NUTRITIONAL VALUE OF WARM- AND COOL-SEASON GRASSES FOR RUMINANTS

by

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(ABSTRACT)

A metabolism trial was conducted to compare the nutritional value of: 1)'Quickstand' bermudagrass [*Cynodon dactylon* (L.) Pers.], 2)caucasian bluestem [*Bothriochloa caucasia* (Trin.) C.E. Hubb], 3)tall fescue (*Festuca arundinacea* Schreb.), and 4)orchardgrass (*Dactylis glomerata* L.). The warm-season grasses (bermudagrass and bluestem) were higher ($P < .01$) in fiber components than the cool-season grasses (tall fescue and orchardgrass). Bluestem was lower ($P < .001$) in CP, hemicellulose, and ash, and higher in NDF ($P < .001$), ADF ($P < .001$), cellulose ($P < .001$), and lignin ($P < .01$) than bermudagrass. The warm-season grasses were lower in the apparent digestibility of DM ($P < .001$), NDF ($P < .01$), ADF ($P < .05$), cellulose ($P < .05$), and hemicellulose ($P < .01$) than cool-season grasses. Apparent digestibility of NDF ($P < .001$), ADF ($P < .001$), cellulose ($P < .01$), and hemicellulose ($P < .01$) was higher for bluestem than bermudagrass. Fescue was higher ($P < .001$) in apparent digestibility of DM and CP and lower ($P < .01$) in apparent digestibility of NDF, ADF, cellulose, and hemicellulose than orchardgrass. Lambs fed bluestem had lower ($P < .05$) N retention than those fed bermudagrass, when expressed as g/d. Lambs fed fescue had higher ($P < .001$) N retention, than those fed orchardgrass. When expressed as a percent of intake or absorption, N retention values were similar among treatments. The results of this study suggest that cool-season grasses are of higher nutritional value than warm-season grasses.

Key Words: Bermudagrass, Caucasian Bluestem, Tall Fescue, Orchardgrass, Digestibility, Ruminants

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INTRODUCTION

Forages are key components of ruminant livestock production systems. Maximizing use of forages is essential to minimize production costs. Forage systems that maximize year-round grazing and minimize the need for mechanically harvested forage can improve profitability. In the northern two-thirds of the United States, cool-season grasses, such as tall fescue (*Festuca arundinacea* Schreb.) and orchardgrass (*Dactylis glomerata* L.) are very important pasture species. These grasses exhibit a seasonal growth pattern in which greater than 50% of their annual growth is often produced prior to June 1. Limited growth is produced during mid-summer. Supplemental feeding of livestock may be necessary during the periods of inadequate herbage growth in a cool-season pasture system, which would increase the cost of production.

Research on alleviation of the seasonal growth pattern exhibited by cool-season grassses has recently been focused on integration of warm-season grasses into grazing management systems. Warm-season grasses start growth later in the spring than cool-season grasses and produce at least 60% of their growth between June 1 and August 1. Therefore, warm-season grasses such as Caucasian bluestem [*Bothriochloa caucasia* (Trin.) C.E. Hubb] and bermudagrass [*Cynodon dactylon* (L.) Pers.] offer the potential to provide abundant herbage during mid-summer when cool-season species growth is limited.

Grazing livestock on warm-season pastures during summer months can relieve stress on cool-season pastures and allow for more abundant fall forage production by the cool-season pastures, which will provide grazing further into the winter months. Research results have shown that bluestem produces adequate gains for grazing steers. Gains similar to steers grazing bluestem have been reported for steers grazing bermudagrass pastures. Bermudagrass use in the

United States has generally been confined to the southern areas. Release of winter-hardy cultivars such as ‘Quickstand’ has extended the use of bermudagrass into the mid- and upper-southern United States. Considerable research evaluating the nutritional value and digestibility, both *in vitro* and *in situ*, of warm- and cool-season grasses has been conducted. However, research that has directly compared the nutritional value and apparent digestibility of warm- and cool-season grasses has been limited.

The objectives of this research were to compare the nutrient content, apparent digestibility and utilization of two warm-season grasses (‘Quickstand’ bermudagrass and Caucasian bluestem) and two cool-season grasses (tall fescue and orchardgrass).

LITERATURE REVIEW

General Characteristics of Cool-Season (C_3) Grasses

Temperature and Light. In the northern two thirds of the United States, cool season grasses such as tall fescue, smooth brome (*Bromis inermis* L.), timothy (*Phleum pratense* L.), orchardgrass, bluegrass (*Poa pratensis* L.), and the wheatgrasses (*Agropyron*, *Elymus*, and *Elytrigia* spp.) are often the dominant pasture species (Anderson, 1988). Optimum temperatures for growth of most cool-season grasses are between 20° and 25° C (Moser and Hoveland, 1996). Below 5° C and above 35° C growth is greatly reduced or will even cease. Most cool-season grasses have the C_3 photosynthetic pathway of carbon fixation and most warm-season grasses have the C_4 pathway (Waller and Lewis, 1979). The C_3 grasses have a photosynthetic rate that is only about one-half that of C_4 grasses under light saturation (Moser and Hoveland, 1996). In most C_3 plants, at normal atmospheric CO_2 levels, photosynthesis saturates with light levels of about 500 to 1000 μmole of photons $m^{-2}s^{-1}$ whereas with C_4 species, light saturation is never really achieved (Hopkins, 1999).

Photosynthesis. In cool-season grasses, the first product of the process of fixation of atmospheric CO_2 is a three carbon acid (3-phosphoglyceric acid), evolving the name C_3 photosynthesis (Waller and Lewis, 1979). The three-carbon acid is metabolized in the mesophyll cells through a reduction process to form carbohydrates, especially sucrose, which is translocated to other parts of the plant (Moser and Hoveland, 1996). The N concentration in the tissue of cool-season grasses is higher than that in warm-season grasses (Bjorkman et al., 1976). The higher growth rates, nitrogen use efficiency and lower tissue protein content of C_4 versus C_3 plants have been related to differences in pathways of carbon fixation (Brown, 1978). Ribulose-

1,5-bisphosphate carboxylase (Rubisco) constitutes about 50% of the soluble protein in mesophyll cells in C_3 plants and its low activity is the major limiting step in photosynthetic carbon fixation. In C_4 plants, Rubisco is restricted to the bundle sheath cells where it represents about 20 percent of the soluble protein (Bjorkman et al., 1976). There is more N present in the leaves than the stem and the proportion of stem tends to be greater in warm-season, than in cool-season grasses (Wilson and Minson, 1980).

Photorespiration. One associated aspect, characteristic of C_3 photosynthesis is photorespiration (Ogren, 1984). This is the process in which O_2, instead of CO_2, reacts with ribulose-1,5-bisphophate to form a two carbon acid (glycolic acid) and a three carbon acid (phosphoglycerate). This process produces no net CO_2 fixation and therefore results in a loss of energy and offers one explanation for the higher level of dry matter production by C_4 grasses. Nelson (1988) suggested that reduction or elimination of photorespiration would give a large increase in leaf photosynthesis of C_3 crops. However, he questioned the feasibility and long-term response of such a change. Bjorkman (1971) noted that most of the differences in photosynthetic gas exchange characteristics between C_3 and C_4 species disappear when the O_2 content is reduced to 1 to 2%. Therefore, he suggested that the differences may largely be attributable to the presence of O_2 inhibition in C_3 but not C_4 plants.

Digestibility. Most cool-season grasses are relatively high in digestible energy and protein when utilized in the vegetative state (Ulyatt, 1981). Cool-season forage grasses are highly digestible, averaging about 70% for DM over the year. Cool-season leaf tissue breaks down rapidly in the rumen because it is composed of mostly thin-walled mesophyll cells, and does not have as many vascular or resistant bundle sheath cells, compared to warm-season grasses (Moser and Hoveland, 1996). Akin and Burdick (1975) reported leaf blades of tropical grasses had an average of 22 percentage units less of the easily digested tissue (mesophyll and phloem) and 25 percentage units more of the slowly digested tissues (epidermis and parenchymal bundle sheath) than temperate species.

Cool-season grasses accumulate the water-soluble carbohydrates, including glucose, fructose and sucrose, and fructosan, which act as readily-available sources of energy for microbial fermentation (Norton, 1981). The higher content of water-soluble carbohydrates, compared to warm-season grasses, partially accounts for the higher digestibility of cool-season grasses. Crude protein content is high in immature cool-season grasses but most of it is degradable in the rumen, and there is less rumen bypass protein or escape protein, compared to warm-season grasses (Mullahey et al., 1992). Cool-season grasses are generally lower in Mg, Na, Cu, and Zn than C_4 grasses, while being higher in P, Ca and Co (Minson, 1981; Follett and Wilkinson, 1995).

Tall Fescue

History and Distribution. Tall fescue is a cool-season grass species native to Europe (Smith et al., 1986). Although the exact time of introduction in the U.S. is not known, the presence of the grass was first recorded in Camden, New Jersey in 1879 (Sleper and Buckner, 1995). Originally, tall fescue was thought to be a variety of meadow fescue (*Festuca eliator*, L), a less productive species of the genus (Smith et al., 1986). In 1771, meadow fescue and tall fescue were recognized as separate and distinct species by Schreber who assigned the species name *arundinacea* to tall fescue (Sleper and Buckner, 1995). Tall fescue did not gain widespread use in the United States until release of the cultivars ‘Alta’ and ‘Kentucky 31’ in 1940 and 1943, respectively (Smith et al., 1986; Sleper and Buckner, 1995). However, tall fescue was shown to be taller, more drought and cold tolerant, more competitive with weeds, to form more dense stands, and thrive on a wider range of soils than other *Festuca* species in field trials conducted in Utah, Kentucky, and Washington, D.C. in the late 1800's (Sleper and Buckner, 1995). Tall fescue is the major cool-season grass species in a region of the humid eastern United States that is defined approximately as 32° N to 40° N latitude, and from the meridian of eastern Kansas (95° W longitude) to the eastern edge of the piedmont area. It occupies approximately 12 to 14 million ha in pure and mixed stands in the U.S. and is considered to be the predominant cool-season grass species.

About 60% of the growth of tall fescue is produced before June 1, and the grass can become a dormant, unproductive, and low quality forage in summer (Anderson, 1988). With advanced maturity, tall fescue increases in cell wall concentration and decreases in protein concentration, palatability, and overall feed value (Diggins et al., 1984).

Endophyte Infection of Tall Fescue. Tall fescue is often associated with an endophyte fungus (*Neotyphodium coenaphialum* Morgan-Jones and W. Gams) that can result in reduced growth, conception, milk production, and intolerance to heat in cattle (Hoveland, 1993). There are endophyte-free tall fescue cultivars available, however, these cultivars may not be as widely adapted and tolerant to stress as the endophyte-infected tall fescue (Read and Camp, 1986). The mutualistic symbiosis of the endophyte and the grass confers a number of benefits on the host plant such as insect and nematode resistance, drought tolerance, and improved competitive ability with other plant species (Hoveland, 1993).

Management. Tall fescue tolerates close grazing, thus, it can be managed using continuous stocking (Smith et al., 1986). Management practices also include harvesting tall fescue as hay in the spring or hay and grazed forage in the spring and summer. Tall fescue is often stockpiled in Virginia. Stockpiling allows for the growth of tall fescue when energy fixed in photosynthesis is in excess of the requirements for growth and results in the availability of forage that is high in TNC (Brown and Blaser, 1965). Management of stockpiled tall fescue includes an application of 70 to 90 kg N per ha in early August, with removal of animals, to ensure optimum forage yield (Allen et al., 1992). Brown et al. (1963) found fall grown tall fescue forage to either increase or not change significantly in dry matter digestibility with age, thereby providing high quality forage for winter grazing. They suggested that the lack of decline in dry matter digestibility with age of fall grown tall fescue was due to an increase in soluble carbohydrate with age of the grass and the fact that CP and lignin contents do not increase as the grass grows older. Bagley et al. (1983) found deterioration in the quality of stockpiled tall fescue occurred from November to February. A decrease in CP occurred, and total nonstructural carbohyrates (TNC) decreased from 15.9% to 5.5% from November to February. Accompanying the drop in TNC was an increase in the percentage of fibrous components in the forage. Digestibilities for all forage components were lower for February than November harvested tall fescue.

Orchardgrass

History and Distribution. Orchardgrass is a cool-season perennial forage native to Europe (Christie and McElroy, 1995). Most likely, it was introduced into the U.S. in the 1750's and then improved strands were exported to Great Britain from Virginia in 1763 (Leafe, 1988). The largest proportion of the orchardgrass area in the U.S. is found in the central region east of the Missouri River, in the Northeast, and in the Pacific Northwest (Smith et al., 1986).

Management. Orchardgrass produces a fibrous root system. Because of rapid growth and good tillering ability, orchardgrass is well suited for spring pastures and better suited to rotational stocking than to continuous stocking (Christie and McElroy, 1995). Frequent mowing, as a simulator of grazing, has been shown to result in a thinner stand of orchardgrass (Davies, 1988). Orchardgrass has been shown to be very responsive to N fertilization. Donahue et al. (1981) found increases in herbage yield with applied N up to 600 kg/ha.

Panditharatne et al. (1986) found no significant difference in apparent digestibility of CP in orchardgrass pastures when fertilized with N alone. However, when the sward was fertilized with S, apparent CP digestibilities increased with level of N application.

Temperature and Light. Baker and Jung (1968) found the optimal temperature for top growth for orchardgrass was between 18.3 and 21.6° C. However, over a wide variation in range of temperature combinations, they found 22°/12° C, day/night, to be the best for maximum top growth. Temperatures above 28° C greatly reduced growth and tillering. Orchardgrass grows rapidly at cool temperatures and is especially productive in early spring (Christie and McElroy, 1995). It is reasonably productive in late fall, although less so than tall fescue (Archer and Decker, 1977).

Orchardgrass is only moderately winter-hardy and will not survive northern climatic conditions if snow cover is lacking (Christie and McElroy, 1995). It is, however, more adaptable to varying light intensities and can be found growing in shaded areas (Singh et al., 1974) as well as areas of direct light (Pearce et al., 1965). Orchardgrass is also drought tolerant, which may be attributable to its extensive, fibrous root system. In addition, it persists and grows on moderately poorly drained soils. Orchardgrass is very competitive and in the presence of an abundance of nutrients will become dominant. Competitiveness of orchardgrass depends on light, soil moisture, and nutrients (Wilkinson and Gross, 1964).

Quality. Of 415 orchardgrass clones examined by Stratton et al. (1979), a range of *in vitro* dry matter digestibility (IVDMD) from 49% to 68% was observed. In comparison to orchardgrass as fall-grazing forage, fescue excelled, due to superior growth (Archer and Decker, 1977). Differences in quality between the species have not been consistent, however. The minimum IVDMD levels measured over a 2-yr study by Archer and Decker (1977) was 73% for orchardgrass.

Blaser and Collegues (1986) found tall fescue pastures produced about 24% more growth (steer days grazing) than orchardgrass, but the lower quality from the fescue pastures depressed daily liveweight gains 22%. Therefore, the liveweight gains of steers per hectare were similar for the fescue and orchardgrass pastures. In Tennessee, Fribourg et al. (1979) showed orchardgrass pastures produced more gains per steer over the entire grazing season than bermudagrass pastures. However, many more steers could be maintained on bermudagrass after early July than on orchardgrass. The authors suggested that orchardgrass may be more susceptible to drought stress than bermudagrass in less favorable years. Brown and Blaser (1970) found moisture stress in orchardgrass increases soluble carbohydrates in stem bases. They concluded that the buildup is due to a greater reduction in utilization than in synthesis of photosynthesis products.

General Characteristics of Warm-Season (C_4) Grasses

Photosynthesis. Warm-season grasses commonly found in production in the U.S. include bermudagrass (Burton and Hanna, 1995), switchgrass (*Panicum virgatum* L.) (Moser and Vogel, 1995), Old World bluestems (Voigt and Sharp, 1995), bahiagrass (*Paspalum notatum* Flugge) (Burson and Watson, 1995), and dallisgrass (*Paspalum dilatatum* Poir.) (Burson and Watson, 1995). Optimum temperature for photosynthesis in C_4 plant species has been shown to range from 30° to 40° C with a rapid decline in photosynthesis below 15° to 20° C (Downton, 1971).

The C_4 grasses utilize the Hatch-Slack pathway for their photosynthetic processes which produces the four carbon compounds, oxaloacetic acid, malic acid and aspartic acid (Hatch and Slack, 1970). Hatch (1971) described the C_4 photosynthetic pathway in the following manner. Initially, CO_2 is incorporated into C_4 acids in the mesophyll cells. Then, either malate or aspartate or both acids (depending on species) are transported to the bundle sheath chloroplasts where the CO_2 is liberated and refixed by Rubisco. The remaining C_3 compound (pyruvate or alanine) is then returned to the mesophyll cell to serve as a precursor of phosphoenolpyruvate (PEP). He proposed this process acted to concentrate the CO_2 in the bundle sheath cell at the site of Rubisco action.

Kranz Anatomy. One distinguishing feature in the C_4 plant is the “radial arrangement” of tightly packed, often thick-walled, bundle sheath cells around the vascular bundles which separates them from the predominant mesophyll cells. This arrangement is known as Kranz anatomy (Laetsch, 1974). El-Sharkawy and Hesketh (1965) conducted one of the first investigations linking Kranz anatomy with the physiological aspects of photosynthesis. They reported that species with high photosynthetic rates, which did not leak CO_2 to the environment in the light, had Kranz anatomy.

Warm-season grasses utilize soil N, P and K more efficiently than cool-season grasses (Brown, 1978; Norton, 1981; Morris et al., 1982). Brown (1978) suggested that the greater N use efficiency by C_4 plants was a result of the relatively small investment of N in the photosynthetic carboxylation enzymes in C_4 versus C_3 plants. Morris et al. (1982) reported warm-season grasses yield up to three times greater than those of cool-season grasses grown on soil with a low P level. However, the P concentrations in the forages of cool-season grasses were twice those of warm-season grasses, thereby possibly requiring supplementation when fed to livestock.

Digestibility. Griffin and Jung (1983) found increases in the proportion of stem tissue with maturity to be a major determinate of whole-plant nutritive value in big bluestem (*Andropogon gerardii* Vitman) and switchgrass. However, when harvested on the same date, IVDMD of both leaves and stems did not differ between big bluestem and indiangrass [*Sorghastrum nutans* (L.) Nash] (Perry and Baltensperger, 1979), indicating leaf maturation, rather than plant development, had the greatest influence on nutritive value (Hendrickson et al., 1997). Griffin and Jung (1983) found crude protein and IVDMD were lower and fiber estimates were higher for big bluestem than tall fescue. This could be due to anatomical differences between C_3 and C_4 species. Results obtained by Akin and Burdick (1975) indicate that leaf blade microanatomy and inherent characteristics of cell walls affect digestibility by rumen microorganisms. They found that of the five C_4 plant species examined, the mesophyll accounted for less than 55%, while the parenchyma bundle sheath accounted for greater than 9% of the total leaf tissue. Of the six C_3 plant species examined, mesophyll tissue accounted for greater than 50% and parenchyma bundle sheath accounted for less than 9% of the total leaf tissue. Hendrickson et al. (1997) suggested a decrease in cell wall digestibility, rather than reductions in the cell-soluble fraction, to be the major factor associated with the reduction in leaf IVDMD.

Leaves of warm-season grasses store starch which consists of amylose and amylopectin, instead of fructosan which may also account for lower digestiblity, compared to cool-season grasses (Norton, 1981). Amylopectin is not water soluble and is less easily digested than water soluble carbohydrates. Chloroplasts of bundle sheath cells frequently contain nearly all the leaf starch, with little present in chloroplasts of more loosely arranged surrounding mesophyll cells (Salisbury and Ross, 1985). Akin and Burdick (1975) found parenchyma bundle sheaths of most plants listed as having the C_4, CO_2 fixation were more slowly digested than mesophyll and phloem.

Reid et al. (1988b) reported that C_4 grasses are consumed at levels higher than would be expected from their dry matter digestibility (DMD) and fiber concentrations. Redfearn et al. (1995) found total protein and individual protein fractions in switchgrass and big bluestem were generally at higher concentrations and present for longer periods of time than smooth bromegrass. They suggested that a mechanism may exist in C_4 species that allows certain protein fractions to remain undegraded for longer, compared with smooth bromegrass. Protein not ruminally degraded allows more amino acids to reach the small intestine (Chalupa, 1975). Utilization of nutrients post-ruminally eliminates energy losses associated with fermentation and protein losses incurred in the transformation of dietary protein to microbial protein (Black, 1971). This may be a good explanation for the fact that although C_4 grasses have a high fiber and low CP content, and a low DMD, they have relatively high intake and support reasonable rates of average daily gain in cattle when grazed (Vona et al., 1984; Reid et al., 1992; Fontenot et al., 1993).

Caucasian Bluestem

History and Growth Pattern. Caucasian bluestem is a C_4 warm-season perennial grass (Voigt and Sharp, 1995). It is an Old World bluestem, which are best adapted to fine-textured soils and are native to Africa, the Middle East, and southern Asia. Caucasian bluestem is adapted to the southern Corn Belt, where it provides a high yield of medium quality forage for mid-summer grazing. It produces 60% of annual growth between June 1 and August 31 in the southern United States (Anderson, 1988). Forwood et al. (1988) found Caucasian bluestem provided a steady increase of digestible dry matter yield (DDMY) of summer regrowth from July 2 through September 10. Therefore, it would supply forage for livestock during the dry, hot period of the year when cool-season species are usually unproductive. Because of plant architecture that protects the crown from destruction by grazing, Caucasian bluestem is tolerant of continuous grazing at high stocking rates (Christiansen and Svejcar, 1987). The crown consists of densely packed stem bases, containing numerous sites for tiller initiation, and leaf material that, because of its protected location, escapes defoliation (Voigt and Sharp, 1995). Because of an indeterminate growth habit (Anderson and Matches, 1983), Caucasian bluestem, when grown in the southern Corn Belt, is more responsive to added N fertilizer and late season precipitation than switchgrass (Taliaferro et al., 1975).

Forage Quality. The forage quality of Old World bluestems decrease rapidly as they mature (Dabo et al., 1988). Therefore, in order to achieve optimum animal performance for growing livestock, forage must be in a vegetative and actively growing state. Caucasian bluestem does not supply sufficient protein, Cu, P, and Zn for lactating beef cows or growing finishing steers (Reid et al., 1988a). However, it appears to meet all the requirements for beef cows at maintenance. Dabo et al (1988) found Caucasian bluestem to be low in CP and high in indigestible fiber component, compared to other Old World bluestems.

Animal Performance. Research results with cattle and sheep fed Caucasian bluestem has indicated that forage quality is higher than is indicated by laboratory tests (Reid et al., 1988a). In Missouri, Matches et al. (1982) found yields of Caucasian bluestem met or exceeded yields of tall fescue forage while producing similar daily and per hectare gains in steers. When warm-season grasses are incorporated into forage systems that are based on cool-season grasses, average daily gain is improved (Reid et al., 1988a). Summer gains of steers grazing Caucasian bluestem were higher, compared to steers grazing cool-season forages during July and August in Virginia (Fontenot et al., 1993). Daily gains of steers that grazed Caucasian bluestem from late June to late August averaged 1.1 to 1.4 kg/d. Anderson and Matches (1983) suggested that unless an animal is at maintenance, Caucasian bluestem should not be grazed past the jointing stage without supplementation. They reported that forage quality (based on chemical analyses) is poor after head emergence and will not meet energy requirements for body maintenance.

Bermudagrass

Environment and Production. Bermudagrass is a C_4, warm-season, perennial grass that is best adapted to the states south of the line connecting the southern boundaries of Virginia and Kansas (Burton and Hanna, 1995). It grows best when mean daily temperatures are above 24° C. At temperatures between 6° and 9° C very little growth occurs, and temperatures of -2° and -3° C will usually kill the stems and leaves back to the ground. Bermudagrass grows well on a wide variety of soils. It will grow satisfactorily on calcareous soils (Adams et al., 1967) and is highly tolerant to low pH and saline conditions (Lundberg et al., 1977). Bermudagrass has previously been restricted to the southern part of the United States and along the Atlantic coast states from Maryland south because of its poor winter hardiness. However, in recent years, Mathias et al. (1973) showed 'Midland' bermudagrass to withstand temperatures of -22° C where more than 112 kg N per ha was applied. 'Quickstand' bermudagrass is another available winter hardy bermudagrass cultivar. In a controlled environment study, Wright et al. (1984) showed DM yield of 'Quickstand' was as much as 230% higher than 'Midland'. 'Quickstand' has also been shown to persist in areas where 'Midland' will winterkill and exhibit greater growth rates at temperatures ranging between 18° and 35° C (Belesky et al., 1991; Phillips et al., 1997).

Fertilization. The production of bermudagrass is highly correlated with day length and solar radiation (r = .95 and .93, respectively) (Burton et al., 1988). However, rainfall, air temperature and soil moisture also affect bermudagrass productivity. Fertility ratios have been shown to play a major role in winter hardiness, and thus stand persistence. Gilbert and Davis (1971) reported that the best cold tolerance was produced when fertilizer was applied in a ratio of 4-1-6, N-P-K, respectively. These ratios also produced the most abundant regrowth. Bermudagrass is especially responsive to N fertilization. When fertilized with 1008 kg N/ha, it produced 30 metric tons of hay per hectare (Burton and Hanna, 1995).

Animal Performance. Performance of animals grazing bermudagrass forage has been low relative to cool-season species (Fribourg et al., 1979; Conrad et al, 1981). Fribourg et al. (1979) reported season-long average daily gains of .84 kg for steers grazing orchardgrass and ladino clover (Trifolium *repens* L.), while performance of steers grazing 'Midland' bermudagrass fertilized with 112, 224 or 448 kg N per ha ranged from .38 to .44 kg. However, total beef production (kg/ha) for 'Midland' fertilized with 448 kg N per ha was 605 whereas the orchardgrass-ladino clover mix produced only 561. Fribourg et al. (1979) reported a drastic decrease in IVDMD of bermudagrass forage over the grazing season, compared to orchardgrass-ladino clover forage.

Carrying Capacity. One beneficial characteristic of bermudagrass is its high carrying capacity relative to other forages (Conrad et al., 1981; McLaren et al., 1983). McLaren et al. (1983) obtained acceptable gains from bermudagrass pastures overseeded with fescue, with stocking rates of 7.3 steers per ha. Fribourg et al. (1979) had to use a stocking rate of 12.4 steers per hectare on ‘Midland’ bermudagrass pasture fertilized with 448 kg N per ha to control excess growth. Orchardgrass-ladino clover pastures in that same trial carried 4.0 steers per ha. The study conducted by McLaren et al. (1983) supported the findings of Fribourg and Overton (1979) that bermudagrass pastures overseeded with tall fescue could produce substantial amounts of good quality forage both in summer and during the cool season, with proper management. In both studies, more forage was produced and the number of days of available forage was higher for the mixture than for either forage grown alone.

Animals graze selectively, choosing the plant parts of higher nutritive value, provided the herbage mass is not limiting (Roth et al., 1990). Generally, the removal of forage by grazing animals is higher in green leaf content and nutrient concentration than the whole canopy (Minson, 1981). Bermudagrass, however, produces a canopy in which the leaf and stem are not easily separated, thereby reducing overall forage quality (Burns et al., 1991; Fisher et al., 1991). Using steers fitted with esophageal cannulas, Fisher et al. (1991) tested esophageal masticates for quality and related this information to canopy structure. Masticate samples taken from steers on bermudagrass were found to have the highest proportion of smaller particles (passing a .5 mm screen), compared to tall fescue, switchgrass and flaccidgrass (*Pennisetum flaccudum* Griseb.). However, bermudagrass masticates were lower in IVDMD. Bermudagrass and switchgrass canopies had the highest proportion of stem. The bermudagrass canopy varied less in IVDMD and prohibited prehension of a diet with quality similar to that of the others. Burns et al. (1991) suggested special grazing strategies, such as short duration grazing, are necessary if high performance is desired on bermudagrass pasture.

OBJECTIVES

The overall objective of this research was to compare the nutritional value of warm-season (C_4) and cool-season (C_3) grasses. Specifically, the objectives were to compare the nutrient content, apparent digestibility and utilization of ‘Quickstand’ bermudagrass, caucasian bluestem, orchardgrass, and low endophyte tall fescue.

EXPERIMENTAL PROCEDURES

A metabolism trial was conducted with 24 crossbred (1/2 Dorset, 1/4 Rambioullet, 1/4 Finnsheep) wether lambs (avg. BW, 43 kg). The lambs were blocked into six blocks of four according to BW and were randomly allotted within blocks to four experimental diets containing the following kinds of hay 1)’Quickstand’ bermudagrass; 2)caucasian bluestem; 3)orchardgrass; or 4)low endophyte tall fescue. The hays were harvested, sun dried, and baled into square bales using a conventional square baler. An identifying tag was placed on each bale and the hays were stored in the loft at Smithfield barn, Blacksburg.

The Caucasian bluestem hay was obtained from a previously established stand at Kentland Research Farm, McCoy, VA (37°13’N; 80°35’W). A soil sample had been taken on April 14, 1998. The soil had a pH of 6.8 with medium levels of P (13ppm), K (64 ppm), and Ca (540 ppm) and very high levels of Mg (120 ppm). On June 17, 1998, the area was fertilized at a rate of 67 kg N/ha. The bluestem was cut in the early reproductive stage at a height of 20.3 cm with a sickle bar on July 7, 1998. Rain was received that day and the next day. The hay was tettered on July 9, baled on July 10, and transported to the barn for storage. The ‘Quickstand’ bermudagrass hay was obtained from a previously established stand at the Southwest Virginia

Agricultural Research and Extension Center, Glade Spring (36°47’N; 81°46’W). On March 17, 1998, a soil sample had been taken. The soil had a pH of 6.3 and high levels of P (49 ppm), medium levels of K (84 ppm) and Ca (648 ppm), and very high levels of Mg (120 ppm). The bermudagrass was cut in an early reproductive stage on July 27, 1998, with a mower conditioner. The hay was tettered on the following day. On July 29, 1998, the hay was baled and transported to the barn for storage.

The orchardgrass hay was obtained from a previously established stand at the Virginia Tech Dairy Center, Blacksburg (37°13’N; 80°24’W). A soil sample had been taken on April 30, 1997. At that time, the soil pH was 6.4. High levels of P (27 ppm), K (90 ppm), and Ca (924 ppm) and very high levels of Mg (120 ppm) were reported. In March 1998, the area was fertilized at a rate of 67 kg N/ha. The orchardgrass was cut in the vegetative stage with a mower conditioner on July 20, 1998, baled, and stored at the Virginia Tech Beef Center on July 21, 1998. The hay was stored at Smithfield Barn with the other hays on October 12, 1998. The low-endophyte tall fescue hay was obtained from a previously established stand of ‘Phytar’ fescue at Kentland Research Farm. It was harvested in a vegetative stage on July 31, 1998, using a mower conditioner. On August 1, 1998, the weeds were removed by hand and the hay was tettered. On August 2, 1998, the hay was baled and transported to Smithfield Barn for storage.

Prior to the beginning of the metabolism trial, the hays were ground separately in a hammermill to pass a 38.1-mm mesh screen. They were allowed to mix for 10 minutes in a batch mixer and then placed in previously labeled sacks according to hay type. The sacks were stored in a room at Smithfield Barn and transported to the Metabolism Barn (temperature controlled) as needed.

The lambs were castrated and vaccinated for *Clostridium perfringens* types C and D and tetanus 42 d prior to entering the metabolism barn. Post-castration and before entering the metabolism barn, the lambs were maintained in a dry lot with free access to water. They received .91 kg per head per day of a high roughage diet containing 40.5% ground corn, 50.4% grass hay, 3.5% soybean meal, 5.0% molasses, and .6% trace mineralized salt. Health was closely monitored and any lambs showing signs of sickness received immediate veterinary attention. On October 23, 1998 and again 6 d after they were placed in the metabolism stalls, the lambs were treated with Ivomec® (1 mL/50 kg BW, s.c.; MSD, Division of Merck and Co., Inc. Rahway, New Jersey) for internal parasites. Two days prior to entering the metabolism barn, all lambs received 1,000,000 I.U. of vitamin A and 150,000 I.U. of vitamin D. The lambs were placed in the metabolism stalls on October 28, 1998. The stalls are similar to those described by Briggs and Gallup (1949), designed for separate collection of feces and urine.

The metabolism trial consisted of 10 d adaptation, 5 d transition, 10 d preliminary and 10 d collection periods. Each lamb was fed 700 g of feed and 10 g of trace mineralized salt daily in equal portions at 12 h intervals at 0800 and 2000 h. Water was provided throughout the trial except during the two 2 h feeding periods. Samples of each hay were collected beginning 2 d prior to the start of the trial until 2 d prior to the end of the trial. At the end of the trial, the feed samples for every 2 d were composited and subsampled, for each hay. The feed samples were ground to pass a 1 mm-mesh screen in a Wiley mill (Thomas Wiley, Laboratory Mill Model 4, Arthur H. Thomas Co. Philadelphia, PA.) for chemical analysis. Refusals were weighed at the end of each feeding. They were fed back to the individual lambs at the following feeding in addition to the allotted diet. When refusals reached approximately 250 g, they were removed and stored in plastic bags. At the end of the trial, all refusals for each lamb were composited, subsampled, and ground to pass a 1 mm-mesh screen in a Wiley mill for chemical analysis.

Feces were collected daily in metal pans. At the time of collection, the feces were weighed and a 20% representative sample was taken and dried for 48 h in a forced-draft oven maintained at 60°C. The daily dried subsamples were weighed upon removal from the forced draft oven and stored in plastic bags. At the end of the trial, the dried feces were composited and subsampled and ground to pass a 1 mm-mesh screen in a Wiley mill.

Urine was collected in 4 L plastic jugs containing 15 mL of 1:1 (w:w) concentrated H_2SO_4 and H_2O plus approximately 500 mL of H_2O. Urine was collected once daily and diluted to a fixed weight (5000 g) with H_2O. A 2% aliquot (100 mL) was taken for each lamb and placed in a 1 L bottle and refrigerated. At the end of the trial, urine samples were subsampled and kept frozen for N analysis.

At the end of the trial, ruminal fluid samples were collected 2 h post-feeding using a stomach tube and a vacuum pump. Ruminal fluid was strained through four layers of cheesecloth and the pH was measured immediately using a portable pH meter (Accumet® Mini pH Meter, Model 640A, Fisher Scientific Company). Samples (5 mL each) for VFA and NH_3N determination were collected in 15 mL tubes containing 1mL of 25% metaphosphoric acid or one drop of sulfuric acid, respectively. Ruminal NH_3N was determined by the method described by Beecher and Whitten (1970). The analyses of VFA were performed by gas chromatography (Varian Vista 6000 gas Chromatograph, column packed with 10% SP-1200 /10% H_3PO_4 on 80/100 chromosorb WAW). The detector, column, and inlet temperatures were 175, 125, and 180°C, respectively. Sample VFA concentrations were determined by integration, using a VFA standard containing acetic (51.66 μmol/mL), propionic (30.63 μmol/mL), butyric (10.4

μmol/mL), valeric (5.18 μmol/mL), isobutyric (4.96 μmol/mL), and isovaleric (4.95 μmol/mL) acids.

Blood was drawn by jugular venipuncture from all wethers on the final day of the collection period 6 h post-feeding and centrifuged at 600 x g for 15 min and serum was separated. Urea N in serum was determined by an Autoanalyzer (Beckman CX®5, Beckman Instruments, Inc., Brea, CA.), using BUN (Rate) reagent, Sigma Diagnostic, St. Louis, MO.

Feed, feces and refusals were analyzed for DM and ash (AOAC, 1990), NDF (Van Soest and Wine, 1967), ADF (Van Soest, 1963), cellulose (Van Soest and Wine, 1968), and lignin (Goering and Van Soest, 1970). Feed, fecal, refusal and urinary N were determined by kjeldahl method (AOAC, 1990).

For mineral analyses, the feeds were wet ashed with a mixture of 2:1 (vol:vol) HNO_3:$HclO_4$ (Muchovej et al., 1986). Feeds were analyzed for Ca, Mg, K, Cu and Zn with an atomic absorption Spectrophotometer (Perkin Elmer 5100 PC, Norwalk CT.). Phosphorus was analyzed using the colorimetric method of Fiske and Subbarow (1925).

Statistical Analysis

The data were treated by analysis of variance using the JMP® (JMP, 1996) procedure for a completely randomized block design. Contrasts were made between and within warm- and cool-season varieties. Contrasts to test the least squares mean were: 1) bermudagrass and caucasian bluestem vs. tall fescue and orchardgrass, 2) bermudagrass vs. bluestem, and 3) fescue vs. orchardgrass.

RESULTS AND DISCUSSION

Chemical Composition

The chemical composition of bermudagrass, bluestem, fescue and orchardgrass are presented in Table 1. There were no significant differences between warm- and cool-season grasses in CP content. The level of CP in bermudagrass was higher ($P < .001$) than in bluestem. The CP of bermudagrass forage averaged 14.4%, DM basis. Values obtained by Baker (1993) for 'Quickstand' bermudagrass averaged 10.9%, DM basis, during the grazing season, from May 31 to September 18. In that experiment, the CP value of the bermudagrass harvested in August was 14.7%, DM basis. Hill et al. (1993) reported average CP of 14.0%, DM basis, over 3 yr for 'Tifton 78' and 'Tifton 85' bermudagrass.

The CP for Caucasian bluestem averaged 7.1%, DM basis, similar to the value reported by Crozier et al. (1997). Vona et al. (1984) reported a higher level of 9.1% CP, DM basis, for big bluestem. A lower value of 4.0% CP, DM basis, was obtained by Pacheco et al. (1983) for 'Kleberg' bluestem. Dabo et al. (1988) found CP content differed between plant parts. The CP values were 9.5, 7.1 and 4.7%, DM basis, for leaf, whole plant and stem samples, respectively. The CP content of esophageal samples (6.94%, DM basis) was significantly higher than the CP content of hand-clipped samples (4.30%, DM basis) of mixed bluestem pastures, suggesting selective grazing occurred (Rao et al., 1973).

The CP content of fescue was greater ($P < .001$) than for orchardgrass. Tall fescue forage averaged 12.3% CP, DM basis, which is in agreement with other studies (Brown et al., 1963; Pendlum et al., 1980; Fritz and Collins, 1981; Crozier et al., 1997). Bagley et al. (1983) recorded a lower CP value of 10.3%, DM basis, for tall fescue harvested August 1. The CP of

Table 1. Chemical Composition of Different Kinds of Hay

Component	Kind of hay				SE
	Bermuda-grass	Bluestem	Fescue	Orchard-grass	
	--------------------------------%-------------------------------				
Dry matter	90.9	90.7	90.7	91.0	.11
Composition of dry matter					
Crude protein [ab]	14.4	7.1	12.3	11.8	.15
NDF [abcd]	69.3	78.7	58.0	62.5	.57
ADF [abef]	34.9	50.9	32.2	37.1	.34
Cellulose [abf]	29.1	40.8	30.0	30.6	.41
Hemicellulose [ad]	34.4	27.8	25.8	25.4	.55
Lignin [bg]	2.6	5.1	2.2	3.0	.31
Ash [abd]	7.0	4.5	8.0	9.5	.11

[a] Bermudagrass is different ($P < .001$) from bluestem.
[b] Fescue is different ($P < .001$) from orchardgrass.
[c] Neutral detergent fiber.
[d] Bermudagrass and bluestem are different ($P < .001$) from fescue and orchardgrass.
[e] Acid detergent fiber.
[f] Bermudagrass and bluestem are different ($P < .01$) from fescue and orchardgrass.
[g] Bermudagrass is different ($P < .01$) from bluestem.

orchardgrass was 11.8%, DM basis. Brake et al. (1989) reported a CP value of 9.6%, DM basis, for orchardgrass harvested in the early heading stage. This is in contrast to values obtained by Galloway et al. (1993) who also harvested orchardgrass at early anthesis. They recorded a CP value of 15%, DM basis. Lagasse et al. (1990) reported the CP of orchardgrass harvested in the vegetative regrowth stage was 16.5%, DM basis. The higher CP value reported in that experiment suggests the forage was grown in the presence of higher soil N. Panditharatne et al. (1986) found CP levels increased linearly in response to increasing levels of N fertilization.

Neutral detergent fiber content of the warm-season grasses was higher ($P < .001$) than the NDF content of the cool-season grasses. The level of NDF was higher ($P < .001$) in bluestem than in bermudagrass. The NDF of bermudagrass was 69.3%, DM basis, similar to values obtained by Hill et al. (1993). However, NDF values of 78.9, 75.0, 75.2 and 76.8%, DM basis, have been reported by Brake et al. (1989), Lagasse et al. (1990), Baker (1993) and Galloway et al. (1993), respectively. The lower NDF values in this experiment could indicate the hay was harvested at an earlier stage of maturity than in other experiments. The NDF of bluestem in the present study was 78.7%, DM basis. Crozier et al. (1997) recorded a lower NDF of 73.0% for Caucasian bluestem, but similar NDF values were reported for ‘Kleberg’ bluestem by Pacheco et al. (1983) and for big bluestem by Vona et al. (1984). Dabo et al. (1988) obtained a similar NDF content for a mixture of Old World bluestem varieties.

Orchardgrass had a higher ($P < .001$) NDF than fescue. Tall fescue forage averaged 58% NDF, DM basis. Pendlum et al. (1980) recorded an NDF value of 64.3%, DM basis, for tall fescue harvested in the vegetative regrowth stage. Crozier et al. (1997) obtained an NDF value of 72.0%, DM basis, for tall fescue harvested in early June. Fritz and Collins (1991) reported a higher season-long NDF value of 63.9%, DM basis. In the present study, NDF of orchardgrass forage was 62.5%, DM basis. Brake et al. (1989) reported NDF of orchardgrass harvested in the early heading stage was 77.5%, DM basis. This is in contrast to the NDF value of 64.5%, DM basis, recorded by Galloway et al. (1993) at early anthesis. Their value is lower than the value reported by Brake et al. (1989) and similar to the value obtained in this experiment.

Acid detergent fiber was higher ($P < .01$) in warm-season than in cool-season grasses due mainly to the high value (50.9%, DM basis) for bluestem. The ADF content of bluestem was higher ($P < .001$) than bermudagrass. The ADF content of bermudagrass of 34.9%, DM basis, is in agreement with ADF values of 37.3 and 34.6%, DM basis, reported by Lagasse et al. (1990) and Galloway et al. (1993), respectively, for bermudagrass harvested in the vegetative growth stage. A higher ADF of 44%, DM basis, was recorded by Brake et al. (1989) for bermudagrass in the vegetative growth stage.

The ADF of bluestem of 50.9%, DM basis, is similar to values obtained by Pacheco et al. (1983) for bluestem and for big bluestem by Vona et al. (1984). Crozier et al. (1997) reported an ADF value of 39%, DM basis, for Caucasian bluestem. This lower value suggests the forage in that experiment was harvested at an earlier stage of maturity. Dabo et al. (1988) found ADF concentrations increased with stage of maturity for Old World bluestem grasses.

The ADF concentration in orchardgrass was higher ($P < .001$) than in fescue. Tall fescue had an average ADF concentration of 32.2%, DM basis. Bagley et al. (1983) reported an average ADF of 37.3%, DM basis, for tall fescue harvested in May, August, November and March. Pendlum et al. (1980) obtained an average ADF concentration of 34.9%, DM basis, for tall fescue harvested at the early vegetative, dough and regrowth vegetative stages of maturity. In that experiment, the ADF concentration of tall fescue harvested in the regrowth vegetative stage of maturity was 33.1%, DM basis. Crozier et al. (1997) found tall fescue harvested in early

June had an ADF concentration of 40%, DM basis. In the present study the ADF of orchardgrass was 37.1%, DM basis. Brake et al. (1989) reported the ADF of orchardgrass harvested in the early heading stage was 45.9%, DM basis. Galloway et al. (1993) reported ADF of 36.5%, DM basis, for orchardgrass harvested at early anthesis. Lagasse et al. (1990) found the ADF of orchardgrass harvested in the regrowth vegetative stage of maturity was 34.4%, DM basis.

The warm-season grasses were higher ($P < .01$) than the cool-season grasses in cellulose content. The level of cellulose was higher ($P < .001$) in bluestem forage than in bermudagrass forage (29.1 *vs*. 40.8%, DM basis). Lagasse et al. (1990) and Galloway et al. (1993) obtained values of 29.0 and 27.9% cellulose, DM basis, respectively, for long-stemmed bermudagrass hay. A higher cellulose value of 34.2%, DM basis, was recorded by Brake et al. (1989) for common bermudagrass hay. A cellulose concentration of 33%, DM basis, was reported by Crozier et al. (1997) for Caucasian bluestem. Pacheco et al. (1983) found the cellulose content of ‘Kleberg’ bluestem was 35.2%, DM basis.

The level of cellulose was similar in orchardgrass and in fescue (30.0 *vs*. 30.6%, DM basis). The value for fescue agrees with values reported by others. Tall fescue cellulose concentrations obtained by Brown et al. (1963), Fritz and Collins (1991) and Crozier et al. (1997) were 30.2, 28.7, and 33%, DM basis, respectively.

Reid et al. (1966) found the average cellulose content of orchardgrass across treatments with different levels and types of N fertilizer was 33.8%, DM basis. They found no effect of level or type of N fertilizer on cellulose concentration. In contrast, Panditharatne et al. (1986) found the average cellulose concentration across treatments from 0 to 448 kg N/ha was 29.2%, DM basis, and reported a quadratic effect of increasing levels of N fertilization on cellulose content. Lagasse et al. (1990) and Galloway et al. (1993) obtained cellulose values of 27.2 and 29.9%, DM basis, respectively, for orchardgrass hay.

The level of hemicellulose was higher ($P < .001$) in the warm-season grasses than in the cool-season grasses. Within the warm-season grasses, hemicellulose was higher ($P < .001$) in bermudagrass than bluestem. In the present study the level of hemicellulose in bermudagrass was 34.4%, DM basis. A similar hemicellulose value of 35%, DM basis, was obtained by Brake et al. (1989). Lagasse et al. (1990) and Galloway et al. (1993) reported higher values of 38.1 and 42.2%, DM basis, respectively, for long-stemmed bermudagrass hay. The level of hemicellulose in bluestem in the present study was 27.8%, DM basis. A higher hemicellulose value of 34%, DM basis, was recorded by Crozier et al. (1997) for Caucasian bluestem. A lower hemicellulose value of 24.7%, DM basis, was obtained by Pacheco et al. (1983) for ‘Kleberg’ bluestem.

The level of hemicellulose was similar between fescue and orchardgrass (25.8 *vs*. 25.4%, DM basis). Bagley et al. (1983) reported the average hemicellulose content of tall fescue harvested in May, August, November and March was 28.1%, DM basis. Values of 32.5 and 34%, DM basis, were recorded by Fritz and Collins (1991) and Crozier et al. (1997), respectively, for first cutting tall fescue. Bagley et al. (1983) reported the hemicellulose concentration of tall fescue harvested in August was 25%, DM basis. Brake et al. (1989), Lagasse et al. (1990) and Galloway et al. (1993) obtained hemicellulose values of 31.6, 29.7 and 28%, DM basis, respectively, for orchardgrass hay cut at early anthesis. Panditharatne et al. (1986) found level of N and S fertilization affected hemicellulose concentration of orchardgrass with an average hemicellulose concentration across treatments of 29.7%, DM basis.

Lignin concentration was similar between warm- and cool-season grasses. The level of lignin in bluestem was higher ($P < .01$) than in bermudagrass (2.6 *vs*. 5.1%, DM basis). Lignin concentrations of 8.7, 6.7 and 5.5%, DM basis, were obtained by Brake et al. (1989), Lagasse et al. (1990) and Galloway et al. (1993), respectively, for long-stemmed bermudagrass hay. Crozier et al. (1997) recorded a lignin concentration of 6.7%, DM basis, for Caucasian bluestem. Dabo et al. (1988) reported an average lignin content of 5.6%, DM basis, for a mixture of Old World bluestem varieties. A higher value of 7.4%, DM basis, was recorded for big bluestem by Vona et al. (1984). Pacheco et al. (1983) also obtained a higher lignin value of 8.0%, DM basis, for 'Kleberg' bluestem.

The lignin content of orchardgrass was higher (P < .001) than that of tall fescue (3.0 *vs*. 2.2%, DM basis). Brown et al. (1963) reported a lignin concentration of 7.6%, DM basis, for fall grown tall fescue forage. Pendlum et al. (1980) found the lignin content of fescue in the vegetative regrowth stage was 3.3%, DM basis. Bagley et al. (1983) reported the average lignin content of tall fescue harvested in May, August, November and March was 7.3%, DM basis. A value of 3.2% lignin, DM basis, was recorded by Fritz and Collins for tall fescue harvested in May, July and September 1986 and May, June and August 1987. Higher values of 6.7, 6.2 and 5.3%, DM basis, were reported by Brake et al. (1989), Lagasse et al. (1990) and Galloway et al. (1993), respectively, for orchardgrass harvested at early anthesis.

The ash content of the cool-season grasses was higher (P < .001) than the ash content of the warm-season grasses. The level of ash in bermudagrass was higher (P < .001) than the level of ash in bluestem (7.0 *vs*. 4.5%, DM basis). Brake et al. (1989), Lagasse et al. (1990) and Galloway et al. (1993) obtained levels of 6, 7.3 and 7.1% ash, DM basis, respectively, for long-stemmed bermudagrass hay. Pacheco et al. (1983) reported an ash content of 'Kleberg' bluestem of 10.9%, DM basis.

There was a higher (P < .001) amount of ash in orchardgrass than in fescue (9.5 *vs*. 8.0%, DM basis). Pendlum et al. (1980) found the ash content of tall fescue in the vegetative regrowth stage of maturity was 6.9%, DM basis. Bagley et al. (1983) reported the average ash content of tall fescue harvested in May, August, November and March was 8.9%, DM basis. Brake et al. (1989), Lagasse et al. (1990) and Galloway et al. (1993) reported the ash content of orchardgrass harvested at early anthesis was 6.9, 8.1 and 9.4%, DM basis, respectively.

The mineral composition of the forages is given in Table 2. There was a trend (P < .10) for the cool-season grasses to be higher in Ca than the warm-season grasses. Bermudagrass had a higher (P < .001) percentage of Ca than bluestem (.46 *vs.* .20%, DM basis). The value for bermudagrass is in agreement with values of .36 and .40% Ca, DM basis, reported by Ammerman et al. (1982) and Ott and Asquith (1995) for Coastal bermudagrass hay.

The level of Ca in the bluestem hay was lower than reported by Crozier et al. (1997). Vona et al. (1984) and Puoli et al. (1983) found Ca levels of .32 and .25%, DM basis, respectively, for big bluestem. Pacheco et al. (1983) obtained a higher Ca level of .51%, DM basis, for ‘Kleberg’ bluestem. In the present study, Ca level in bluestem was sufficient to meet the nutrient requirements for ewes at maintenance but not for growing lambs (NRC, 1985), lactating or gestating cows, or growing steers (NRC, 1996).

The level of Ca was higher (P < .001) in orchardgrass than in fescue (.48 *vs*. .36%, DM basis). A lower level of .26% Ca, DM basis, was reported by Crozier et al. (1997) for first-cutting tall fescue. This is in contrast to values of .41 and .42% Ca, DM basis, obtained by Pendlum et al. (1980) and Vona et al. (1984), respectively, for first-cutting tall fescue. Pendlum et al. (1980) found the Ca concentration of tall fescue harvested in the vegetative regrowth

Table 2. Mineral Composition of Different Kinds of Hay

Mineral element	Kind of hay				SE
	Bermuda-grass	Bluestem	Fescue	Orchard-grass	
Calcium, %[abc]	.46	.20	.36	.48	.009
Magnesium, %[bcd]	.27	.18	.33	.29	.005
Phosporus, %[bce]	.36	.19	.33	.53	.003
Potassium, %[bdf]	2.05	1.44	2.65	2.79	.040
Copper, ppm[bf]	8.33	5.23	6.95	7.77	.220
Zinc, ppm[bc]	23.51	15.05	16.43	27.35	.580

[a] Bermudagrass and bluestem are different ($P < .10$) from fescue and orchardgrass.
[b] Bermudagrass is different ($P < .001$) from bluestem.
[c] Fescue is different ($P < .001$) from orchardgrass.
[d] Bermudagrass and bluestem are different ($P < .001$) from fescue and orchardgrass.
[e] Bermudagrass and bluestem are different ($P < .01$) from fescue and orchardgrass.
[f] Fescue is different ($P < .10$) from orchardgrass.

stage of maturity was .47%, DM basis. Panditharatne et al. (1986) reported a Ca concentration of .48%, DM basis, for orchardgrass with no N or S fertilization. The level of Ca in the tall fescue used in the present study was deficient for growing lambs, but sufficient for ewes at maintenance (NRC, 1985), cows in lactation or gestation, and growing steers (NRC, 1996). The level of Ca in the other forages was sufficient to meet the requirements for these classes of ruminants.

The level of Mg in the cool-season grasses was higher ($P < .001$) than the warm-season grasses. Bermudagrass was higher ($P < .001$) in Mg than bluestem (.27 *vs*. .18%, DM basis). A level of .16%, DM basis, was reported by Ammerman et al. (1982) for Coastal bermudagrass. Crozier et al. (1997) recorded a concentration of .18% Mg, DM basis, in Caucasian bluestem. Vona et al. (1984) and Puoli et al. (1991) obtained similar values of .18 and .16% Mg, DM basis, respectively, for big bluestem.

The level of Mg in fescue was higher ($P < .001$) than the level of Mg in orchardgrass (.33 vs. .29%, DM basis). A value of .33% Mg, DM basis, was reported by Pendlum et al. (1980) for tall fescue harvested in the regrowth vegetative stage of maturity. Pendlum et al (1980), Vona et al. (1984) and Crozier et al. (1997) obtained lower values of .27, .18 and .25% Mg, DM basis, respectively, for first-cutting tall fescue. Reid et al. (1966) and Panditharatne et al. (1986) reported Mg levels of .17 and .21%, DM basis, respectively, for orchardgrass with no N or S fertilization.

The level of Mg found in the caucasian bluestem used in the present study was sufficient to meet the requirements of growing lambs, ewes at maintenance, (NRC, 1985), gestating cows, and growing steers, but not sufficient for lactating cows (NRC, 1996). The Mg levels in the other forages were sufficient to meet the requirements of these classes of animals.

The level of P in the cool-season grasses was higher ($P < .01$) than in the warm-season grasses. The level of P in bermudagrass was higher ($P < .001$) than in bluestem (.36 *vs*. .19%, DM basis). A level of .25% P, DM basis, was recorded by Ott and Asquith (1995) for Coastal bermudagrass hay. Crozier et al. (1997) reported the level of P in Caucasian bluestem was .14%, DM basis. Levels of .19 and .17% P, DM basis, were reported by Vona et al. (1984) and Puoli et al. (1991), respectively, for big bluestem. A much lower P value of .09%, DM basis, was obtained by Pacheco et al. (1983) for 'Kleberg' bluestem.

The concentration of P was higher ($P < .001$) in orchardgrass than in fescue (.53 *vs*. .33%, DM basis). Pendlum et al. (1980) reported .33% P, DM basis, for fescue in the regrowth vegetative stage of maturity. Pendlum et al. (1980), Vona et al. (1984) and Crozier et al. (1997) obtained values of .38, .27 and .28% P, DM basis, respectively. Reid et al. (1966) reported second-cutting orchardgrass with no N fertilization had a P content of .57%, DM basis.

In the present study, the level of P in bluestem was sufficient for growing steers and lactating or gestating cows (NRC, 1996), but deficient for both growing lambs and ewes at maintenance (NRC, 1985). The level of P in the other forages was sufficient to meet the minimum requirement for these classes of ruminants.

The level of K in cool-season forages was higher ($P < .001$) than the level of K in warm-season forages. Bermudagrass had a higher ($P < .001$) concentration of K than bluestem (2.05 *vs*. 1.44%, DM basis). The value of 2.05%, DM basis, is higher than the 1.12% K, DM basis, recorded by Ammerman et al. (1982) for Coastal bermudagrass. Crozier et al. (1997) reported Caucasian bluestem had a K content of 1.8%, DM basis. A value of 1.37% K, DM basis, was obtained by both Vona et al. (1984) and Puoli et al. (1991) for big bluestem.

Orchardgrass tended to be higher ($P < .10$) in K than fescue (2.79 *vs.* 2.65%, DM basis). A value of 1.99% K, DM basis, was recorded by Pendlum et al. (1980) for fescue in the regrowth vegetative stage of maturity. Values of 2.8, 2.6 and 2.3% K, DM basis, were reported by Pendlum et al. (1980), Vona et al. (1984) and Crozier et al. (1997), respectively, for first-cutting tall fescue. Values of 3.24 and 3.78% K, DM basis, were obtained by Reid et al. (1966) for first- and second-cutting orchardgrass, respectively, with no applied N fertilizer. In the present study, all forages contained levels of K sufficient for meeting the minimum requirement for all classes of sheep (NRC, 1985) and cattle (NRC, 1996).

Copper content was similar between warm- and cool-season grasses. Bermudagrass had a higher ($P < .001$) level of Cu than bluestem (8.33 *vs*. 5.23 ppm, DM basis). Values of 4.8 and 5.7 ppm, DM basis, were recorded by Ammerman et al. (1982) and Ott and Asquith (1995), respectively, for Coastal bermudagrass. Crozier et al. (1997) reported Cu content in Caucasian bluestem was 4 ppm, DM basis, and Puoli et al. (1991) reported Cu content of big bluestem was 5 ppm, DM basis.

There was a trend ($P < .10$) for Cu levels to be higher in orchardgrass than in fescue (7.77 *vs*. 6.95 ppm, DM basis). Pendlum et al. (1980) reported a Cu level of 3.67 ppm, DM basis, for tall fescue in the regrowth vegetative stage of maturity. Pendlum et al. (1980) and Crozier et al. (1997) obtained similar values of 5.33 and 5 ppm, DM basis, respectively, for first-cutting tall fescue. Values of 17 and 15 ppm Cu, DM basis, were recorded by Reid et al. (1966) for first- and second-cutting orchardgrass, respectively. In the present study, Cu levels of all the grasses were adequate for ewes at maintenance and growing lambs (NRC, 1996), but all grasses were to low in Cu concentration for meeting the requirements of any class of cattle (NRC, 1996).

The level of Zn was not significantly different between warm- and cool-season forages. Bermudagrass Zn content was higher ($P < .001$) than bluestem Zn content (23.51 *vs*. 15.05 ppm, DM basis). Ott and Asquith (1995) reported a Zn concentration of 28.5 ppm, DM basis, for Coastal bermudagrass. A value of 56 ppm Zn, DM basis, was obtained by Crozier et al. (1997) for Caucasian bluestem. Puoli et al. (1991) reported a value similar to the value found in this experiment for big bluestem. A value of 36.5 ppm, DM basis, was recorded by Vona et al. (1984) for big bluestem.

The level of Zn was higher ($P < .001$) in orchardgrass than in fescue (27.35 *vs*. 16.43 ppm, DM basis). A value of 13.9 ppm Zn, DM basis, was obtained by Pendlum et al. (1980) for tall fescue in the vegetative regrowth stage of maturity. Pendlum et al. (1980), Vona et al. (1984) and Crozier et al. (1997) recorded levels of 23.8, 23.5 and 17 ppm Zn, DM basis, respectively, for first-cutting tall fescue. Reid et al. (1966) reported values of 25 and 32 ppm Zn, DM basis, for first- and second-cutting orchardgrass, respectively. In the present study, all forages were either deficient or borderline deficient for meeting the Zn requirements of all classes of sheep (NRC, 1985) and cattle (NRC, 1996).

Martz et al. (1993) reported Ca, P, K, and Na were higher for cool-season pastures than warm-season pastures. The cattle grazing cool-season forages in that experiment were supplied nearly twice the level of these minerals as the cattle grazing warm-season pastures. Martz et al. (1994) found the level of Cu tended to be lower in big bluestem than in the cool-season pasture species.

Apparent Digestibility

The apparent digestibility of DM ranged from 53.1 to 62.9% among the diets (Table 3). The warm-season forages were lower ($P < .001$) in DM digestibility than the cool-season forages. Reid et al. (1988b) reported results in agreement with these. Average DM digestibility of the 36 cool-season grasses fed in that experiment was 61.7%, whereas the DM digestibility of 57 warm-season grasses was 54.6%. In the present study, the DM digestibility of tall fescue averaged 62.9%, compared to 58.3% for orchardgrass ($P < .01$). Brown et al. (1963) and Pendlum et al. (1980) obtained values of 63.4 and 64.3% for fescue. Bagley et al. (1983) recorded a DM digestibility of 67.5% for tall fescue harvested in May. They reported highest values for fescue harvested in May and lowest values for forage harvested in February. Reid et al. (1966) reported DM digestibility of orchardgrass fertilized with 0 to 448 kg of urea per hectare ranged from 53.2 to 68.8%. Panditharatne et al. (1986) found DM digestibility of orchardgrass increased linearly with fertilization of N and S. Applications of 448 kg N/ha and 34 kg S/ha increased the DM digestibility from 58.0 to 61.1%.

Apparent digestibility of CP tended to be higher ($P < .10$) for lambs fed cool-season forages compared to lambs fed warm-season forages. For lambs fed warm-season grasses, the digestibility of CP was higher ($P < .001$) for those fed bermudagrass than for those fed bluestem (68.0 *vs*. 48.5%). Lagasse et al. (1990) and Galloway et al. (1993) reported N digestibility was higher for orchardgrass than for bermudagrass hays. Long-stemmed bermudagrass hays were used in these two experiments. In the present study, the value for bermudagrass was numerically higher than for orchardgrass (68.0 *vs*. 61.4%). The shorter growth habit of 'Quickstand' bermudagrass would result in a forage that consisted of a higher

Table 3. Apparent Digestibility of Different Kinds of Hay

	Kind of hay				
Component	Bermuda-grass	Bluestem	Fescue	Orchard-grass	SE
	----------%----------				
Dry matter[ab]	53.1	54.1	62.9	58.2	.55
Crude protein[bcd]	68.0	48.5	68.0	61.4	.46
Organic matter	49.7	50.4	50.3	56.1	3.38
NDF[defg]	52.2	61.1	60.5	64.8	.73
ADF[dghi]	46.2	54.4	51.7	55.9	.78
Cellulose[gij]	50.5	60.7	58.6	66.5	1.76
Hemicellulose[dfg]	58.3	73.5	71.5	77.7	.96

[a] Bermudagrass and bluestem are different (P < .001) from fescue and orchardgrass.
[b] Fescue is different (P < .001) from orchardgrass.
[c] Bermudagrass and bluestem are different (P < .10) from fescue and orchardgrass.
[d] Bermudagrass is different (P < .001) from bluestem.
[e] Neutral detergent fiber.
[f] Bermudagrass and bluestem are different (P < .01) from fescue and orchardgrass.
[g] Fescue is different (P < .01) from orchardgrass.
[h] Acid detergent fiber.
[i] Bermudagrass and bluestem are different (P < .05) from fescue and orchardgrass.
[j] Bermudagrass is different (P < .01) from bluestem.

percentage of leaf and a lower percentage of stem which may account for the CP digestibility of 'Quickstand' bermudagrass.

The average CP digestibility of tall fescue was higher ($P < .001$) than for orchardgrass (68.0 *vs*. 61.4%). Values of 62.9, 59.2 and 56.2% CP digestibility were determined for tall fescue forage by Brown et al. (1963), Pendlum et al. (1980) and Bagley et al. (1983), respectively. Crude protein digestibilities of 62.2 and 58.9% were obtained by Lagasse et al. (1990) and Galloway et al. (1993), respectively. Reid et al. (1966) and Panditharatne et al. (1986) have shown a linear relationship between increasing N fertilization rates and CP digestibility of orchardgrass. In the present study, although apparent digestibility of CP was higher for fescue than for orchardgrass, the forages were harvested at comparable stages of maturity.

There were no significant differences in OM digestibility. The results differ from those reported by Lagasse et al. (1990) and Galloway et al. (1993) in which OM digestibility of orchardgrass was greater than that of bermudagrass. In the present study, lambs fed the cool-season forages had a higher ($P < .01$) NDF digestibility than those fed the warm-season forages, which was due, at least partly, to the lower value for bermudagrass (49.7%). Vona et al. (1984) found tall fescue had a higher NDF digestibility (76.6%) than big bluestem (70%) when fed to cattle, but in the present study values were similar for the two forages. Lagasse et al. (1990) and Galloway et al. (1993) reported NDF digestibility of 68.3% for orchardgrass and 58.1% for bermudagrass.

Lambs fed the cool-season forages had higher ($P < .05$) ADF digestibility than those fed the warm-season forages. When compared to lambs fed bermudagrass, lambs fed bluestem had higher ($P < .001$) NDF and ADF digestibilities. The higher NDF and ADF digestibilities of bluestem could be accounted for, at least partially, by the selective feeding habits of the lambs in which stems were mainly refused.

Digestibility of NDF and ADF of tall fescue was lower (P < .01) than for orchardgrass (60.5 and 51.7 *vs*. 64.8 and 55.9%, respectively). Values of 66.1 and 61.4% for NDF and ADF digestibility, respectively, were recorded by Pendlum et al. (1980) for tall fescue harvested in the regrowth vegetative stage of maturity. Bagley et al. (1983) reported ADF digestibility of July harvested tall fescue was 52.4%. Lagasse et al. (1990) and Galloway et al. (1993) reported NDF digestibility of orchardgrass was 67.8 and 68.5%, respectively. Panditharatne et al. (1986) found an average NDF digestibility of 59.6% for orchardgrass hay.

Cellulose and hemicellulose digestibilities were higher (P < .05 and .01) for lambs fed cool-season forages than for those consuming warm-season forages. Bluestem-fed lambs had higher (P < .01) cellulose (60.7 *vs*. 50.5) and hemicellulose (73.5 *vs*. 58.3) digestibillity, when compared to bermudagrass-fed lambs. Cellulose and hemicellulose digestibility was lower (P < .01) for tall fescue than for orchardgrass (58.6 and 71.5 *vs*. 66.5 and 77.7%, respectively). Bagley et al. (1983) found an average cellulose digestibility of 62.2%, and an average hemicellulose digestibility of 64.6% for tall fescue harvested in May, July, November and February. Panditharatne et al. (1986) reported an average cellulose digestibility of 59.8%.

Nitrogen balance

Values for nitrogen balance by the sheep fed different kinds of hay are presented in Table 4. Fecal N excretion was lower (P < .001) for lambs fed bluestem than bermudagrass, a reflection of the CP in the hay. The N excretion in feces was higher (P < .001) for lambs fed orchardgrass than for those fed fescue hay, although N intake was lower (P < .001) for lambs fed

Table 4. Nitrogen Balance By Sheep Fed Different Kinds of Hay

Item	Kind of hay				SE
	Bermudagrass	Bluestem	Fescue	Orchardgrass	
Intake, g/d[ab]	14.93	7.35	12.70	12.17	.01
Excretion, g/d					
Fecal[ab]	4.78	3.71	4.06	4.67	.06
Urinary[ac]	8.30	2.88	6.64	5.91	.26
Total[a]	13.07	6.58	10.70	10.58	.27
Apparent absorption					
g/d[ab]	10.15	3.64	8.64	7.50	.06
% of intake[abd]	68.02	49.62	68.01	61.65	.49
Retention					
g/d[e]	1.86	.77	2.00	1.59	.27
% of intake	12.44	10.43	15.74	13.03	2.25
% of absorbed	18.23	21.01	23.06	21.20	3.74

[a] Bermudagrass is different (P < .001) bluestem.
[b] Fecue is different (P < .001) from orchardgrass.
[c] Fescue is different (P < .10) from orchardgrass.
[d] Bermudagrass and bluestem are different (P < .10) from fescue and orchardgrass.
[e] Bermudagrass is different (P < .05) from bluestem.

orchardgrass. Urinary N excretion was much higher ($P < .001$) for lambs fed bermudagrass than for those fed bluestem hay. There was a trend for lambs fed fescue to excrete higher ($P < .10$) levels of urinary N than those fed orchardgrass. Urinary excretion of N generally reflected N intake.

There was a trend for lambs fed cool-season forages to absorb a higher ($P < .10$) percentage of the total N intake than those fed warm-season forages. Lambs fed bermudagrass had higher ($P < .001$) N absorption than lambs fed bluestem. Apparent N absorption, when expressed in either g/d or as percent of intake, was higher ($P < .001$) for lambs fed fescue than for those fed orchardgrass.

Expressed as g/d, N retention by lambs fed bermudagrass was higher ($P < .05$) than for those fed bluestem. However, when expressed as percent of intake or percent absorbed, retention values were similar. Expressed as g/d, there was a trend ($P < .10$) for lambs fed fescue to have higher N retention than those fed orchardgrass.   When expressed as percent of intake or percent absorbed, N retention did not differ between the lambs fed fescue and those fed orchardgrass. Lambs in this experiment were limit-fed, which restricted energy intake and growth. Lambs consuming all forages, except fescue, were deficient in the energy for maintenance (NRC, 1985). Therefore, most lambs lost BW (data not shown), although they were in positive N balance.

Blood Urea Nitrogen and Ruminal Ammonia Nitrogen

Blood urea-N (BUN) and ruminal NH_3N did not differ between lambs fed warm-season forages and those fed cool-season forages (Table 5). Both blood urea-N and rumen NH_3N were

Table 5. Blood Urea Nitrogen and Ruminal Ammonia Nitrogen

	Kind of Hay				
Item	Bermuda-grass	Bluestem	Fescue	Orchard-grass	SE
BUN, mg/dl[ab]	15.38	4.33	11.59	10.02	.81
Ruminal ammonia[b] nitrogen, μg/ml	130.25	38.58	80.67	69.80	6.46

[a] Blood urea nitrogen.
[b] Bermudagrass is different ($P < .001$) from bluestem.

Table 6. Volatile Fatty Acids in Ruminal Fluid of Wether Lambs Fed Different Kinds of Hay

Item	Kind of hay: Bermuda-grass	Bluestem	Fescue	Orchard-grass	SE
Total VFA[a] µmol/mL	69.6	64.0	81.4	57.8	5.83
Mol/100mol					
Acetic[bcd]	73.2	78.0	64.1	72.5	.48
Propionic[bde]	18.2	16.1	27.2	19.6	.42
Isobutyric[c]	1.1	.6	.9	.9	.06
Butyric[f]	4.6	4.0	5.5	5.5	.33
Isovaleric[c]	1.2	.7	1.1	1.0	.08
Valeric[fg]	1.8	1.1	.8	.5	.20

[a] Fescue is different ($P < .05$) from orchardgrass.
[b] Bermudagrass and bluestem are different ($P < .001$) from fescue and orchardgrass.
[c] Bermudagrass is different ($P < .001$) from bluestem.
[d] Fescue is different ($P < .001$) from orchardgrass.
[e] Bermudagrass is different ($P < .01$) from bluestem.
[f] Bermudagrass and bluestem are different ($P < .01$) from fescue and orchardgrass.
[g] Fescue is different ($P < .01$) from orchardgrass.

higher ($P < .001$) for lambs fed bermudagrass compared to those fed bluestem. This could be a reflection of the higher ($P < .001$) level of CP in bermudagrass than in bluestem, which provides lambs fed bermudagrass with a higher ($P < .001$) level of N intake than lambs fed bluestem. Preston and Pfander (1963) reported BUN was directly proportional to the level of dietary protein and inversely proportional to the dietary energy level. They suggested BUN was a sensitive indicator of protein adequacy. There were no differences in blood urea-N and ruminal NH_3N for lambs fed fescue compared to those fed orchardgrass.

There were no differences in total VFA for lambs fed warm-season forages, compared to those fed cool-season forages (Table 6). Lambs fed orchardgrass had lower ($P < .05$) total VFA concentration than those fed fescue, perhaps reflecting the difference in DM digestibility. Acetate concentration was higher ($P < .001$) and propionate concentration was lower ($P < .001$) for lambs fed warm-season grasses compared to those fed cool-season grasses. Khorasani et al. (1994) reported a higher propionate and lower acetate concentration in holstein cows fed barley, a more readily degradable starch source, than those fed corn. This suggests that the cool-season grasses contain a higher concentration of more readily degradable carbohydrates than the warm-season grasses. Akin and Burdick (1975) reported leaf blades of tropical grasses had an average of 22 percentage units less of the easily digested tissue (mesophyll and phloem) and 25 percentage units more of the slowly digested tissues (epidermis and parenchymal bundly sheath) than temperate species.

Butyrate concentrations were lower ($P < .01$) and valerate concentrations were higher ($P < .01$) for lambs fed warm-season grasses, compared to those fed cool-season grasses. Lambs fed bluestem had a higher ($P < .001$) concentration of acetate and lower ($P < .01$) concentration of propionate, compared to bermudagrass, perhaps reflecting differences in digestibility.

Isobutyrate and isovalerate concentrations were lower in lambs fed bluestem than lambs fed bermudagrass. Lambs fed fescue had a lower ($P < .001$) concentration of acetate and a higher ($P < .001$) concentration of propionate than those fed orchardgrass. Concentration of valerate was higher ($P < .01$) for lambs fed fescue than for lambs fed orchardgrass.

The results of this study show that the nutritional value of warm-season grasses is lower than that of cool-season grass. However, the warm-season grasses provide an abundance of good quality forage during a time of the year when cool-season forage production is inadequate. Therefore, integration of warm- and cool-season grasses into a grazing management system would provide producers with an excellent strategy for providing good quality forage during spring and summer.

IMPLICATIONS

Cool-season grasses are higher in nutritional value than warm-season grasses. They are lower in fiber and higher in digestibility. Cool-season grasses are also higher in most minerals than warm-season grasses. Within warm-season grasses, bermudagrass is higher in nutritional value than bluestem. Despite the lower quality of warm-season grasses, they produce abundant forage during times when cool-season forage production is less than desirable. Therefore, the abundance of forage available may partially overcome the lower quality of the warm-season grasses, allowing acceptable animal performance during summer months. The integration of warm-season grasses with cool-season forages could potentially allow producers the opportunity to increase stocking rates and thereby increase production per unit of land area.

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