson, C.J. and L.E. Moser. 1994. Plant factors affecting forage quality. p. 115-154. *In* Fahey, G.C. Jr. (ed) Forage Quality, Evaluation, and Utilization. ASA, CSSA, SSSA, Madison, WI.

NRC. 1996. Nutrient requirements of beef cattle. (7th Ed.). National Academy Press, Washington, D.C.

Phillips, W.A. 1998. Personal communication.

Powell, K., R.L. Reid and J.A. Balasko. 1978. Performance of lambs on perennial ryegrass, smooth bromegrass, orchardgrass and tall fescue pastures. II. Mineral utilization, in vitro digestibility and chemical composition of herbage. J. Anim. Sci. 46:1503-1514.

Redmon, L.A. 1997. Cool-Season Perennial Grass Update. Production Technology Report. PT 97:42. Oklahoma State University.

Redmon, L.A. 1999. Cool-Season Perennial Grass in Oklahoma: January 1999 Update. Production Technology Report. PT 99:1. Oklahoma State University.

Redmon, L.A., E.G. Krenzer, Jr. D.J. Bernardo and G.W. Horn. 1996. Effect of wheat morphological stage at grazing termination on economic return. Agron. J. 88:94.

Reid, R.L., K. Powell, J.A. Balasko and C.C. McCormick. 1978. Performance of lambs on perennial ryegrass, smooth bromegrass, orchardgrass and tall fescue pastures. I. Live weight changes, digestibility, and intake of herbage. J. Anim. Sci. 46:1493-1502.

Roe, M. B., C. J. Sniffen, and L. E. Chase. 1991. Techniques for measuring protein fractions in feedstuffs. Proc. Cornell Nutrition Conference. p. 81-88.

Schuster, J.L. and R. C. De Leon Garcia. 1973. Phenology and forage production of cool-season grasses in the Southern Plains. J. Range Mgt. 26:336-339.

Shain, D., T. Klopfenstein, R. Stock, and M. Klemesrud. 1997. Forage combinations for summer and fall grazing. Nebraska Beef Report MP 67-A. Univ. of Nebraska-Lincoln. p. 56-59.

Sleper, D.A. and R.C. Buckner. 1996. The Fescues. p. 345-356. *In* Forages Vol. I: An Introduction to Grassland Agriculture. Barnes, R.F., D.A. Miller, and C.J. Nelson (ed.). Iowa State University Press. Ames, IA.

Spears, J.W. 1994. Minerals in forages. p. 281-317. *In* Fahey, G.C. Jr. (ed) Forage Quality, Evaluation, and Utilization. ASA, CSSA, SSSA, Madison, WI.

Stovall, T.C., D.R. Gill, H. Han, J.T. Wagner, and R.L. Ball. 1999. Effect of Agrado™ on the health and performance of transport-stressed heifer calves. Okla. State Univ. Animal Science Research Report. P-973.

Turner, K.E., D.P. Belesky, J.M. Fedders and E. B. Rayburn. 1996. Canopy management influences on cool-season grass quality and simulated livestock performance. Agron. J. 88:199-205.

Van Santen, E., and D.A. Sleper. 1996. Orchardgrass. p. 503-534. *In*. Moser, L.E., D.R. Buxton, and M.D. Casler (ed.) Cool-Season Forage Grasses. Monograph #34. ASA, CSSA, SSSA. Madison, WI.

Table 1. Growth performance of steers grazing three cool-season perennial grasses during the spring of 1998 (Trial 1).

	Grass Species[a]				
Item	WG	OG	BG	SE	*P*[b]
No. pastures	2	2	2		
Initial forage mass, kg/ha	1975	1945	2119	232.2	.86
Final forage mass, kg/ha	1597	1704	1845	187.8	.68
Stocking rate, steers/ha	5.29	5.29	5.29		
kg BW/ha	1357	1362	1368	.69	.004
Initial forage allowance,					
kg/steer	374	368	401	43.9	.86
kg/100 kg BW	146	143	155	17.1	.88
Initial wt, kg (April 3)	257	258	259	.13	.004
Final wt, kg (May 29)	313	307	314	2.03	.16
ADG, kg/d (56 days)	1.00	.88	.99	.03	.14
Gain/steer, kg	56	49	55	1.75	.12
Gain/ha, kg	296	260	292	207.3	.13

[a] WG = pubescent wheatgrass (*Thinopyrum intermedium*), OG = orchardgrass (*Dactylis glomerata*), and BG = smooth bromegrass (*Bromus inermis*)

[b] Observed significance for effect of grass species.

Table 2. Growth performance of heifers grazing three cool-season perennial grasses during the spring of 1999 (Trial 2).

	Grass Species[a]				
Item	WG	OG	BG	SE[b]	*P*[c]
No. pastures	4	2	4		
Initial forage mass, kg/ha	3925	2883	3428	342	.20
Final forage mass, kg/ha	3051	2942	2499	184	.11
Stocking rate, heifers/ha[d]	6.51	5.85	6.19	.40	.58
kg BW/ha	1509	1380	1435	96.4	.67
Initial forage allowance,					
kg/heifer	602	491	548	28.1	.08
kg/100kg BW	260	208	236	12.5	.08
Initial wt, kg (March 31)	232	236	232	1.46	.23
Final wt, kg (June 9)	278	278	281	3.37	.73
ADG, kg/d (54 or 70 days)	.81[e]	.61[f]	.80[e]	.05	.05
Gain/heifer, kg	47	43	49	2.86	.37
Gain/ha, kg	303	247	302	17.2	.14

[a] WG = pubescent wheatgrass (*Thinopyrum intermedium*), OG = orchardgrass (*Dactylis glomerata*), and BG = smooth bromegrass (*Bromus inermis*)

[b] Average standard error.

[c] Observed significance for effect of grass species.

[d] Initial stocking rate, put and take system was used near the end of the trial.

[ef] Within a row, means lacking a common superscript letter differ ($P < .05$)

Table 3. Growth perfor
grasses dur

Item
No. pastures
Initial forage mass, kg/ha
Final forage mass, kg/ha
Stocking rate, heifers/ha
kg BW/ha
Initial forage allowance,
kg/heifer
kg/100kg BW
Initial wt, kg (Sept. 23)
Final wt, kg (November 3
ADG, kg/d (40 days)
Gain/heifer, kg
Gain/ha, kg

[a]WG = pubescent whea
(*Dactylis glomerata*),

[b]Observed significance fo

Table 4. Nutritive value responses to time of sampling of three cool-season perennial grasses pooled over three trials.

Item	Initial[a]	Middle	Final
Wheatgrass[b]			
OM, %DM	90.0^{cx}	89.5^{cx}	87.9^{dx}
IVOMD, %OM	85.0^{cx}	80.1^{dx}	74.3^{ex}
S, %DM	.277^{cx}	.215^{dx}	.168^{ex}
Orchardgrass			
OM, %DM	88.2^{cy}	86.2^{dy}	84.8^{ey}
IVOMD, %OM	80.3^{cy}	71.6^{dy}	66.1^{ey}
S, %DM	.262^{cy}	.220^{dxy}	.207^{dy}
Bromegrass			
OM, %DM	89.2^{cx}	88.6^{cdz}	88.2^{dx}
IVOMD, %OM	82.7^{cz}	71.0^{dy}	67.0^{ey}
S, %DM	.297^{cz}	.228^{dy}	.201^{ey}

[a] Initial = Initiation of each trial, Middle = midpoint of each trial, Final = termination of each trial.

[b] Average standard error and observed significance for the interaction of time x grass; OM: SE = .326 P = .0157; IVOMD: SE = .712 P = .0002; S: SE = .00478 P = .0005 (n=59).

[cde] Within a row, means lacking a common superscript letter differ ($P < .05$).

[xyz] Within a column, means of like terms lacking a common superscript letter differ ($P < .05$).

Table 5. Crude protein content of three cool-season perennial grasses in three trials.

Item	Wheatgrass	Orchardgrass	Bromegrass
Trial 1			
Initial[a,b]	22.4^{cx}	19.3^{dx}	24.2^{cx}
Middle	19.7^{cy}	17.4^{dy}	21.5^{cy}
Final	18.0^{cy}	18.3^{cxy}	19.1^{cz}
Trial 2			
Initial	30.6^{cx}	32.4^{cx}	31.8^{cx}
Middle	21.4^{cy}	21.0^{cy}	19.1^{dy}
Final	10.7^{cz}	17.1^{dz}	15.0^{dz}
Trial 3			
Initial	26.0^{cx}	23.4^{dx}	28.7^{ex}
Middle	20.5^{cy}	18.2^{dy}	21.2^{cy}
Final	15.8^{cz}	13.6^{dz}	17.8^{ez}

[a] Initial = Initiation of each trial, Middle = midpoint of each trial, Final = termination of each trial.

[b] Average standard error and observed significance for the interaction of trial x grass x time; SE = .641 *P* = .026 (n=59).

[cde] Within a row means lacking a common superscript letter differ ($P < .05$).

[xyz] Within a column, means from each trial lacking a common superscript letter differ ($P < .05$).

Table 6. Degradable ir

Item
DIP[a], %CP

[a] Average standard errc
1.25 *P* = .001 (n=59

[bcd] Within a row means

Table 7. Mineral content of three cool-season perennial grasses[ab].

	WG		OG		BG		Animal
Mineral	F	S	F	S	F	S	Req.[c]
Calcium, %DM	.34	.28	.50	.34	.46	.39	.60
Phosphorus, %DM	.30	.29	.25	.29	.34	.25	.29
Sodium, %DM	.04	.01	.08	.12	.02	.06	.07
Potassium, %DM	2.29	2.17	2.24	2.72	2.99	2.69	.60
Magnesium, %DM	.24	.12	.31	.22	.25	.16	.10
Copper, ppm	20	15	19	13	19	16	10

[a] WG = pubescent wheatgrass (*Thinopyrum intermedium*), OG = orchardgrass (*Dactylis glomerata*), and BG = smooth bromegrass (*Bromus inermis*)

[b] F = fall 1997; S = spring 1998.

[c] For 227-kg, medium-frame steer calf with .91 kg/d ADG and 4.99 kg DMI (NRC, 1996).

CHAPTER IV

CHANGES IN NUTRITIVE VALUE OF THREE FORAGE TYPES ACROSS A GRAZING SEASON

Abstract

Three warm-season perennial grasses, Old World bluestem, native midgrass prairie, and native tallgrass prairie, were sampled monthly across the summer grazing season of 1998 to characterize changes in nutritive value. Ruminally cannulated steers were used to collect samples in an attempt to accurately portray diet selection by cattle. In vitro organic matter digestibility and crude protein generally decreased across the grazing season for all three forages. Both native forages were generally more digestible than Old World bluestem. Ruminal degradability of forage crude protein was variable across forages and time. The Level 1 model of the 1996 NRC indicated that gain of stocker cattle grazing these forages was often limited by supply of degradable intake protein. Additionally, degradable intake protein supplied by the forages was below the level required for complete utilization of the fermentable organic matter in the forages during all months for midgrass prairie and during all months except May for tallgrass prairie. These data indicate that ruminally degradable protein supplementation may be beneficial earlier in the grazing season.

Keywords: Ruminal Protein Degradability, Forage Type, Nutrient Balance

Introduction

The 1996 edition of the Nutrient Requirements of Beef Cattle utilizes a metabolizable protein system to express protein requirements of various classes of beef cattle. This system partitions nitrogen requirements into a fraction required by the rumen microbes for digestion and microbial synthesis (degradable intake protein: DIP), and a fraction required by the animal at the small intestine for production (metabolizable protein: MP). In order to use this system most effectively, accurate values of ruminal degradability of feed and forage protein is essential. Forages generally decrease in nutritive value as they mature, and supplementation is often used to balance nutrient deficiencies. However, data characterizing the degradability of crude protein (CP) of grazed forages and how it changes with maturity is limited. Values for DIP of warm-season native grasses, for example, range from 36% (Mathis et al., 1997) to 85% of total CP (Lardy et al., 1997). Crude protein alone may not be an acceptable measure of protein supply to cattle grazing rangeland (McCollum et al., 1985). More precise characterization of the supply of nutrients to grazing ruminants should lead to more efficient production programs.

Grazing ruminants select diets that are higher in nutritive value than the average quality of forage on offer (Minson, 1990). Consideration of this selective ability is important to accurately portray nutritive value of diets of grazing cattle. The rumen evacuation technique is a reliable method for obtaining samples from pasture that reflect the diets animals select (Olson, 1991). The objective of this study was to quantify nutritive value of three forage types across a grazing season using the rumen evacuation technique.

Materials and Methods

Research Locations

Forage samples were collected from two locations. Tallgrass prairie (TGP) samples and Old World bluestem (*Bothriochloa ischaemum*; OWB) samples were collected from Location 1 (Bluestem Research Range 11 km southwest of Stillwater, OK). Principal species in TGP were indiangrass (*Sorghastrum nutans*), big bluestem (*Andropogon gerardii*), switchgrass (*Panicum virgatum*), and little bluestem (*Schiazchyrium scoparium*). The OWB pasture, established in 1989, was of the Plains variety and was fertilized with 112 kg/ha of actual nitrogen early in the growing season. Principal soil types at this location are Coyle loam, Coyle-Lucien complex, Grainola-Lucien complex, Renfro loam, Stephenville-Darnell complex, Stephenville fine sandy loam, and Zaneis loam.

Midgrass prairie (MGP) samples were collected at Location 2 (Marvin Klemme Range Research Station 17 km southwest of Clinton, OK). Species include sideoats grama (*Bouteloua curtipendula*), blue grama (*Bouteloua gracillis)*, buffalograss (*Buchloe dactyloides*), hairy grama (*Bouteloua hirsuta*), and silver bluestem (*Bothrichloa saccharoides*). Principal soil type was Cordell silty clay loam, averaging 15 cm of topsoil and 20 cm of subsoil. Thirty-year average and 1998 precipitation is presented for these locations in Appendix E (Figures 2 and 3).

Experimental Design

Ruminally cannulated steers were used to obtain masticate samples from each forage type by rumen evacuation as described by Lesperance et al. (1960). Steers were placed in the pasture approximately 5 d before sampling to acclimate to the forage. On sampling days, steers were gathered into a corral at approximately 0800 and reticulo-ruminal contents were immediately removed. The animals were then allowed to graze the pastures for approximately 1 h. Masticate samples (1 to 2 liters) were then removed, and original reticulo-ruminal contents replaced. Two steers were used to sample each forage type and samples were collected near the mid-point of each month from May through September 1998, for OWB and TGP, and June through September 1998, for MGP.

Chemical Analysis

Masticate samples were frozen immediately after collection, then thawed and dried at 55°C after all samples were collected. Oven dried masticate samples were ground through a 2-mm screen in a Wiley mill. Samples were analyzed for DM and ash. A combustion technique (LECO NS-2000, St. Joseph MI: AOAC, 1996), utilizing a combustion catalyst (COM-CAT, LECO, St. Joseph MI) was used for N and S analysis. Degradable intake protein was determined by measuring nitrogen disappearance during a 48-h in vitro incubation in a borate-phosphate buffer containing protease type XIV from *Streptomyces griseus*. This procedure was similar to that described in Roe et al. (1991) except that the pH of the buffer in the present procedure was 7.8 rather than 6.7. A 48-h in vitro procedure described by Goering and Van Soest (1970) was used to estimate digestible organic matter.

Statistical Analysis

Nutritive value components were analyzed by analysis of variance for a completely randomized design. Sources of variation included in the model were forage type, month, and the month x forage type interaction. A significant interaction ($P < .05$) was detected for each dependent variable. Comparisons among forage types and comparisons among months were both desired. Therefore, the data are presented by forage type and month. Least squares means were separated by least significant difference. Additionally, nutritive value data were pooled across forage types and months, and regression analysis was used to determine the relationship of DIP to CP and IVOMD, and the relationship of S to CP.

NRC Modeling

In vitro organic matter digestibility (%DM), CP, and DIP values for each month were inserted into the Feed Library of the Level 1 model of the 1996 NRC. Also, NDF (50%) and % effective NDF (50%) values were inserted so that the model would not reduce intake and microbial yield because of low pH. Other inputs were either 227, 272, or 317 kg weights for a Angus X Hereford, 8 mo. old steer. Environmental factors were left as default values, the option of "no implant or ionophore" was selected, and microbial efficiency was set at 12%. Dry matter intake, DIP and metabolizable protein (MP) balance, as well as average daily gain allowed by metabolizable energy (ME) and MP intake, was predicted by the model for each forage, month, and weight combination. First limiting nutrient was determined by the following rationale. Negative DIP balance precludes full utilization of the ME in the feed, therefore DIP is limiting if DIP balance is negative. If DIP balance is positive, MP balance determines the first limiting nutrient. The requirement listed for MP by the model is the amount of MP required to achieve the gain allowed by ME. Therefore, if MP balance is positive, excess MP is present for the amount of ME, and energy is first limiting. These guidelines were applied regardless of magnitude of differences. However, small negative or positive balances may not be biologically significant. Fifty grams of DIP is supplied by only 154 g of soybean meal (49% CP, 65% of CP as DIP).

Additionally, CP and DIP were multiplied to calculate g DIP supply per 100 g of forage in each month. Similarly, IVOMD (% DM) was multiplied by an assumed microbial efficiency (10%, 12%, or 14%) to calculate g DIP required for complete utilization of the digestible organic matter per 100 g of forage. Dividing DIP supply by DIP required yields a ratio that can be used to evaluate the relative DIP balance of each forage type in each month, regardless of dry matter intake. A ratio of 1 indicates that the forage supplies just enough DIP to allow ruminal microbes to fully utilize all of the fermentable organic matter in the forage. A ratio higher than 1 indicates a DIP excess, while a ratio lower than 1 indicates a DIP deficiency.

Results and Discussion

Old World bluestem decreased in IVOMD across the grazing season, ranging from 74.5% in May to 58.3% in September (Table 1). However, MGP increased in IVOMD from June to July, and then decreased from July to September. Tallgrass prairie IVOMD remained relatively constant from May through July, and then gradually decreased through September. The native forages were generally higher in IVOMD than Old World bluestem, but Gunter et al. (1991) observed that Old World bluestem was more digestible than midgrass prairie from June to August. Forages typically decline in digestibility as they mature (McCollum et al., 1985), but yearly variation in climatic conditions may have a large effect on nutritive value of forages (Cochran and Van Zant, 1991).

Crude protein was more erratic in its response with time. Old World bluestem CP was highest in June and lowest in August, with the other months being intermediate. Midgrass prairie steadily declined in CP across the grazing season. Tallgrass prairie declined in CP from May to August, but then increased in September to 10.9%, similar to OWB. Gunter et al. (1991) also observed OWB to be higher in CP than MGP.

Degradable intake protein, as a percent of CP, varied in its response to month. May and September were highest in DIP for both OWB and TGP.

Midgrass prairie had greater concentration of DIP in July and September as compared with June and August. Degradable intake protein was not linearly related to either CP or IVOMD ($R^2 = .0039$ and .0151, respectively). Buxton et al. (1996) reported that DIP averages about 75% of CP for all forages, but that warm-season grasses are generally lower in DIP than other forages. Degradable intake protein was 50% of DIP for switchgrass, and decreased as the forage matured (Mullahey et al., 1992). Ackerman (1999) also observed that OWB decreased in DIP from June to August. Forages tend to decrease in DIP as they mature (Buxton et al., 1995), possibly as a result of more protein being contained in the parenchyma bundle sheath cells, and therefore being somewhat protected from microbial degradation (Mullahey et al., 1992; Vaughn et al., 1998). Sulfur content of these forages was highly related to CP ($S = .01654 + .01235(CP)$; $R^2 = .69$, $S_{y \cdot x} = .0337$).

The Level 1 model of the 1996 NRC indicated that DIP was the first-limiting nutrient for growth of stocker cattle grazing midgrass prairie from June to September (Appendix D, Table 5). However, metabolizable energy intake was first-limiting during May, June, and September for Old World bluestem, and during May for tallgrass prairie, while DIP was first-limiting for these forages during the other months (Appendix D, Tables 4 and 6). Gunter et al. (1992) studied ruminal degradability of OM and CP, and reported that a supplement providing additional DIP may have been beneficial to stocker cattle grazing Old World bluestem and midgrass prairie during most of the grazing season. McCollum (1992) reported a similar finding for tallgrass prairie. Degradable intake protein ratio of OWB (assuming 12% microbial efficiency) was below 1.0 (balanced) for July and August (Figure 1). However, DIP ratio was below 1.0 from June to September for both MGP and TGP (Figures 2 and 3). It is common practice for stocker producers to feed a CP supplement that provides additional DIP in late summer, but these data suggest that a DIP supplement may also be needed earlier in the grazing season.

Precipitation may also affect nutritive value relationships (Buxton et al., 1995; Bittman et al., 1988; Cochran and Vanzant, 1991). Summer drought has been shown to increase leaf senesce, and therefore increase the rate of decline of protein, of cool-season grasses (Bittman et al., 1988). However, the decline in digestibility was actually slowed due to slower accumulation of lignin and ADF (Wilson, 1983; Mislevy and Evertt, 1981; Bittman et al., 1988). Thus, drought conditions may accentuate deficiencies of DIP. The low overall levels of CP and DIP in midgrass prairie samples could be reflecting the severe drought in this area during the sampling months (Appendix E, Figure 3.)

Implications

Digestibility of native forages generally were superior to Old World bluestem. Stocker cattle grazing these forages would have required supplementation of degradable intake protein during most months of the summer grazing season. Nutritive value can be greatly influenced by yearly variation in climatic conditions; therefore, data reflecting nutritive value of these forages under more diverse environments may be required before a supplementation strategy that will be applicable for a range of locations can be suggested. Likewise, accurate estimates of microbial efficiency and ruminal degradability of crude protein are essential.

Literature Cited

Ackerman, C.J. 1999. Performance of light *vs.* heavy weight steers grazing plains Old World bluestem at three stocking rates. Ph.D. Dissertation. Oklahoma State University.

AOAC. 1996. Official Methods of Analysis (14th ed.). Association of Official Analytical Chemists, Washington, D. C.

Buxton, D.R. D. R. Mertens and D.S. Fisher. 1996. Forage Quality and Ruminant Utilization. p. 229-266. *In*. Moser, L.E., D.R. Buxton, and M.D. Casler (ed.) Cool-Season Forage Grasses. Monograph #34. ASA, CSSA, SSSA. Madison, WI.

Buxton, D.R. D. R. Mertens and K.J. Moore. 1995. Forage quality for ruminants: plant and animal considerations. Prof. Anim. Sci. 11:121-131.

Cochran, R.C. and E.S. Vanzant. 1991. Seasonal variation in quality of grazed forage during a drought year. p. 45-47. Cattlemen's Day. Report of Progress 623. AES, Kansas State Univ., Manhattan.

Goering and Van Soest. 1970. Forage Fiber Analysis: Apparatus, Reagents, Procedures, and Some Applications. USDA-ARS Washington, D. C. Handbook No. 379.

Gunter, S.A., F.T. McCollum, and R.L. Gillen. 1991. Chemical composition of diets consumed by cattle grazing native range or plains bluestem pasture. Okla. State Univ. Animal Science Research Report. MP-134.

Gunter, S.A., F.T. McCollum, and R.L. Gillen. 1992. Midgrass prairie range *vs.* plains bluestem pasture for stocker cattle. Okla. State Univ. Animal Science Research Report. MP-136.

Lardy, G., D. Adams, T. Klopfenstein, D. Clark and J. Lamb. 1997. Seasonal changes in protein degradabilities of Sandhills native range and subirrigated meadow diets and application of a metabolizable protein system. Nebraska Beef Report MP 67-A. Univ. of Nebraska-Lincoln. p. 3-5.

Lesperance, A. L.. V. R. Bohman, and D. W. Marble. 1960. Development of techniques for evaluation grazed forage. J. Dairy Sci. 43:682-689.

Mathis, C.P., I.E.O. Abdelgadir, R.C. Cochran, J.S. Heldt, K.C. Olson, B.C. Woods, E.C. Titgemeyer, and E.S. Vanzant. 1997. Evaluation of the protein characteristics of four diverse grasses. p. 58-59. Cattlemen's Day. Report of Progress 783, AES Kansas St. Univ., Manhattan.

McCollum, F.T. 1992. Chemical composition of cattle diets on tallgrass prairie. p. 25-26. In Range Research Highlights. Circular E-905. CES, Okla. State Univ.

McCollum, F.T., M.L:. Galyean, L.J Krysl, and J.D. Wallace. 1985. Cattle grazing blue grama rangeland I. Season diets and rumen fermentation. J. Range Mangt. 38(6):539-543.

Minson, D.J. 1990. Forage in ruminant nutrition. Acad. Press, Inc, New York.

Mullahey, J.J., S. S. Waller, K. J. Moore, L. E. Moser and T. J. Klopfenstein. 1992. In situ ruminal protein digestion of switchgrass and smooth bromegrass. Agron J. 84:183-188.

Olson, K.C. 1991. Diet sample collection by esophageal fistula and rumen evacuation techniques. J. Range Mangmt. 44(5):515-519.

Roe, M. B., C. J. Sniffen, and L. E. Chase. 1991. Techniques for measuring protein fractions in feedstuffs. Proc. Cornell Nutrition Conference. p. 81-88.

Vaughn, D., W. Schacht, L. Moser, R. Graybosch, and T. Klopfenstein. 1998. Ruminal degradation of rubisco by beef cattle grazing switchgrass and big bluestem. Nebraska Beef Report MP 69-A. Univ. of Nebraska-Lincoln. p. 21-23.

Table 8. Nutritive value components of three warm-season forages over a grazing season.

	Month				
	MAY	JUN	JUL	AUG	SEP
OWB[a]					
OM[b], %DM	89.8^{ch}	89.9^{ch}	89.5^{ch}	93.0^{dh}	88.1^{c}
IVOMD, %OM	74.5^{c}	70.0^{cdh}	66.3^{deh}	62.8^{efh}	58.3^{fh}
CP, %DM	15.1^{ch}	16.8^{ch}	14.3^{ceh}	9.9^{dh}	12.0^{deh}
DIP, %CP	56.2^{c}	52.8^{cd}	45.7^{dh}	51.9^{cd}	58.3^{c}
S, %DM	$.19^{cdh}$	$.21^{dh}$	$.17^{cdh}$	$.15^{ch}$	$.20^{dh}$
MGP					
OM, %DM	--	86.8^{ci}	86.2^{ci}	86.3^{ci}	87.9^{c}
IVOMD, %OM	--	65.3^{ch}	74.4^{di}	72.0^{dei}	69.1^{cei}
CP, %DM	--	8.5^{ci}	7.6^{cdi}	6.4^{cdij}	5.7^{di}
DIP, %CP	--	50.5^{c}	62.2^{di}	54.1^{ce}	61.3^{de}
S, %DM	--	$.14^{ci}$	$.10^{cdi}$	$.08^{di}$	$.07^{di}$
TGP					
OM, %DM	87.6^{ci}	90.3^{dh}	89.3^{cdh}	90.4^{dj}	87.6^{c}
IVOMD, %OM	78.0^{c}	78.1^{ci}	78.5^{ci}	74.3^{cdi}	70.5^{di}
CP, %DM	19.0^{ci}	13.1^{dj}	10.7^{dej}	8.9^{ehj}	10.9^{deh}
DIP, %CP	62.3^{c}	51.9^{d}	51.7^{dh}	46.4^{d}	62.9^{c}
S, %DM	$.25^{ci}$	$.16^{dhi}$	$.12^{dehi}$	$.11^{ehi}$	$.25^{ch}$

[a] OWB = Old World bluestem, MGP = midgrass prairie, TGP = tallgrass prairie.

[b] OM = Organic matter (SE = .63), IVOMD = In vitro organic matter digestibility (SE = 1.57), CP = Crude protein (SE = .86), DIP = Degradable intake protein (SE = 2.56), S = sulfur (SE = .016) (n=28).

[cdefg] Within a row, means lacking a common superscript differ (*P* < .05).

[hij] Within a column, means of like terms lacking a common superscript differ (P<.05).

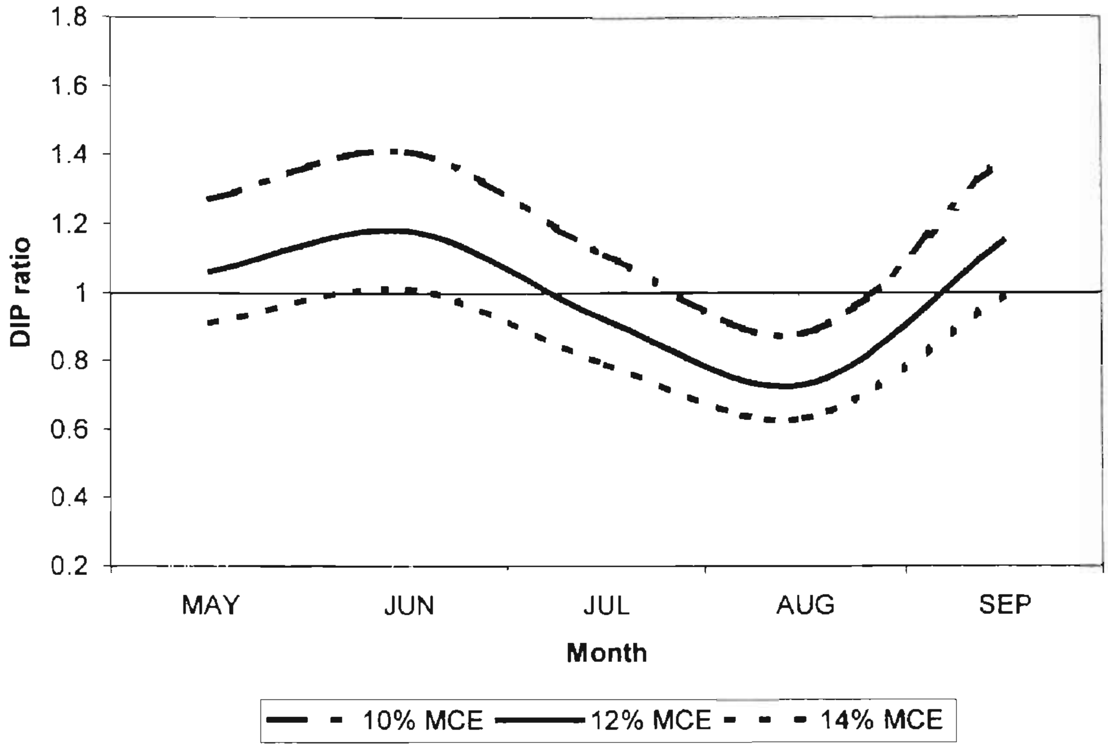

Figure 1. Degradable intake protein ratio (DIP supply:DIP required) of Old World bluestem across the summer grazing season with three microbial efficiencies (MCE).

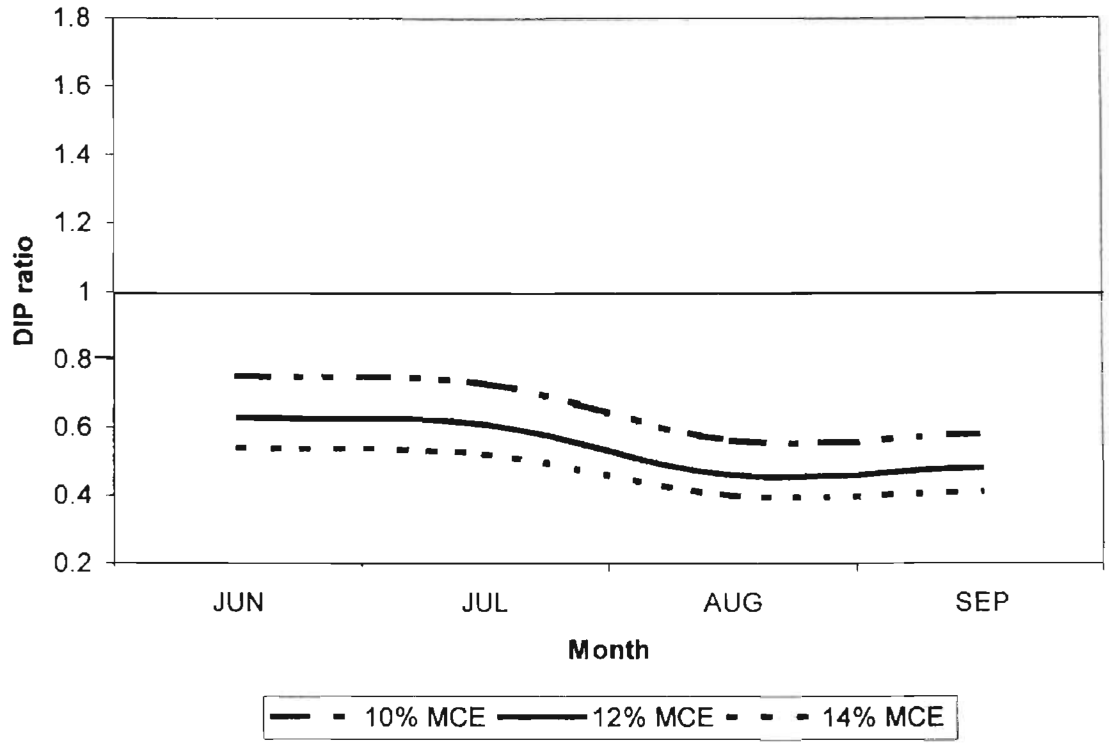

Figure 2. Degradable intake protein ratio (DIP supply:DIP required) of midgrass prairie across the summer grazing season with three microbial efficiencies (MCE).

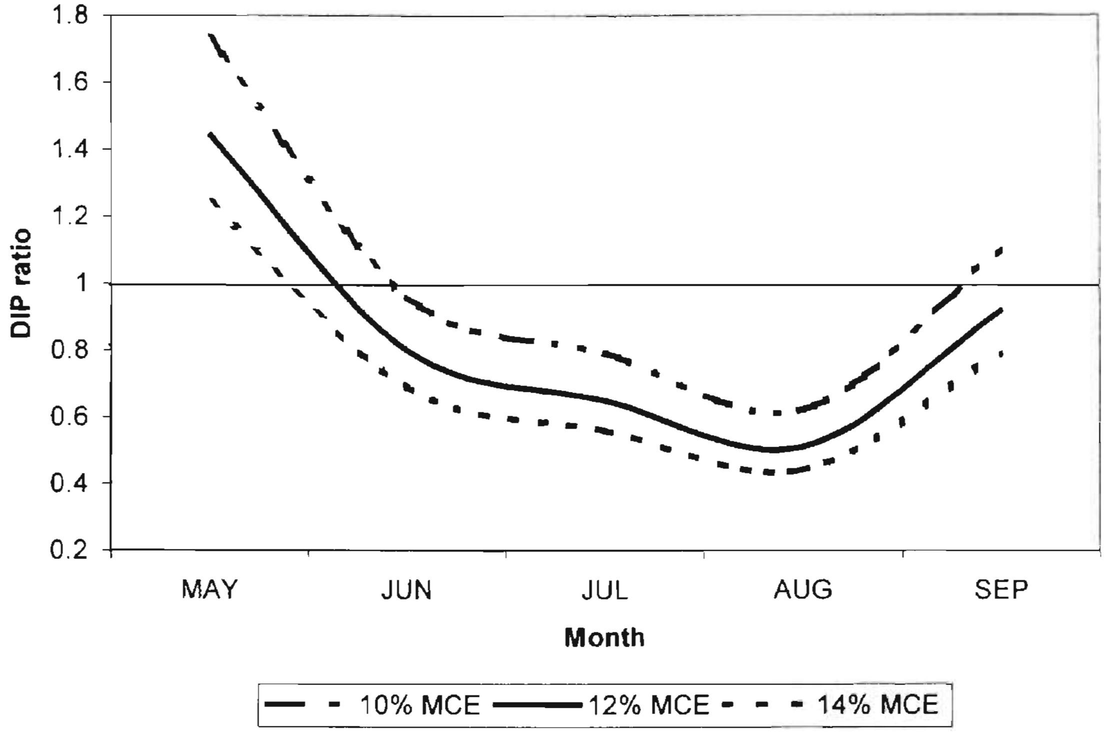

Figure 3. Degradable intake protein ratio (DIP supply:DIP required) of tallgrass prairie across the summer grazing season with three microbial efficiencies (MCE).

APPENDIXES

APPENDIX A

Observed Statistical Interactions

Table 1. Observed significance levels for interactions of trial, grass species, and collection time of nutritive value of cool-season perennial grasses.

Item	Source	P-value
OM	Trial x grass x time	.103
IVOMD	Trial x grass x time	.324
CP	Trial x grass x time	.026
DIP	Trial x grass x time	.999
S	Trial x grass x time	.096
OM	Grass x time	.006
IVOMD	Grass x time	.0002
DIP	Grass x time	.085
S	Grass x time	.0003
DIP	Trial x grass	.855

Table 2. Observed significance levels for interactions of forage type and month for Old World bluestem, midgrass prairie and tallgrass prairie.

Item	Source	P-value
OM	Forage type x month	.0062
IVOMD	Forage type x month	.0022
CP	Forage type x month	.0077
DIP	Forage type x month	.0337
S	Forage type x month	.0024

APPENDIX B

Nutritive Value of Three Cool-Season Perennial Grasses in Three Trials

Table 1. Nutritive value responses to time of sampling of three cool-season perennial grasses during the spring of 1998.

Item	April 22	May 13	May 29
Wheatgrass			
OM, %DM	91.6	90.8	90.0
IVOMD, %OM	83.6	80.6	79.0
CP, %DM	22.4	19.7	18.0
DIP, %CP	70.6	68.5	62.3
S, %DM	.237	.209	.208
Orchardgrass			
OM, %DM	89.8	86.4	85.6
IVOMD, %OM	78.5	71.9	71.1
CP, %DM	19.3	17.4	18.3
DIP, %CP	60.5	60.1	49.7
S, %DM	.207	.208	.241
Bromegrass			
OM, %DM	90.1	90.1	88.8
IVOMD, %OM	84.2	69.8	71.1
CP, %DM	24.2	21.5	19.1
DIP, %CP	68.5	56.5	52.0
S, %DM	.265	.228	.223

Table 2. Nutritive value responses to time of sampling of three cool-season perennial grasses during the spring of 1999.

Item	April 7	May 13	June 10
Wheatgrass			
DM, %	28.9	31.2	33.5
OM, %DM	91.2	91.2	91.1
IVOMD, %OM	89.0	81.9	69.3
CP, %DM	30.6	21.4	10.7
DIP, %CP	71.9	76.6	71.5
S, %DM	.307	.214	.116
Orchardgrass			
DM, %	25.7	25.9	37.4
OM, %DM	88.1	86.8	87.3
IVOMD, %OM	85.4	73.4	62.5
CP, %DM	32.4	21.0	17.1
DIP, %CP	56.9	68.0	59.4
S, %DM	.334	.242	.199
Bromegrass			
DM, %	26.4	30.1	38.8
OM, %DM	90.2	90.1	90.0
IVOMD, %OM	84.7	71.5	61.3
CP, %DM	31.8	19.1	15.0
DIP, %CP	68.9	66.1	65.3
S, %DM	.326	.202	.164

Table 3. Nutritive value responses to time of sampling of three cool-season perennial grasses during the fall of 1999.

Item	September 22	October 15	November 5
Wheatgrass			
DM, %	33.8	51.9	--
OM, %DM	87.1	86.6	82.8
IVOMD, %OM	82.3	77.9	74.2
CP, %DM	26.0	20.5	15.8
DIP, %CP	75.5	67.7	56.4
S, %DM	.287	.222	.180
Orchardgrass			
DM, %	35.6	50.2	--
OM, %DM	86.9	85.4	81.4
IVOMD, %OM	77.2	69.6	64.9
CP, %DM	23.4	18.2	13.6
DIP, %CP	62.9	59.2	40.8
S, %DM	.246	.209	.182
Bromegrass			
DM, %	29.4	51.1	--
OM, %DM	87.5	85.7	85.8
IVOMD, %OM	79.6	71.6	68.8
CP, %DM	28.7	21.2	17.8
DIP, %CP	72.6	61.1	50.4
S, %DM	.298	.255	.215

APPENDIX C

Management of Cool-Season Perennial Grass Pastures

Table 1. Management events for the cool-season perennial grass pastures at the "East location" at Marshall, OK.

Date	Event	$/acre
9/5/96	East 42 acres established	
	12 lb. seed / acre @ $1.80/lb.	$21.60
	No fall 1996 grazing, establishment deferment	
10/18/96	Herbicide: 2,4-D	$4.74
3/13/97	Fertilizer: 76 lb. N/ac (urea)	$21.89
8/29/97 - 10/3/97	Fall grazing 1.1 – 1.9 ADG; 80-131 lb. Gain/ac	
2/24/98	Fertilizer: 35 lb N, 33 lb P	$14.95
3/3/98	Herbicide: 2,4-D	$4.14
4/3/98 - 5/29/98	Spring grazing trial (Trial 1) 2.1 lb ADG; 252 lb Gain/acre	
Summer 1998	Severe drought – loss of old orchardgrass stand	
8/18/98	Fertilizer: 60 lb N	$14.83
	No fall grazing - drought	
3/3/99	Fertilizer: 52 lb N	$10.87
3/31/99 - 6/10/99	Spring grazing trial (Trial 2) 1.69 lb ADG; 260 lb Gain /acre	
6/17/99	Herbicide: 2,4 D & Ally	$8.78
8/20/99	Fertilizer: 53 lb. N (urea)	$10.62
	No fall grazing – inadequate forage production	
Average establishment cost (seed, fertilizer, herbicide), $/acre		**$48.22**
Pro-rated over 5 years, $/acre/year		**$9.64**
Average yearly maintenance cost (fertilizer and herbicide), $/acre		**$32.10**
Beef production, lb beef/acre		**256[a]**

[a] Average of gain/acre in the spring of 1998 and spring of 1999.

Table 2. Management events for the cool-season perennial grass pastures at the "West" location at Marshall, OK.

Date	Event	$/acre
9/3/97	West 60 acres established	
	12 lb. Seed / acre @ $1.80/lb.	$21.60
	No fall grazing – establishment deferment	
2/24/98	Fertilizer: 35 lb N, 33 lb P	$14.95
3/3/98	Herbicide: 2,4-D	$4.14
8/18/98	Fertilizer: 60 lb N, 32 lb. P/acre (West 60)	$21.05
3/3/99	Fertilizer: 52 lb N/acre	$10.87
3/31/99 - 6/10/99	Spring grazing trial (Trial 2) 1.69 lb ADG; 260 lb Gain /acre	
8/20/99	Fertilzier: 53 lb. N/acre (urea)	$10.62
9/23/99 - 11/3/99	Fall grazing trial (Trial 3) 1.09 lb ADG; 52 lb Gain/acre	
Average establishment cost (seed, fertilizer, herbicide), $/acre		**$40.69**
Pro-rated over 5 years, $/acre/year		**$8.14**
Average yearly maintenance cost (fertilizer and herbicide), $/acre		**$28.36**
Average yearly beef production, lb beef/acre		**312**

APPENDIX D

Degradable Intake Protein and Metabolizable Protein Balance of Forages

Table 1. NRC[a] model estimates of degradable intake protein and metabolizable protein balance for cool-season perennial grasses during the spring of 1998 (Trial 1).

			Gain		DIP, g			MP, g			First limiting
	Sample	DMI[b]	ME[c]	MP[d]	Supply	Req.	Bal.	Supply	Req.	Bal.	nutrient[e]
Wheatgrass	Initial	5.58	1.15	1.34	883	510	373	620	563	57	Energy
Wheatgrass	Middle	5.62	1.02	1.25	759	494	265	596	528	68	Energy
Wheatgrass	Final	5.67	0.94	1.32	636	484	152	618	503	115	Energy
Orchardgrass	Initial	5.67	0.91	1.44	662	480	182	653	494	159	Energy
Orchardgrass	Middle	5.62	0.44	1.17	588	419	169	581	359	222	Energy
Orchardgrass	Final	5.58	0.36	1.45	508	408	100	672	334	338	Energy
Bromegrass	Initial	5.58	1.14	1.50	925	508	417	666	560	106	Energy
Bromegrass	Middle	5.62	0.49	1.53	683	425	258	693	371	322	Energy
Bromegrass	Final	5.62	0.49	1.51	559	426	133	685	374	311	Energy

[a] Nutrient Requirements of Beef Cattle, Seventh Ed., 1996.

[b] Estimated dry matter intake, kg/d.

[c] Metabolizable energy allowable gain (kg/d), calculated from total digestible nutrients.

[d] Metabolizable protein allowable gain (kg/d), calculated from microbial protein and undegraded feed protein supply.

[e] Rationale for declaring which nutrient was first-limiting (regardless of magnitude of nutrient balances): (1) A negative DIP balance precludes full utilization of ME, therefore DIP was declared first-limiting in the case of a negative DIP balance. (2) If DIP balance was positive, MP balance determined which nutrient was first-limiting. The stated MP requirement is the requirement of MP to achieve ME allowable gain. Therefore, in cases of a negative MP balance, MP was declared first limiting. If DIP and MP balances were both positive, energy was declared first-limiting.

Table 2. NRC[a] model estimates of degradable intake protein and metabolizable protein balance for cool-season perennial grasses during the spring of 1999 (Trial 2).

			Gain		**DIP, g**			**MP, g**			First limiting
	Sample	DMI[b]	ME[c]	MP[d]	Supply	Req.	Bal.	Supply	Req.	Bal.	nutrient[e]
Wheatgrass	Initial	5.44	1.32	1.67	1198	531	667	714	612	102	Energy
Wheatgrass	Middle	5.62	1.10	1.10	922	504	418	548	550	(2)	MP
Wheatgrass	Final	5.62	0.49	0.61	430	426	4	410	374	36	Energy
Orchardgrass	Initial	5.58	1.10	2.44	1029	504	525	946	550	396	Energy
Orchardgrass	Middle	5.67	0.55	1.18	810	434	376	582	370	212	Energy
Orchardgrass	Final	5.26	0.00	0.00	535	345	190	513	222	291	Energy
Bromegrass	Initial	5.58	1.17	1.85	1223	512	711	769	568	201	Energy
Bromegrass	Middle	5.67	0.59	1.16	716	438	278	574	401	173	Energy
Bromegrass	Final	5.31	0.00	--	520	352	168	446	222	224	Energy

[a] Nutrient Requirements of Beef Cattle, Seventh Ed., 1996.

[b] Estimated dry matter intake, kg/d.

[c] Metabolizable energy allowable gain (kg/d), calculated from total digestible nutrients.

[d] Metabolizable protein allowable gain (kg/d), calculated from microbial protein and undegraded feed protein supply.

[e] Rationale for declaring which nutrient was first-limiting (regardless of magnitude of nutrient balances): (1) A negative DIP balance precludes full utilization of ME, therefore DIP was declared first-limiting in the case of a negative DIP balance. (2) If DIP balance was positive, MP balance determined which nutrient was first-limiting. The stated MP requirement is the requirement of MP to achieve ME allowable gain. Therefore, in cases of a negative MP balance, MP was declared first limiting. If DIP and MP balances were both positive, energy was declared first-limiting.

Table 3. NRC[a] model estimates of degradable intake protein and metabolizable protein balance for cool-season perennial grasses during the fall of 1999 (Trial 3).

			Gain		DIP, g			MP, g			First limiting
	Sample	DMI[b]	ME[c]	MP[d]	Supply	Req.	Bal.	Supply	Req.	Bal.	nutrient[e]
Wheatgrass	Initial	5.67	0.97	1.27	1113	488	625	601	513	88	Energy
Wheatgrass	Middle	5.67	0.75	1.23	787	459	328	594	449	145	Energy
Wheatgrass	Final	5.62	0.41	1.14	501	415	86	575	348	227	Energy
Orchardgrass	Initial	5.67	0.73	1.54	835	457	378	686	443	243	Energy
Orchardgrass	Middle	5.53	0.26	1.14	596	395	201	581	304	277	Energy
Orchardgrass	Final	5.08	0.00	--	282	322	(40)	533	222	311	DIP
Bromegrass	Initial	5.67	0.87	1.46	1182	474	708	660	482	178	Energy
Bromegrass	Middle	5.58	0.35	1.31	723	407	316	629	332	297	Energy
Bromegrass	Final	5.53	0.24	1.33	497	392	105	642	298	344	Energy

[a] Nutrient Requirements of Beef Cattle, Seventh Ed., 1996.

[b] Estimated dry matter intake, kg/d.

[c] Metabolizable energy allowable gain (kg/d), calculated from total digestible nutrients.

[d] Metabolizable protein allowable gain (kg/d), calculated from microbial protein and undegraded feed protein supply.

[e] Rationale for declaring which nutrient was first-limiting (regardless of magnitude of nutrient balances): (1) A negative DIP balance precludes full utilization of ME, therefore DIP was declared first-limiting in the case of a negative DIP balance. (2) If DIP balance was positive, MP balance determined which nutrient was first-limiting. The stated MP requirement is the requirement of MP to achieve ME allowable gain. Therefore, in cases of a negative MP balance, MP was declared first limiting. If DIP and MP balances were both positive, energy was declared first-limiting.

Table 4. NRC[a] model estimates of degradable intake protein and metabolizable protein balance for Old World bluestem during the 1998 grazing season.

			Gain		DIP, g			MP, g			First limiting
	Wt, kg	DMI[b]	ME[c]	MP[d]	Supply	Req.	Bal.	Supply	Req.	Bal.	nutrient[e]
MAY	227	5.67	0.72	1.22	481	455	26	591	439	152	Energy
	272	6.53	0.75	1.41	554	525	29	681	483	198	Energy
	317	7.30	0.76	1.56	626	586	40	762	518	244	Energy
JUN	227	5.62	0.49	1.32	499	425	74	629	371	258	Energy
	272	6.49	0.52	1.52	576	490	86	725	416	309	Energy
	317	7.26	0.53	1.68	644	548	96	811	451	360	Energy
JUL	227	5.53	0.25	1.19	362	394	(32)	596	303	293	DIP
	272	6.35	0.28	1.35	415	452	(37)	684	343	341	DIP
	317	7.12	0.29	1.49	406	507	(101)	767	380	387	DIP
AUG	227	5.49	0.19	0.73	282	385	(103)	455	282	173	DIP
	272	6.30	0.21	0.83	324	442	(118)	523	324	199	DIP
	317	7.07	0.23	0.93	364	496	(132)	587	361	226	DIP
SEP	227	4.90	0.00	--	343	302	41	390	222	168	Energy
	272	5.62	0.00	--	394	347	47	447	255	192	Energy
	317	6.30	0.00	--	441	389	52	501	286	215	Energy

[a] Nutrient Requirements of Beef Cattle, Seventh Ed., 1996.

[b] Estimated dry matter intake, kg/d.

[c] Metabolizable energy allowable gain (kg/d), calculated from total digestible nutrients.

[d] Metabolizable protein allowable gain (kg/d), calculated from microbial protein and undegraded feed protein supply.

[e] Rationale for declaring which nutrient was first-limiting (regardless of magnitude of nutrient balances): (1) A negative DIP balance precludes full utilization of ME, therefore DIP was declared first-limiting in the case of a negative DIP balance. (2) If DIP balance was positive, MP balance determined which nutrient was first-limiting. The stated MP requirement is the requirement of MP to achieve ME allowable gain. Therefore, in cases of a negative MP balance, MP was declared first limiting. If DIP and MP balances were both positive, energy was declared first-limiting.

Table 5. NRC[a] model estimates of degradable intake protein and metabolizable protein balance for midgrass prairie during the 1998 grazing season.

			Gain		DIP, g			MP, g			First limiting
	Wt, kg	DMI[b]	ME[c]	MP[d]	Supply	Req.	Bal.	Supply	Req.	Bal.	nutrient[e]
JUN	227	5.40	0.06	0.59	232	367	(135)	417	242	175	DIP
	272	6.17	0.07	0.66	265	420	(155)	476	279	197	DIP
	317	6.94	0.10	0.74	298	472	(174)	536	319	217	DIP
JUL	227	5.67	0.57	0.61	268	436	(168)	410	396	14	DIP
	272	6.49	0.59	0.70	307	499	(192)	469	434	35	DIP
	317	7.30	0.61	0.78	345	562	(217)	527	475	52	DIP
AUG	227	5.62	0.44	0.58	195	419	(224)	401	359	42	DIP
	272	6.44	0.46	0.66	223	480	(257)	459	398	61	DIP
	317	7.21	0.47	0.73	250	538	(288)	514	434	80	DIP
SEP	227	5.58	0.35	0.44	195	407	(212)	359	331	28	DIP
	272	6.39	0.37	0.50	224	466	(242)	411	370	41	DIP
	317	7.17	0.38	0.55	250	522	(272)	461	407	54	DIP

[a] Nutrient Requirements of Beef Cattle, Seventh Ed., 1996.

[b] Estimated dry matter intake, kg/d.

[c] Metabolizable energy allowable gain (kg/d), calculated from total digestible nutrients.

[d] Metabolizable protein allowable gain (kg/d), calculated from microbial protein and undegraded feed protein supply.

[e] Rationale for declaring which nutrient was first-limiting (regardless of magnitude of nutrient balances): (1) A negative DIP balance precludes full utilization of ME, therefore DIP was declared first-limiting in the case of a negative DIP balance. (2) If DIP balance was positive, MP balance determined which nutrient was first-limiting. The stated MP requirement is the requirement of MP to achieve ME allowable gain. Therefore, in cases of a negative MP balance, MP was declared first limiting. If DIP and MP balances were both positive, energy was declared first-limiting.

Table 6. NRC[a] model estimates of degradable intake protein and metabolizable protein balance for tallgrass prairie during the 1998 grazing season.

			Gain		DIP, g			MP, g			First limiting
	Wt, kg	DMI[b]	ME[c]	MP[d]	Supply	Req.	Bal.	Supply	Req.	Bal.	nutrient[e]
MAY	227	5.67	0.79	1.33	671	465	206	622	461	161	Energy
	272	6.53	0.83	1.53	773	535	238	717	505	212	Energy
	317	7.30	0.83	1.70	865	599	266	802	539	263	Energy
JUN	227	5.67	0.91	1.24	386	480	(94)	593	494	99	DIP
	272	6.49	0.93	1.41	441	549	(108)	678	532	146	DIP
	317	7.30	0.95	1.58	497	618	(121)	764	513	251	DIP
JUL	227	5.67	0.89	1.06	314	477	(163)	540	488	52	DIP
	272	6.49	0.90	1.21	359	546	(187)	618	526	92	DIP
	317	7.30	0.93	1.36	567	695	(128)	614	404	210	DIP
AUG	227	5.67	0.73	0.95	234	457	(223)	509	444	65	DIP
	272	6.53	0.77	1.09	270	527	(257)	587	488	99	DIP
	317	7.30	0.78	1.21	302	589	(287)	656	523	133	DIP
SEP	227	5.62	0.43	0.73	386	417	(31)	449	354	95	DIP
	272	6.44	0.44	0.83	442	478	(36)	514	393	121	DIP
	317	7.21	0.45	0.92	495	535	(40)	576	429	147	DIP

[a] Nutrient Requirements of Beef Cattle, Seventh Ed., 1996.

[b] Estimated dry matter intake, kg/d.

[c] Metabolizable energy allowable gain (kg/d), calculated from total digestible nutrients.

[d] Metabolizable protein allowable gain (kg/d), calculated from microbial protein and undegraded feed protein supply.

[e] Rationale for declaring which nutrient was first-limiting (regardless of magnitude of nutrient balances): (1) A negative DIP balance precludes full utilization of ME, therefore DIP was declared first-limiting in the case of a negative DIP balance. (2) If DIP balance was positive, MP balance determined which nutrient was first-limiting. The stated MP requirement is the requirement of MP to achieve ME allowable gain. Therefore, in cases of a negative MP balance, MP was declared first limiting. If DIP and MP balances were both positive, energy was declared first-limiting.

APPENDIX E

Precipitation Data

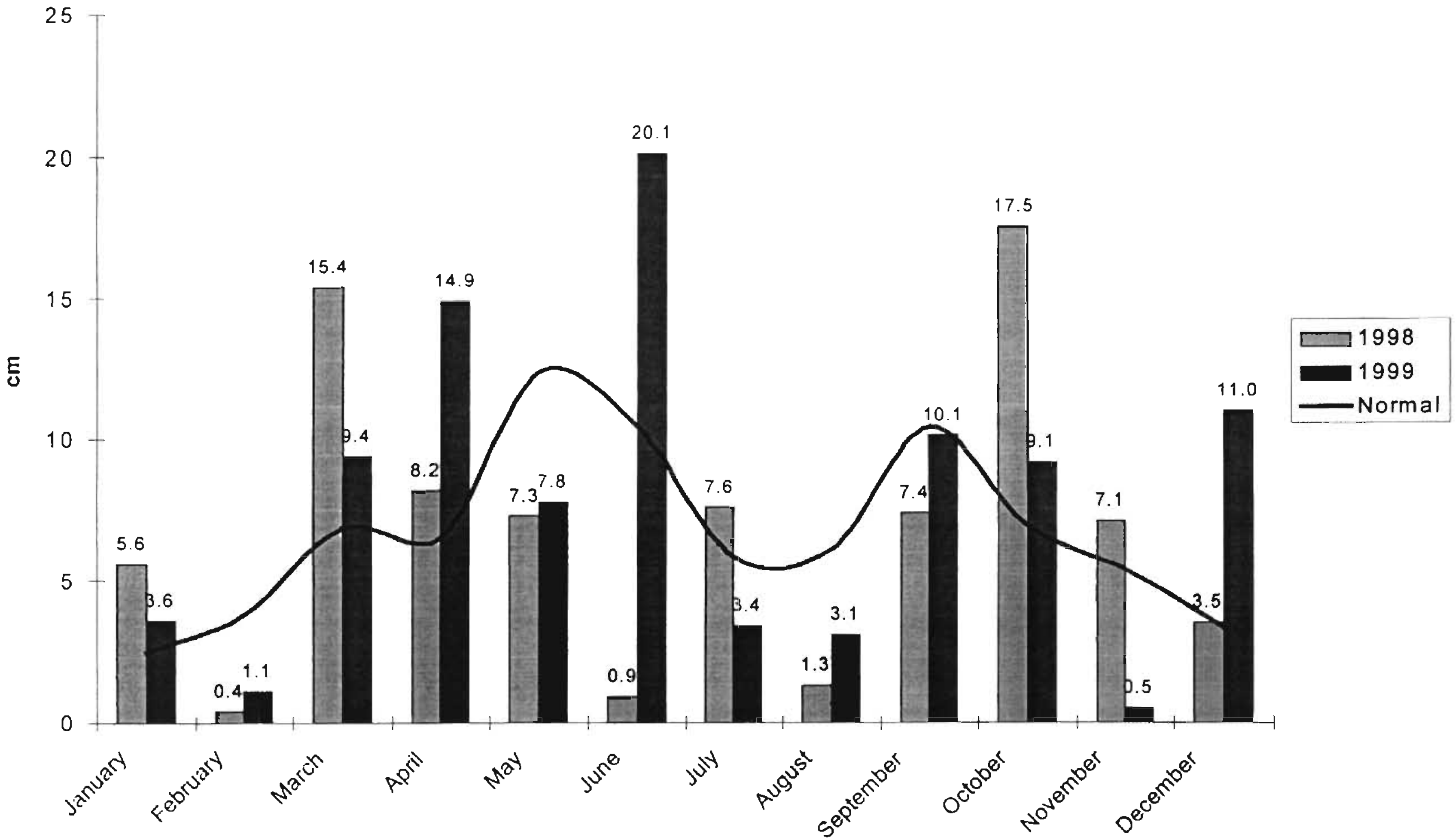

Figure 1. 1998, 1999, and normal (30-yr avg.) precipitation at the Marshall site of the Oklahoma Mesonet system at the OSU Wheat Pasture Research Unit in Logan Co., Oklahoma.

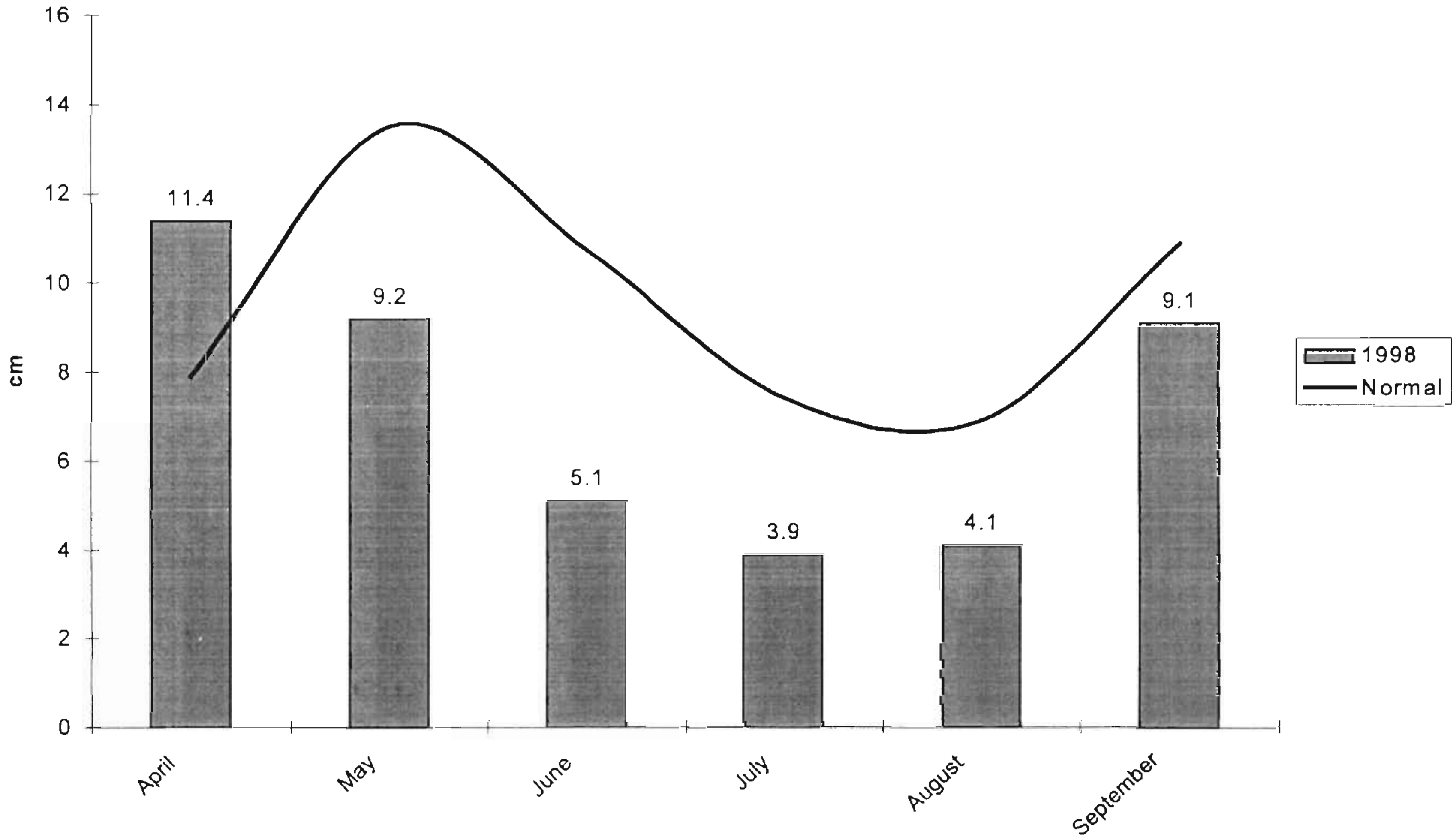

Figure 2. 1998 and normal (30-yr avg.) precipitation at the Marena site of the Oklahoma Mesonet system near the OSU Bluestem Research Range in Payne Co., Oklahoma.

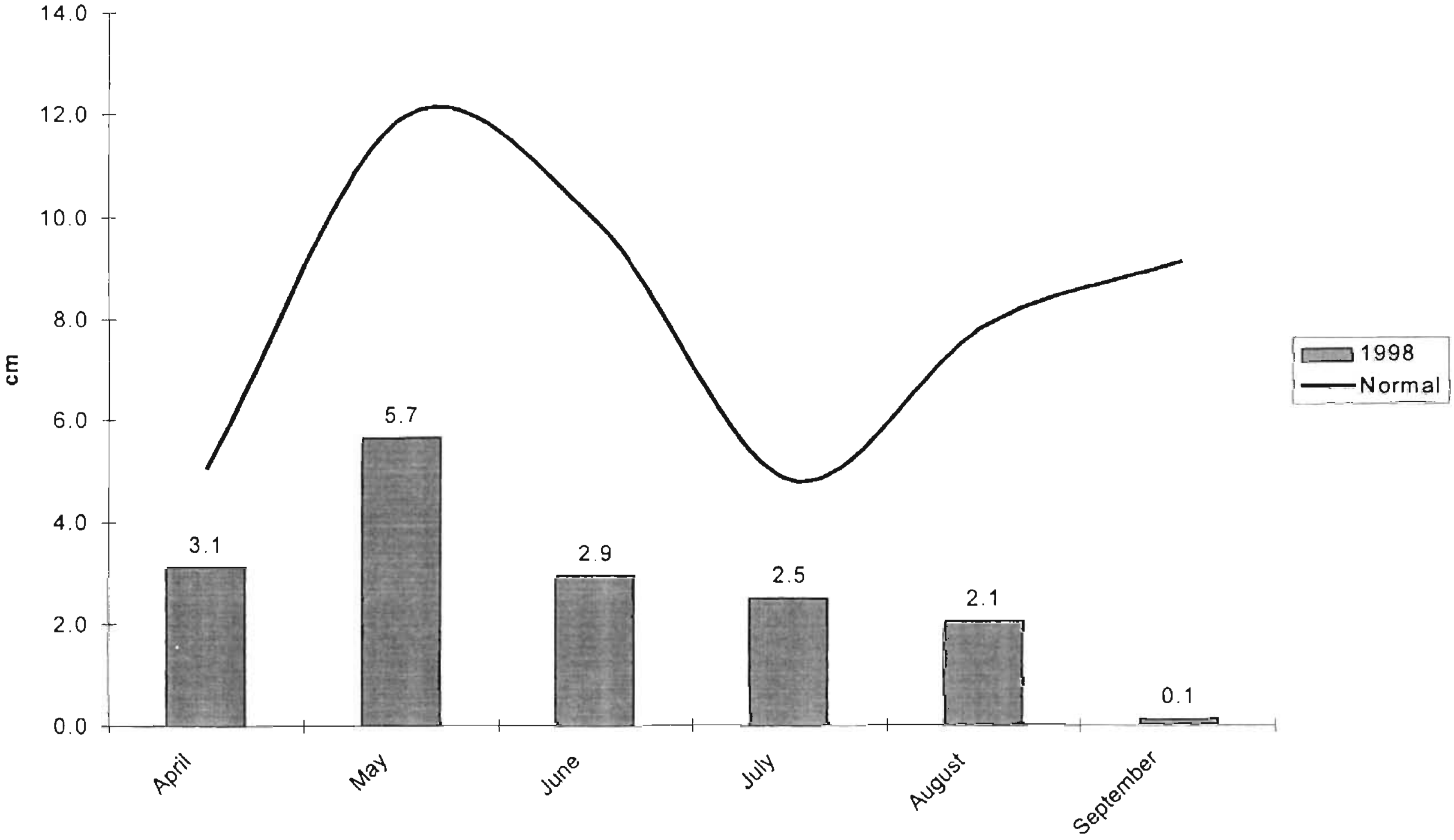

Figure 3. 1998 and normal (30-yr avg.) precipitation at the Bessie site of the Oklahoma Mesonet system near the OSU Marvin Klemme Research Range in Washita Co., Oklahoma

VITA

Richard Ryan Reuter

Candidate for the Degree of

Master of Science

Thesis: GRAZING COOL-SEASON PERENNIAL GRASSES AND CHANGES IN NUTRITIVE VALUE OF THREE FORAGE TYPES IN THE SOUTHERN GREAT PLAINS.

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