

SUPPLEMENTATION EFFECTS ON EARLY WEANED CALVES GRAZING  
COOL- AND WARM-SEASON GRASSES

By

JOAO MAURICIO BUENO VENDRAMINI

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by

Joao Mauricio Bueno Vendramini

To the memory of my grandfather, Jose Pereira Bueno

For being an inspiration for me and my brothers

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Joao Mauricio Bueno Vendramini

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Chair: Lynn E. Sollenberger  
Cochair: John D. Arthington  
Major Department: Agronomy

Early weaning of their calves increases the likelihood that first calf heifers will rebreed, but there is little information regarding pasture-based feeding programs for the weaned calf. Research was conducted in Gainesville, FL, to evaluate the effect of supplement rates on performance of early weaned (80 d of age) beef calves grazing annual ryegrass (*Lolium multiflorum*)-rye (*Secale cereale*) mixtures from January to April (winter) and Tifton 85 bermudagrass (*Cynodon sp.*) from May to August (summer) 2003 and 2004. Three levels of supplement (10, 15, and 20 g kg<sup>-1</sup> of calf liveweight) were evaluated in a completely randomized design with three replications. The supplement contained 147 and 700 g kg<sup>-1</sup> of crude protein (CP) and total digestible nutrients, respectively. Pastures were rotationally stocked using a variable stocking rate in both seasons with 21- and 14-d regrowth periods for rye-ryegrass and Tifton 85 bermudagrass, respectively. Average daily gain increased linearly during the winter (0.74-0.89 kg) and summer (0.53-0.72 kg) as supplementation rate increased. There was a linear increase in

live weight gain per hectare with increasing supplement rate during the winter (950-1320 kg) and summer (1100-1780 kg). In addition, two plot studies were conducted with the same species used in the grazing trials to evaluate the effect of N fertilization levels and forage regrowth interval on in situ CP fractionation of the forage. Treatments were the factorial combinations of three N rates (0, 40, and 80 kg ha<sup>-1</sup>) and two regrowth intervals, 3- and 6-wk (rye-ryegrass) and 2- and 4-wk (Tifton 85). Increasing N fertilization levels increased rye-ryegrass CP Fraction A (readily degradable) (410-590 g kg<sup>-1</sup>) and decreased linearly CP Fraction B (slowly degradable) (510-360 g kg<sup>-1</sup>) and Fraction C (undegradable) (74-48 g kg<sup>-1</sup>). On Tifton 85, increasing N fertilization increased linearly Fraction B (330-455 g kg<sup>-1</sup>) and decreased linearly Fraction C (283-208 g kg<sup>-1</sup>). In addition, greater proportions of fraction C were observed in forage of 4-wk (280 g kg<sup>-1</sup>) than 2-wk maturity (200 g kg<sup>-1</sup>). Results of these studies indicate that pasture-based feeding systems with modest levels of supplementation (10-15 g kg<sup>-1</sup> of liveweight) are practical options for raising early weaned calves in Florida.

## CHAPTER 1 INTRODUCTION

Grasslands cover ~ 4.5 million ha in Florida, most of which are utilized by beef cattle (*Bos sp.*; Chambliss, 1999). The beef industry is a very important component of Florida's agriculture industry. In 2003, Florida had a total of 950 000 beef cows that accounted for \$348 million of income to Florida farmers and ranchers (Florida Agriculture Statistics, 2004).

The profitability of the Florida cow-calf enterprise is largely dependent on cow productivity. The low nutritive value of Florida's tropical forages in combination with reduced pasture production during winter reduces cow reproductive performance. Low body condition is responsible for lower conception rates and overall cow herd productivity (Arthington, 2002). These effects are most pronounced in young cows and heifers which have higher nutritional demands to support both lactation and growth (Arthington, 2002). Early weaning calves from young cows and first-calf heifers is a management strategy that has potential to address this problem. At early weaning, cows stop lactating and their requirement for total digestible nutrients (TDN) decreases by as much as 49%. As a result they are able to restore body condition rapidly (Arthington, 2002). Bishop and Wettemann (1990), cited by Lusby (1995), reported that 100% of cows with body condition scores > 5 had begun cycling within 25 d after their calves were weaned at 45 d of age compared to only 43% of cows with condition score < 5.

Although the benefits of early weaning, e.g., improving reproduction and reducing nutrient requirements of the cow, have been recognized for many years, producer

adoption of early weaning has been limited by lack of management information about the weaned calves (Lusby, 1995). The major expense in raising these calves is feed cost (Lusby and Donald, 1994). Therefore, low-cost alternatives to high concentrate diets are needed. Forage intake of early weaned calves has not been well documented and varies greatly between the time of early and normal weaning due to increasing development of rumen function. The quantity of concentrate supplementation required during this period for calves on pasture is likewise not well defined. Muehlmann et al. (1997) studied different species of tropical pastures as the sole source of feed to early weaned calves. Daily gains were low, averaging  $0.2 \text{ kg d}^{-1}$ . The National Research Council - NRC (1996) reported that calves of 100-kg live-weight must consume  $2.6 \text{ kg}$  of dry matter  $\text{d}^{-1}$  with  $250 \text{ g kg}^{-1}$  of protein and  $820 \text{ g kg}^{-1}$  of TDN to achieve  $1.0 \text{ kg}$  of daily weight gain. Considering that most forages and all of the C4 grasses are unable to supply these CP and TDN concentrations, providing the appropriate amount of concentrate supplement to early weaned calves is critical to achieving high performance. Research to quantify the effect of various levels of concentrate on forage intake and calf performance is needed to improve the management of early weaned calves.

The research described in this dissertation consists of four experiments. The first two experiments were grazing trials with early weaned calves fed three levels of concentrate supplement while grazing rye (*Secale cereale* L.)-annual ryegrass (*Lolium multiflorum* Lam.) pastures during winter (Chapter 3) and Tifton 85 bermudagrass (*Cynodon spp.*) pastures during summer (Chapter 4). The objectives of these studies were to measure animal responses including average daily gain, stocking rate, live weight gain per unit of pasture area, and forage intake. Pastures were characterized in terms of

herbage mass, accumulation, allowance, and nutritive value. Economic analyses for the different rates of concentrate were performed. These data will allow producers to better assess the profitability of early weaning of beef calves in North-Central Florida.

The last two experiments were plot studies with the same forage species used in the grazing trials, rye-ryegrass (Chapter 5) during the winter-spring and Tifton 85 bermudagrass (Chapter 6) during the spring-summer. The primary objective was to characterize the forage N fractions using an in situ technique. This is an important tool for characterizing the rate and extent of N release in the rumen, potentially resulting in better supplementation programs that increase animal performance and decrease loss of N to the environment. Information regarding the N profile of forages is also useful to guide future research and development of animal nutrition models. Additional forage responses, including botanical composition and herbage accumulation, were measured in these studies.

## CHAPTER 2

### LITERATURE REVIEW

#### **Early Weaning**

Early weaning is a management practice used by dairy and beef cattle (*Bos sp.*) producers. The definition of early weaning varies, but typically calves weaned < 150 d of age are considered early weaned. Several authors have reported that increasing the fertility rates of beef cows is a benefit of early weaning. Lusby and Wetteman (1980) compared reproductive performance in first-calf heifers following early and normal weaning of their calves. Conception rate was greater among heifers whose calves were early weaned (EW) (97%) than among those whose calves were normal weaned (NW) (59%) during the 64-d breeding season. The average interval from parturition to conception was reduced from 91 to 73 d by early weaning. According to Arthington and Kalmbacher (2003), early weaning resulted in heavier first-calf heifers with greater body condition score at the time of normal weaning. Heifers with EW calves had higher pregnancy rates than those with NW calves (93 vs. 65%) during a 2-yr study in South Florida.

Despite improved pregnancy rates, the practice of early weaning calves is still a challenge for beef cattle producers, in part because of few management options for the weaned calves. Producers that practice EW could possibly send these animals directly to the feedlots; however, this procedure has not been the most profitable. The necessity of keeping the calves during the winter to target the historically greater values of the spring calf market has resulted in recent studies evaluating feed management of EW calves.

The ability of the young ruminant to sustain itself nutritionally is highly dependent on the development of a functional rumen. During the first 3 wk of life, the calves are limited to milk feeding. This limitation directly related to the presence or absence and activity of digestive enzymes during early development of the gastrointestinal system. From 3 to 8 wk of age, dry feed consumption may increase to the level at which it contributes significantly to the energy and protein requirements to the animal (Davis and Drackley, 1998). There is a large variability among calves for dry-feed intake after 8 wk of age. This variability probably is related to the rate at which the calf develops physiologically and its health. However, the calves are able to the majority of their energy requirement from solid feed after 8 wk (Davis and Clark, 1981). Based on their physiological development and in order to maintain a 365-d calving interval, calves should be EW at less than 80 d of age. About 40 d of age may be a practical minimum for early weaning in beef herds. Calves of at least 40 d of age do not require milk replacers in the ration and are old enough to eat dry feed.

Mild winters in the southern USA offer an opportunity to raise calves on pasture-based systems using high nutritive value cool-season annual forages. According to Arthington (2002), EW calves grazing high quality pastures can grow as fast as NW calves. The practice of raising EW calves on winter pastures is a feasible alternative, especially if pasture quality and quantity are superior to hay available for winter feeding (Barnes et al., 1996). Coffey et al. (2000) stated that calves fed hay plus supplement gained less weight than calves that grazed winter-annual forages. Weder (1997) reported an average daily gain of  $0.8 \text{ kg d}^{-1}$  for EW calves grazing annual ryegrass. According to Rouquette et al. (1997), annual ryegrass resulted in individual live weight gains of 1.25

$\text{kg d}^{-1}$  for suckling calves and  $1.05 \text{ kg d}^{-1}$  for stocker calves. Early weaned calves grazing wheat (*Triticum aestivum* L.) pastures consumed 27% less forage dry matter (DM) during the first 20 d than during the subsequent 50 d (Paisley et al., 1998). The authors suggested that initial performance of EW calves grazing winter wheat is limited by low forage intake. Average daily gain for EW calves grazing wheat pasture was  $0.86 \text{ kg d}^{-1}$  during a study with fall-born calves in Oklahoma (Purvis et al., 1996).

Few studies have been conducted with EW calves grazing summer pastures. Muehlmann et al. (1997) studied tropical pastures as the sole source of feed to EW calves. Calf performance was low with daily gains averaging  $0.2 \text{ kg d}^{-1}$ . Smeaton et al. (1996) reported that concentrate supplementation gave a substantial improvement in live weight gain (+19 kg) in EW calves grazing on low nutritive value summer pastures. In south Florida, supplementing EW calves with concentrate at  $10 \text{ g kg}^{-1}$  of body weight resulted in gains of  $0.59$  and  $0.44 \text{ kg d}^{-1}$  on stargrass (*Cynodon nemfuensis* Vanderyst) and atrapaspalum (*Paspalum atratum* Swallen), respectively (Vendramini et al., 2003). In a study with different forage species, Harvey and Burns (1989) evaluated gain of EW calves grazing hill-land pastures (control), ‘Tillman’ white clover (*Trifolium repens* L.), Tillman white clover and tall fescue (*Festuca arundinacea* Schreb.) mixtures, and pearl millet [*Pennisetum glaucum* (L.) R. Brown]. Calves on each forage treatment were provided ground ear maize (*Zea mays* L.) ad libitum. Calf daily gains were  $0.72$ ,  $0.82$ ,  $0.57$ , and  $0.92 \text{ kg d}^{-1}$ , respectively. Calves grazing millet had the greatest response in gain and conversion of concentrate to liveweight gain.

According to some authors, EW calves have better feed efficiency than NW calves. Myers et al. (1999b) conducted a study comparing EW to NW with or without creep

feeding for beef steers. Early weaned steers had greater average daily gains (ADG) during the entire study than the average of creep-fed or normal-fed steers. Early weaned steers had a lesser intake (7.29 vs. 7.68 kg d<sup>-1</sup>) and better feed conversion (0.16 vs. 0.14 kg gain kg<sup>-1</sup> feed) than the average of NW calves with and without creep feeding. Lusby (1995) reported fall EW calves consumed 20% less hay and were 43% more efficient in converting total digestible nutrients (TDN) to weight gain than NW calves. In a study to determine the effect of age at feedlot entry, Schoonmaker et al. (2001) reported that EW calves (110 d of age) were more efficient than NW (202 d of age) and yearling steers (371 d of age) (0.23, 0.21, and 0.18 kg gain kg<sup>-1</sup> feed, respectively). Ringwall (2002) evaluated EW calves with an average weight at weaning of 70 kg. They gained 0.9 kg d<sup>-1</sup> and the feed efficiency was 5.3 kg of feed kg<sup>-1</sup> of gain. When weaned at 70 d, EW calves were 14 kg heavier, had a greater average daily gain, and were 11-d younger at slaughter than NW calves (Grimes and Turner, 1991).

Considering meat quality traits at slaughter, EW calves had a higher quality grade than NW calves (Fluharty et al., 2000; Myers et al., 1999b). In a similar study Myers et al. (1999a) did not find differences for carcass weight, longissimus muscle area, or yield grade among calves weaned at 90, 152, and 215 d of age. Moreover, there was no difference in marbling score or percentage of steers grading greater than or equal to Choice or Average Choice. Fluharty et al. (2000) reported that EW calves fed either 100 or 90% concentrate diets were heavier than NW calves at 210 d. The NW calves had greater backfat thickness at 210 d but no difference in longissimus muscle area when compared to EW calves fed a 60% concentrate diet.

## Forage Systems in Southern USA

Hoveland (1992) estimated that out of ~ 39 million ha of perennial pastures grown in the eastern USA almost 30 million ha are located in the South. These pastures are mainly used for beef cows and calves and stockering of weaned calves.

Seasonal variation in amount and nutritive value of forage are the main challenges over the course of the growing season. The predominantly warm-season grasses in Florida are bahiagrass (*Paspalum notatum* Flügge) and bermudagrass [*Cynodon dactylon* (L.) Pers.]. These perennial, warm-season forages adapted to the Southeast are typically of lower nutritive value than either cool-season perennials or warm-season annuals (NRC, 1989).

Warm-season grasses are more efficient in light conversion than cool-season species, but the major adaptation advantage is their better water-use efficiency, resulting in higher total forage production when compared with cool-season grasses in tropical and subtropical climates (Brown and Simmons, 1979). While the division of physiological activity between mesophyll and bundle sheath cells in warm-season grasses is beneficial for CO<sub>2</sub> fixation and adaptation, the anatomical organization required for warm-season grasses causes forage quality to generally be lower than for cool-season grasses (Akin, 1986). Warm-season grasses have relatively larger proportions of vascular tissues, bundle sheath, and sclerenchyma than cool-season grasses. Some of these tissues in warm-season grasses are potentially digestible, but because of their chemical composition and plant anatomical structure the rate of degradation and fermentation is relatively slow (Coleman et al., 2004). Although warm-season grasses grow well in the summer, their production is seasonal, being interrupted by cold or dry weather.

Cool-season grass species generally are considered to have high nutritive value than warm-season grasses mainly because of the amount and arrangement of tissues (Akin, 1986). Mild winters in Florida give producers the opportunity to cultivate cool-season annual forages during a period when productivity of warm-season grasses is low. The importance of the cool-season grasses in the southern USA can be appreciated by considering the seed market. The annual sale of seeds of winter annuals is enough to plant 6 million ha of winter pastures (Moser and Hoveland, 1996).

### Bermudagrass

#### General

*Cynodon spp.* are geographically widely distributed. They occur in greatest abundance in tropical and subtemperate environments (Taliaferro et al., 2004). Bermudagrass is one of the most important species in the southeastern USA with ~ 10 to 12 million ha of planted areas for livestock grazing and hay. Many *Cynodons* have been used as herbage for livestock, but several are of minor value because of narrow distribution or characteristics limiting their adaptation. In 1937, USDA-ARS geneticist Glenn W. Burton initiated a bermudagrass breeding program at the Coastal Plain Experiment Station in Tifton, GA, with the objective of developing cultivars that were more productive than the common strains and were capable of supplying highly nutritious and palatable forage during a greater portion of the year (Burton, 1947). In 1943, the release of ‘Coastal’ bermudagrass was a landmark in bermudagrass breeding, because it was widely accepted by livestock producers in the southeastern USA. In 1993, ‘Tifton 85’, a hybrid between a South African bermudagrass and ‘Tifton 68’ stargrass, was released. Burton et al. (1993) described it as taller, with larger culms, broader leaves, and

darker color than other bermudagrass hybrids. Compared with Coastal, Tifton 85 yielded 26% more DM, was 11% more digestible, and was more succulent at harvest.

### **Fertilization, Yield, and Nutritive Value**

Bermudagrasses require relatively high soil nutrient availability to maintain good production performance. The major determinants of fertilizer response are climate, native soil nutrient status, source and rate of applied nutrients, season of application(s), cultivar, and defoliation regimen and method.

Nitrogen has the greatest influence on biomass yield and accordingly influences the amount of other nutrients required to sustain production at specific N levels (Taliaferro et al., 2004). Bermudagrass hay yield and quality are maximized when N is applied in split applications at annual levels higher than  $400 \text{ kg ha}^{-1} \text{ yr}^{-1}$  (Overman et al., 1992).

According to Wilkinson and Langdale (1974), cited by Taliaferro et al. (2004), Coastal and other select bermudagrass cultivars produced maximum yields of about  $27 \text{ Mg ha}^{-1}$  at N rates of  $1200 \text{ kg ha}^{-1}$ , with near linear yield response to N up to about 600 to 700 kg N  $\text{ha}^{-1}$ .

Prine and Burton (1956) evaluated the effects of different N rates and harvest frequencies on Coastal bermudagrass biomass production and nutritive value. There was a curvilinear increase in herbage accumulation as N rate increased from 0 to  $1008 \text{ kg N ha}^{-1}$  with maximum DM accumulation of  $18.4 \text{ Mg ha}^{-1}$  with a 6- to 8-wk harvest interval. Bermudagrass showed the highest efficiency in production ( $\text{kg DM kg}^{-1} \text{ N ha}^{-1}$ ) at  $336 \text{ kg N ha}^{-1}$ . The forage CP concentration ranged from 97 to  $190 \text{ g kg}^{-1}$  with N fertilization rates from 0 to  $1008 \text{ kg ha}^{-1}$ . Typically, increased CP concentrations have been reported with increasing N application. Stallcup et al. (1986) reported that CP concentrations in bermudagrass fertilized with 0 and  $50 \text{ kg N ha}^{-1}$  were  $114$  to  $143 \text{ g kg}^{-1}$ . Burton et al.

(1963) studied different defoliation intervals of Coastal fertilized with 660 kg N ha<sup>-1</sup>. The maximum herbage accumulation was 22 Mg ha<sup>-1</sup> using a 6-wk interval. According to the same author, annual DM production of 20 Mg ha<sup>-1</sup> removed 400 to 450 kg N, 30 to 50 kg P, 260 to 320 kg K, 30 kg S, 30 kg Mg, and 60 kg Ca ha<sup>-1</sup> from the soil.

Johnson et al. (2001b) compared different species of warm-season grasses in Florida. Bermudagrass produced more forage DM ( $1,540 \pm 43$  kg ha<sup>-1</sup> cutting<sup>-1</sup>) than stargrass ( $1,400 \pm 43$  kg ha<sup>-1</sup> cutting<sup>-1</sup>) or bahiagrass ( $1,300 \pm 43$  kg ha<sup>-1</sup> cutting<sup>-1</sup>) when harvested every 28 d. Peak herbage accumulation for all species occurred in late June and July. A quadratic response to N fertilization was noted for in vitro digestible organic matter digestibility (IVDOM) of bermudagrass, whereas bahiagrass was not affected. Bermudagrass was more digestible ( $575 \pm 4$  g kg<sup>-1</sup>) than stargrass ( $546 \pm 4$  g kg<sup>-1</sup>) and bahiagrass ( $519 \pm 4$  g kg<sup>-1</sup>). As fertilization level increased, neutral detergent fiber (NDF) decreased linearly in all three forages. Total N concentration and the concentration of all protein fractions for all forages increased as N fertilization increased. In summary, digestibility, CP concentration, and yield of bermudagrass increased with increasing N application when plants were harvested every 28 d.

### **Grazing Studies**

Bermudagrass is the most popular warm-season perennial grass for hay production and pastures in the southern USA (Taliaferro et al., 2004). In North-Central Florida, Pedreira et al. (1998) compared Florakirk and Tifton 85 bermudagrass in a 3-yr grazing study. The pastures were continuously stocked and fertilized with 210 kg N ha<sup>-1</sup> in four applications yr<sup>-1</sup>. Although the average daily gain was similar between species (0.6 kg d<sup>-1</sup>), Tifton 85 pastures supported higher average stocking rates (6.0 vs. 4.0 heifers ha<sup>-1</sup>), resulting in greater gain (648 vs. 371 kg ha<sup>-1</sup>). Examination of 3-yr, total-season (169 d)

gains of steers grazing high quality bermudagrass pastures revealed that steer ADGs were 0.90 and 0.88 kg, respectively, from April to July, but only 0.30 and 0.43 kg, respectively, for Tifton 78 and Tifton 85 pastures from July to October (Hill et al., 1993). The authors suggested that decreased ADG was the consequence of increased maintenance requirement of heavier steers and lower nutritive value later in the season. Rouquette et al., (2003) reported that stocker steers gained  $1.03 \text{ kg d}^{-1}$  on Tifton 85 compared to  $0.75 \text{ kg d}^{-1}$  on Coastal without supplementation. With supplementation of  $1.4 \text{ kg d}^{-1}$  of a 3:1 maize:soybean (*Glycine max* L.) meal concentrate, steer ADGs were  $1.25 \text{ kg d}^{-1}$ .

Carnevalli et al. (1999) maintained Tifton 85 swards heights of 5, 10, 15, or 20 cm with grazing Santa Inez crossbred lambs (*Ovis aries* L.) paired by sex and body weight. Nutritive value of forage was different for sward heights; short swards (5 cm) had the highest CP and in vitro DM digestibility (IVDMD), but lamb performance was more dependent on carrying capacity and forage allowance, with lambs performing better on taller swards (15 to 20 cm).

### Cool-Season Annual Grasses

#### General

Although warm-season grasses dominate most of the pastures in the southeastern USA, climatic conditions during winter allow for use of cool-season annual grasses, either sod-seeded or in prepared seedbeds. Reasons for use of cool-season annual grasses include the extending the grazing period, high nutritive value, compatibility and ease of establishment in warm-season perennial grass pastures, and tolerance to different defoliation regimens and stocking rates (Rouquette et al., 1997). Small grains are often a component of cool-season grass mixtures because they improve early-season forage

production. Of the options available, annual ryegrass-small grain mixtures provide the earliest and greatest amount of forage if planted early on a well-prepared seedbed; however, they also are expensive and are best used by lactating dairy cows, stocker calves, replacement heifers, or limit grazed by beef cows nursing fall calves (Evers et al., 1997).

Annual ryegrass, a high-yielding, high quality grass, is the most commonly grown cool-season pasture forage in the southern and southeastern USA from November to May (Evers et al., 1997). Common annual ryegrass was successfully grown in the Gulf Coast region of the USA in the 1940s and 1950s. However, crown rust (*Puccinia coronata* f. sp. *avenae*) was a serious problem and reduced forage yields and quality. Plant breeding efforts in Texas, Mississippi, and Florida resulted in the release of 'Florida Rust Resistant' annual ryegrass (Chapman and Webb, 1965). Hectarage of annual ryegrass planted area has increased due to improved crown rust resistance as well as increased forage and seed yield, and significant gains in winter hardiness (Griffith and Chastain, 1997). Among several cultivars released for southern areas, the tetraploid 'Jumbo' (Reg. no. CV-220, PI 614099) is noted for its high seed yield, high resistance to crown rust and gray leaf spot (*Pyricularia grisea* [*Magnaporthe grisea*]) and moderate resistance to Helminthosporium leaf spot disease (*Drechslera*). Jumbo is late maturing, has larger stems, leaves, seed heads, and seeds than the diploid 'Surrey', with CP concentration and IVDOM comparing favorably with Surrey and other ryegrass cultivars (Prine et al., 2002).

### **Fertilization, Yield, and Nutritive Value**

Robinson et al. (1987) reported annual ryegrass yields in the southern states have generally increased with N application rates up to 450 kg ha<sup>-1</sup>. Hovermale (1993)

obtained maximum ryegrass yields with 380 kg N ha<sup>-1</sup>, however, the maximum yield was only 6.7 Mg ha<sup>-1</sup>. Allen et al. (1974) tested different levels of N in oat (*Avena sativa* L.)-ryegrass mixed swards. Forage yield was 4.3 Mg ha<sup>-1</sup> and 9.0 Mg ha<sup>-1</sup> with 0 and 280 kg N ha<sup>-1</sup>. Morris et al. (1994) reported herbage accumulation of 10.5 Mg ha<sup>-1</sup> when 280 kg N ha<sup>-1</sup> was applied.

In Florida, Dunavan (1975) showed that three equal treatments with ammonium nitrate (133 kg ha<sup>-1</sup> N application<sup>-1</sup>) applied at planting and in January and March produced higher total yields than a single application of 400 kg N ha<sup>-1</sup>. Comparing three N fertilization amounts, the rates of N recovery were 46, 45, and 26% for a single application of ammonium nitrate to a rye-ryegrass mixture at N rates of 100, 200, and 400 kg ha<sup>-1</sup>, respectively.

The CP concentration of cool-season grasses is strongly influenced by the available soil N. Application of N fertilizer to grasses usually increases CP concentration as well as crop growth. The majority of the increased CP is non-protein N (NPN) in the form of nitrate and free amino acids (Van Soest, 1982). Crude protein concentrations in annual ryegrass tend to be high (Haby and Robinson, 1997), commonly averaging 150 to 200 g kg<sup>-1</sup> with no N applied and increasing to 280 g kg<sup>-1</sup> at N rates of 448 kg ha<sup>-1</sup>. The CP concentrations of ryegrass samples collected in mid-January in different locations in Texas were 228, 321, and 311 g kg<sup>-1</sup> for Angleton, Overton, and Knippa, respectively, (Lippke 1993, cited by Lippke and Ellis, 1997). Redfearn et al. (2002) analyzed nutritive value of different cultivars of ryegrass. The CP and IVDOM results in January were 234, 229, and 232 g CP kg<sup>-1</sup>, and 849, 849, and 846 g IVDOM kg<sup>-1</sup> for ‘Gulf’, ‘Jackson’, and

'Marshall', respectively. In general, CP concentrations of cool-season grasses range from 200 to 300 g kg<sup>-1</sup> when well fertilized and in vegetative growth stage.

Lippke and Evers (1986) reported that ryegrass forage in vegetative stages of growth usually has IVDOM > 700 g kg<sup>-1</sup>, approaching and sometimes exceeding 800 g kg<sup>-1</sup> in the first weeks of the grazing season (Ulyatt, 1981). In vitro digestibility of annual ryegrass grown at different N rates has been evaluated in Louisiana (Allen et al., 1974). The authors reported a 60 g kg<sup>-1</sup> increase in digestibility at 448 kg N ha<sup>-1</sup> compared with that at 224 kg N ha<sup>-1</sup>. The cell wall digestibility and leaf/stem ratio of cool-season grasses decreases with maturity. Data from Buxton and Russell (1988) for forages sampled following the beginning of reproductive development indicate a decline in IVDOM from 761 to 552 g kg<sup>-1</sup> in orchardgrass (*Dactylis glomerata* L.) leaves from May to July. Buxton and Merten (1989) reported that herbage IVDOM of four cool-season grass species decreased linearly with time during the spring. Plants with a moderate number of reproductive tillers had an average rate of decline in IVDOM of 3.9 g kg<sup>-1</sup> d<sup>-1</sup>.

### Grazing Studies

Cool-season grasses in the southeastern USA usually are productive from late December to early May. The use of small grains such as oat, wheat, and rye (*Secale cereale* L.) in mixtures with ryegrass generally provides forage for grazing during the late fall as well as during the winter (Rouquette et al., 1997). Small grains grow better from late December to mid-February and ryegrass results in rapid forage growth during March to late May, often requiring frequent increases in stocking rate to efficiently use ryegrass pastures.

According to Rouquette et al. (1997), annual ryegrass is very tolerant of frequent and severe defoliation and often supports 2000 kg ha<sup>-1</sup> body weight for a 75- to 100-d

period in the spring. Depending upon management and climate, stocker calf gain may range from 450 to 900 kg ha<sup>-1</sup> from annual ryegrass pastures during 100 d of grazing.

In early studies, Rieve et al. (1963) compared 'Gulf' ryegrass with tall fescue at different stocking rates. The stocking rates ranged from 2.2 to 3.9 steers ha<sup>-1</sup> for ryegrass, and 1.9 to 4.9 steers ha<sup>-1</sup> for tall fescue. The average daily gains for ryegrass were 0.67, 0.49, and 0.28 kg d<sup>-1</sup>, respectively, for low, medium, and high stocking rates. Maximum gain per steer and gain per hectare were higher for ryegrass pastures than for tall fescue.

Rye is more productive than other annual cool-season grasses on sandy, well drained soil of low fertility, while oat, wheat, and barley (*Hordeum vulgare* L.) do not grow as well on very sandy soils. Rye produces more forage in fall than spring, while oat DM production is variable (Phillips et al., 1996). Bransby and Gamble (1993) compared ADG and LWG from pastures planted to 'Bonal' rye only or to Bonal rye plus ryegrass. The inclusion of ryegrass resulted in greater stocking rates and ADGs, resulting in greater LWG. At a stocking rate of five, 350-kg steers ha<sup>-1</sup>, LWG were ~330 and 520 kg ha<sup>-1</sup> for rye and rye-ryegrass, respectively. In Louisiana, Feazel (1986) evaluated Marshall and Gulf ryegrass in pure stand and an 'Elbon' rye-Gulf ryegrass mixtures. The average stocking rates were similar among the three treatments, 3.5 head ha<sup>-1</sup>. The LWG ranged from 522 kg ha<sup>-1</sup> for heifers grazing Gulf ryegrass to 688 kg ha<sup>-1</sup> for Marshall ryegrass. In the 3-yr study, there was no advantage to including Elbon rye in mixture with ryegrass. In North Florida, Bertrand and Dunavan (1974) studied length of the grazing season of calves (170 kg liveweight) grazing ryegrass and ryegrass-triticale (*Triticale hexaploide* Lart.). The inclusion of ryegrass in the mixtures extended the grazing season from 533 to 650 animal days ha<sup>-1</sup>.

Feazel (1986) evaluated two methods of establishment of annual ryegrass, prepared seedbed and sod-seeded, on performance of beef steers. Steers grazing prepared seedbeds gained  $1.05 \text{ kg d}^{-1}$  and those grazing sod-seeded stands gained  $1.25 \text{ kg d}^{-1}$ ; however, because initiation of grazing was 36 d later on sod-seeded pastures, total gain per steer was 180 and 157 kg for prepared seedbed and sod-seeded pastures, respectively. In field experiments in Louisiana, rye and ryegrass were sown alone or together into bermudagrass stubble, or into a prepared seedbed. Dry matter forage yields over seven cuts between December and May were  $\sim 6.0$  and  $7.3 \text{ Mg ha}^{-1}$  for ryegrass and rye-ryegrass sown into a prepared seedbed and 3.9 and  $4.8 \text{ Mg ha}^{-1}$  for ryegrass and rye-ryegrass sown into a bermudagrass stubble (Eichhorn and Venuto, 1999). In some environments, ryegrass has produced as much if not more ADG and LWG when planted alone on prepared seedbed as in mixtures of ryegrass and small grains (Bransby, 1996).

Edwards et al. (1978) evaluated various rates of N fertilization (165 to  $371 \text{ kg N ha}^{-1}$ ) of Gulf ryegrass and wheat mixtures. Average daily gain was consistent across treatments at  $0.82 \text{ kg d}^{-1}$ . Total liveweight gain ranged from  $622 \text{ kg ha}^{-1}$  on pastures that received  $165 \text{ kg N ha}^{-1}$  to  $1030 \text{ kg ha}^{-1}$  on pastures that received  $371 \text{ kg N ha}^{-1}$ . Bransby (1993) compared rye-ryegrass pastures under continuous and rotational stocking at 2.5, 3.7, and 5.0 ( $270 \text{ kg}$ ) steer  $\text{ha}^{-1}$  stocking rates. Average daily gain for calves on the rotationally-stocked pastures was 0.82, 0.65, and  $0.63 \text{ kg d}^{-1}$ , respectively, for the three stocking rates compared to 1.05, 0.72, and  $0.43 \text{ kg d}^{-1}$  for the continuously stocked pastures, respectively. Thus, an advantage for rotational stocking was obtained only at high stocking rates. In Brazil, Restle et al. (2000) studied beef heifers grazing oat-

ryegrass pastures under continuous stocking and fertilized with 200 kg N ha<sup>-1</sup>. Average daily gain and gain ha<sup>-1</sup> were 0.58 kg d<sup>-1</sup> and 429 kg ha<sup>-1</sup>, respectively.

Results of a 5-yr study were presented by Rouquette et al. (1992) who compared a range of stocking rates on pure stands of ryegrass plus N and ryegrass-arrowleaf clover (*Trifolium vesiculosum* Savi.), sod seeded on Coastal bermudagrass pastures. Cow-calf pairs grazed the pastures. Average daily gains of suckling calves were similar among treatments and ranged from 1.0 to 1.4 kg d<sup>-1</sup> for ryegrass and arrowleaf pastures at stocking rates of 5.98 to 2.37 animal units (AU) (680-kg liveweight) ha<sup>-1</sup>. The most significant responses to the use of cool-season forages are not only calf ADG but also weaning weight of fall-born calves. Using a fall calving season, the stocker phase is essentially eliminated because calves are heavy enough to enter the feedlot immediately upon weaning (Rouquette et al., 1997).

After an extensive research program with cool-season grasses, Rouquette et al. (1997) concluded that achieving economic optimum grazing management and use of cool-season grasses is not an easy task. A knowledge base of forage growth expectations and the art of managing proper defoliation regimes will allow for the greatest opportunity for positive economic returns and an acceptable transition from cool-season to warm-season pastures.

### **Supplementation**

Flexible management of the grazing system is required to maximize animal performance since forage production and nutritive value are not uniform throughout the year. The use of supplementary feed can overcome the shortfalls of the forage component. When energy and protein requirements increase due to lactation, pregnancy, and growth, part of the roughage component of the diet may need to be replaced by

concentrates (Fontaneli, 1999). Concentrates generally are more digestible than forages and have much higher fermentation rates. According to Stockdale et al. (1987), several factors may affect the response to supplement, including quality of the pasture and supplement, amount of pasture and supplement fed, and degree to which supplemental feeds replace pasture intake.

## **Protein**

Crude protein concentration of high nutritive value herbage may exceed 250 g kg<sup>-1</sup>, however, 650 to 850 g kg<sup>-1</sup> of total protein is degradable in the rumen, with 150 to 350 g kg<sup>-1</sup> escaping the rumen. Microbial protein is a major protein source for ruminants; therefore, optimizing microbial protein synthesis is essential. In a review of protein supplementation of grazing livestock, Petersen (1987) stated that enhanced forage utilization occurs in several ways. Protein supplements provide amino acids, carbon skeletons, and minerals that help satisfy microbial requirements, thereby increasing microbial growth and/or fermentation. These factors combine to increase intake through increased microbial activity and rate of passage (Allison, 1985). In addition to increasing available nutrients in the rumen, protein supplements may also increase the quantity of protein reaching the small intestine through undegraded or bypass protein. Non-structural carbohydrates are needed to utilize the forage N in the rumen, to reduce energy cost of excreting N, and to supply nutrients to the small intestine. Microbial protein synthesis can become a performance-limiting factor for ruminants consuming highly digestible ryegrass diets. Hill (1991) observed that in young calves grazing ryegrass, synthesis of microbial protein was 6 to 10 g 100 g<sup>-1</sup> of OM digested in the rumen, and energy/protein supplements increased the flow of microbial and undegraded dietary protein to the intestines, and increased forage intake proportionally. In a study with beef steers grazing

rye-ryegrass pasture and receiving free-choice mineral, Grigsby et al. (1991) compared corn meal and fish meal concentrates. Average daily gain was 1.5 and 1.0 kg d<sup>-1</sup> for corn meal and fish meal, respectively. Supplemental energy may have provided a source of rapidly fermentable carbohydrate, which was well synchronized with ammonia and peptide production from forage protein degradation, which in turn may have resulted in a greater synthesis of microbial protein. Moore et al. (1999) suggested that the ratio of digestible organic matter (DOM) to CP should be no more than seven to one based on the observation that animals consuming forages with ratios greater than seven were likely to respond to CP supplement.

Hill et al. (1990) studied beef heifers grazing ryegrass pastures (243 g CP kg<sup>-1</sup>) and supplemented with maize, cottonseed meal, blood meal, feather meal, fishmeal, or condensed molasses with cottonseed meal. Meal-based supplements were given at 3.5 g kg<sup>-1</sup> of body weight (DM basis). Forage organic matter intake (OMI) (650 g kg<sup>-1</sup> digestible) was increased by blood and fishmeal supplements and decreased by cottonseed and feather meal. It was concluded that blood and fish meal seemed to be more effective in supplying required protein and essential amino acids that stimulate intake of forage.

In C4 grasses, protein may be excessive or seriously deficient, depending on the pasture species, season, and maturity of growth (Poppi and McLennan, 1995). Minson (1990) compiled a series of studies in which CP was below 62 g kg<sup>-1</sup> in the base forage. There was an average 40% increase in intake due to protein supplement and a 34% increase due to supplementary urea. Probably, the greatest and most uniform response to supplemental N occurs when the CP concentration of the base forage is below 70 g kg<sup>-1</sup>.

(Coleman et al., 2004). Bodine et al. (1999) reported the effect of four sources of ruminal degradable protein and two sources of energy supplementation on steers consuming low-quality hay (< 70 g CP kg<sup>-1</sup> OM). Forage OMI and total OMI increased quadratically as rumen degradable protein increased for both energy supplements. When DOM:CP ratios of limpograss [*Hemarthria altissima* (Poir.) Stapf and Hubb.] were between 8 and 10, cattle responses to CP supplementation were significant (Lima et al., 1999b).

Hammond et al. (1994) suggested assessing blood urea N (BUN) concentrations as a method to monitor the need for supplements by grazing animals when forage nutritive value data are not available. Cattle BUN concentrations from 9 to 12 mg dL<sup>-1</sup> are considered to be a transition range below which gain response to protein supplementation has been positive. Hoffman et al. (1993a) reported a summary of BUN values from several studies with dairy cows. There was an apparent excess of N in the rumen in relation to carbohydrates and wastage of highly degradable N in pasture forage when BUN values ranged from 18.5 to 28.6 mg dL<sup>-1</sup>. Newman et al. (2002b) observed higher BUN concentrations (18 vs. 15 mg dL<sup>-1</sup>) on heifers grazing limpograss either with or without CP supplementation, respectively.

## **Energy**

Energy supplements for forages generally fall into three categories: starch, sugars, and fiber (Poppi and McLennan, 1995). Sources of fibrous highly-digestible energy, such as soybean hulls or wheat middlings, have shown the most consistent response, presumably because of the good synchrony with NH<sub>3</sub> released (Poppi and McLennan, 1995). Johnson et al. (2001a) supplemented mature cows on bermudagrass pastures with soyhulls or corn at 0.17% BW. There was no difference in dry matter intake (DMI) or ADG between the treatments. These results suggest that low levels of corn

supplementation did not affect forage intake and animal performance. Supplementing forage with a starch source, especially at levels  $> 250 \text{ g kg}^{-1}$  of the total DM tends to reduce fermentation of the basal forage [Goetsch et al. (1991), cited by Coleman et al. (2004)]. According to Fieser and Vanzant (2004), when fed at similar levels of OM, soybean hull supplementation provided an average of  $60 \text{ g kg}^{-1}$  greater DOM intake than corn supplementation.

Ordonez-Tercero et al. (2003) used two energy sources [sugar-cane (*Sacharum officinarum* L.), molasses and maize] to test the effect of energy supplementation on intake and digestibility of the basal diet (elephantgrass) [*Pennisetum purpureum* Schum.] and a foliage mix of *Brosimum alicastrum* Sw. and leucena [*Leucaena leucocephala* (Lam). Dewit] There were no differences in basal diet intake ( $5.54 \text{ kg DM d}^{-1}$ ) among treatments. The potentially degradable DM ( $337 \text{ g kg}^{-1}$ ) and OM ( $364 \text{ g kg}^{-1}$ ) fractions were not affected by energy supplementation. Frizzo et al. (2003) studied the effect of levels of energy supplementation on the productive and reproductive performance of Charolais heifers maintained in a cultivated pasture of black oat (*Avena strigosa* Chreb.) [*Avena nuda* L.]) plus annual ryegrass. It was shown that supplementation increased ADG, stocking rate, and LWG. Heifers kept only on pasture had lower body condition and showed lower estrus percentage than heifers supplemented with 0.7 and 1.4% of LWG  $\text{d}^{-1}$ . The estimated intake of DM was lower for the 1.4% BW  $\text{d}^{-1}$  supplementation level. In South Brazil, Rocha et al. (2003) evaluated performance of beef heifers grazing oat-annual ryegrass mixtures with and without ground maize supplement. The utilization of oat and ryegrass pasture with supplementation resulted in higher ADG, stocking rate, and LWG than the mixture with no supplement. Bertrand and Dunavan (1977) studied the

effects of increasing energy supplementation from 0 to 15 g kg<sup>-1</sup> BW on performance of beef steers (180 kg liveweight) grazing ryegrass-rye-white clover (*Trifolium repens* L.). The increase in supplementation levels increased ADG (0.89-1.10 kg d<sup>-1</sup>), stocking rate (4.09-5.32 head ha<sup>-1</sup>), and LWG (582-936 kg).

### **Interactions between Supplements and Forages**

When forages are offered free choice and supplemental concentrates are offered in restricted amounts, forage DMI may either increase, decrease, or remain the same (Moore, 1992). In many cases, animal responses to supplements are either greater or less than expected. The deviations between expected and observed performance are usually explained by associative effects of supplements upon voluntary intake and digestibility of the total diet (Moore et al., 1999). In general, concentrates will decrease forage intake when forage quality is high, other nutrients are in balance with energy, and concentrate is fed in large amounts. Large differences in substitution rates have been reported and the effects have greater relation to differences among forages rather than to differences among concentrates (Waldo, 1986). On the other hand, small amounts of concentrate may increase voluntary intake when forages nutritive value is low, especially when the forage has a high ratio of TDN to CP (Moore, 1994).

Sarker and Holmes (1974) fed supplement in increments of 2, 4, 6, or 8 kg OM d<sup>-1</sup> to non-lactating cows grazing ryegrass. Though total OMI increased with increasing amounts of concentrate, the average increase in forage intake was 0.46 kg OM kg<sup>-1</sup> of concentrate OM fed. Meijs (1986) fed high-starch supplements or high fiber supplements to cows grazing predominantly perennial ryegrass (*Lolium perenne* L.) swards.

Supplement intake was 5.5 and 5.3 kg OM d<sup>-1</sup> with forage intakes of 11.5 and 12.6 kg OM d<sup>-1</sup> for high and low starch treatments, respectively. Average forage substitution rate

for animals receiving supplements was 0.45 vs. 0.21 kg herbage  $\text{kg}^{-1}$  concentrate for animals receiving starch and fibrous supplements, respectively. Royes et al. (2001) evaluated different sources of energy (maize, sugar cane molasses, or soybean hulls) and feeding rates (0, 1.4, or 2.8 kg DM steer $^{-1}\text{d}^{-1}$  in growth trials; 0, 150, or 300g  $\text{kg}^{-1}$  of the ration DM in digestion trials) of supplements fed to cattle receiving ammoniated stargrass hay. Increasing the level of supplementation decreased hay intake but increased total dietary intake for all diets. Daily gain and feed efficiency of steers improved with supplementation. Steers supplemented with corn or soybean hulls at 2.8 kg DM  $\text{d}^{-1}$  had a higher ADG (0.92 kg) and gain:feed (0.103) than steers supplemented with molasses (0.78 kg) at the same level.

According to Galloway et al. (1992), moderate dietary levels of supplement (200-300 g  $\text{kg}^{-1}$ ) can improve nutrient intake and performance by cattle consuming bermudagrass. At greater amounts, nutrient digestion, intake, or both, of the forage portion of the diet can be affected negatively. Cattle grazing forages with DOM:CP ratios greater than seven to eight are likely to have inadequate ruminally degradable protein and should respond to N supplementation by increasing intake and animal performance (Moore and Kunkle, 1999). Wheeler et al. (2002) tested the effects of increasing supplement protein concentration on performance and forage intake of beef steers consuming bermudagrass forage. Treatments were no supplement or daily equivalents of 0.2, 0.4, and 0.6 g of supplemental protein  $\text{kg}^{-1}$  of BW. Forage intake increased 16% and total OMI increased 30% in supplemented compared to unsupplemented steers. Diet OM digestibility increased 145 g  $\text{kg}^{-1}$  in supplemented compared to unsupplemented steers.

A special case of substitution and associative effects is the use of total mixed rations (TMR) for lactating dairy cows. Such diets may include several sources of forage and combinations of concentrates. Because TMRs often are based on high quality forage and include high percentages of concentrates, intake and digestibility of the forage component is very likely less than expected when forage is fed alone (Moore, 1994). Fike et al. (2003) studied the effects of two levels of supplementation on forage and total intake of lactating dairy cows grazing bermudagrass and rhizoma peanut (*Arachis glabrata* Benth.) pastures. The substitution of forage OM by supplement OM ( $\text{kg kg}^{-1}$ ) was 0.48 for rhizoma peanut and 0.06 for bermudagrass. Feeding additional supplement increased total OMI by 230 and 9  $\text{g kg}^{-1}$  for cows grazing bermudagrass and rhizoma peanuts pastures, respectively.

### **Behavior**

According to Stobbs (1975), the energy required to prehend forage from the standing biomass is an insignificant part of the maintenance requirements, but energetic costs of activities associated with grazing have been estimated to account for 25 to 50% of an animal's daily energy requirements. Numerous studies have shown that supplying supplemental protein and (or) energy to cattle consuming low- to moderate-quality forages can increase animal performance and forage OMI, however, data are limited showing the effect of supplementation on grazing behavior (Krysl and Hess, 1993). Adams (1985) postulated that disruption of normal grazing activity resulting from supplementation regimens could adversely affect forage intake and animal performance. In research with yearling beef steers grazing ryegrass, the same authors noticed that although there was an 11.3% decrease in forage intake with supplementation, total daily grazing time was not altered. Macoon (1999) observed that dairy cows supplemented

with high levels of concentrate spent less time grazing during daylight (135 min) than cows that received low levels of concentrate (180 min). Supplementation can cause shifts in daylight grazing behavior patterns; however, there is no indication that supplemented animals alter their percentage of daytime vs. nighttime grazing compared to unsupplemented animals (Adams, 1985). Providing protein supplements to cattle grazing low-quality forages increased harvest efficiency (forage OMI  $\text{kg}^{-1}$  BW  $\text{min}^{-1}$  spent grazing) from 8 to 60% compared with unsupplemented cattle (Barton et al., 1992). In contrast to protein meal-based supplements, high-starch supplements either failed to alter or decreased harvest efficiency (Adams, 1985).

Allden and Whittaker (1970) indicated an upper limit of grazing time of ~ 600 to 720  $\text{min d}^{-1}$  for sheep. Similarly, Stobbs (1975) observed that fatigue limits the time that can be spent grazing to ~ 720  $\text{min d}^{-1}$  in cattle. Numerous studies have reported daily grazing time to be in the range from 359 to 771  $\text{min d}^{-1}$  for cattle over a wide range of environmental temperatures, supplementation regimens, grazing management practices, and forage types (Krysl and Hess, 1993).

### **Intake**

Intake is the most important determinant of performance by grazing ruminants (Lippke, 2002). As much as 60 to 90% of the variation in digestible energy intake may be due to animal variability, with 10 to 40% due to diet digestibility (Crampton et al., 1960). The most important mechanisms controlling intake in ruminants are metabolic, distention, and behavioral. Conrad et al. (1964) examined results from 114 trials with lactating cows and reported the situations where physical and physiological factors were regulating feed intake. Intake of diets having digestibility between 500 and 670  $\text{g kg}^{-1}$  was thought to be limited by physical factors such as digestibility of the feed and its rate

of passage through the digestive tract. Intake of diets having a digestibility  $> 670 \text{ g kg}^{-1}$  was limited primarily by physiological control mechanisms. Intake of perennial warm-season grasses is considered to be limited by physical (distention) mechanisms due to their high fiber concentration and low digestibility. Van Soest (1965) reported negative correlations between cell wall concentration and voluntary intake.

Factors controlling ruminant intake should be assumed to function through multiple interactions, and the simplistic view should be abandoned that only physical factors limit the intake of roughage diets and that only chemical or physiological factors limit intake of concentrate diets (Fisher, 2001; Moore, 1994). Hodgson (1982) stated that under grazing conditions, ingestive behavior (i.e., bite mass, bite rate, and grazing time) might be a more important determinant of forage intake than physical and metabolic controls. Low forage availability and accessibility are situations where ingestive behavior may be an important controlling factor on forage intake. The DMI on pastures is a result of a complex interaction among pasture canopy characteristics, ingestive behavior, and grazing time (Burns and Sollenberger, 2002).

Forage intake is forage species-specific and altered by plant maturity and morphology. The eating behavior of ruminants has been clearly characterized as selective, with strong preference for green leaf and against dead and stem tissues (Minson, 1990). Greater selectivity by the animal for leafy tissue from within the bounds of forage on offer will generally result in a higher quality diet than that on offer and greater DMI (Burns et al., 1991).

### **Measurements of Forage Intake of Grazing Animals**

The ability to measure or predict DMI and nutritive value of forages on pastures has been the impetus for studies of the plant-animal interface (Burns and Sollenberger,

2002). A number of techniques have been adopted to estimate intake because it is not practical to measure intake on pastures directly (Lippke, 2002). There are two general approaches to the indirect estimation of pasture intake. According to Moore and Sollenberger (1997) the techniques may be classified as follows: 1) estimates for individual animals by fecal output and forage digestibility or ingestive behavior, and 2) estimates for groups of animals by disappearance of herbage mass or calculation from animal performance. Each method employs different assumptions which must be met if the estimates are to be valid.

To avoid errors associated with the estimation of forage intake on pastures, researchers have cut and carried green pasture herbage to confined animals kept in confinement. Though this approach affords a great degree of precision, it may be highly inaccurate because it reduces the opportunity for diet selection. Experimental results are likely most affected when swards are highly heterogeneous, and when environmental factors, sward density, and forage accessibility have large effects on grazing behavior.

Intake calculations based on fecal output and forage digestibility have been used extensively. Fecal output is the measure of interest because it can be used to calculate intake using the following equation: Intake = fecal output / (100 - diet digestibility).

Early attempts to estimate intake from total feces collection in individual animals included use of fecal collection bags. In addition to the potential for loss or urine contamination due to poor design or lack of fit, the bags also have the potential to stress the animal and to alter intake by changing grazing behavior.

The alternative is to estimate fecal output using marker technology. Functionally, markers are classified as being internal to the feedstuff or external, i.e., added to the

feedstuff or dosed separately to the animal (Lippke, 2002). Markers are reference compounds used to investigate both chemical and physical digestive processes (Owens and Hanson, 1992). Characteristics of an ideal external marker were outlined by Owens and Hanson (1992) and include the following traits: 1) it should be unabsorbable, 2) it should not affect or be affected by animal or microbial digestive processes, 3) its flow should closely mimic that of the material it marks, and 4) it must be analyzable with a specific and sensitive methodology. No single marker currently meets all of these criteria.

Chromium oxide has been the most widely used external marker for estimation of intake during the last 50 yr (Huston et al., 1999). The primary problem associated with this marker is that it moves through the digestive tract independently of the undigested particles of the diet, and fecal concentrations of chromium may exhibit strong diurnal variation. Measuring daily DM intake with Cr requires a continuous period of Cr intake and frequent spot feces collection during different hours on the days following dosing. This additional handling of the animals is undesirable, particularly when it has potential to disturb established patterns of grazing behavior.

An alternative method of calculating fecal output from a single dose of Cr has been presented by (France et al., 1988). Animals are dosed once with labeled feed fractions, and numerous fecal samples are collected over a period of time long enough for the label source to clear the animal. A nonlinear equation relating time after dosing to fecal Cr concentration is used to generate parameters for the estimation of fecal output (Pond et al., 1989).

According to Buntinx et al. (1992), controlled-release Cr capsules offer the potential of reduced labor, coupled with the possibility of preventing adverse effects on

animal behavior from repeated daily dosing, or from the presence of fecal bags during total fecal collection. Controlled-release devices greatly reduce the within-day coefficient of variation for fecal concentration of Cr in sheep and cattle when compared with daily dosing (Adams et al., 1991). However, total fecal collection must be used on a subset of animals to correct for possible payout differences from manufacturer specifications and/or subsampling influences on chromium recovery.

Dosed and plant alkanes are options as external and internal markers, respectively. Mayes et al. (1984) showed that dosed even-chain length n-alkanes and naturally occurring odd-chain plant n-alkanes could be used as fecal markers to determine forage intake. Forage species contain variable quantities of alkanes, and the concentration of odd-chain alkanes may be too low in some tropical forages for them to be used as an internal marker (Laredo et al., 1991). The problems associated with species-specific alkane concentrations and analytical determination of the n-alkanes make the technique less likely to be used in a wide range of environments.

Associated with the use of inert markers in estimating DM intake of grazing animals is the requirement of knowing the digestibility of the animal's diet. Obtaining samples that represent the diet of the dosed animals can frequently be the major factor limiting the accuracy of the method. Surgically altered animals and "hand plucked" samples are the two most-used methods to obtain samples of the diet in grazing studies. After a representative sample is collected, the accuracy of the marker technique resides with the method used to estimate the absolute digestibility of the diet (Burns et al., 1991). In vitro dry matter digestibility has been the most-used method because it is cheap, precise, and in most of the cases, well correlated with in vivo digestibility. Although in

vitro dry matter digestibility (IVDMD) has perhaps been most widely used to predict digestible DM, a variety of internal markers also have been used.

Ingestive behavior has been suggested as a method of estimating daily DM intake (Coleman et al., 1989). The parameters to be measured are bite mass, bite rate, and grazing time. Mechanical methods for short-interval measurements have been reviewed, but recent advances have occurred through automation to aid quantification. Bite rate may be recorded by observing, listening, or by electronic devices, however, it is necessary to discriminate between biting and non-biting jaw movements. Artificial swards can be used in measurement of bite weight, or esophageal extrusa can be collected over a short period of time. Finally, grazing time can be recorded visually or by using electronic devices. Errors associated with these devices and especially with extrapolation of intake during short measurement periods to daily intake are the most common.

If the pastures are uniform and under intensive management, forage disappearance can provide a reasonable estimation of forage intake. Forage mass is measured before and after grazing, and the forage that disappears is considered to have been consumed. The technique is very labor intensive because a large number of sites have to be measured to provide an acceptable estimation of herbage mass. The difficulty of achieving accurate estimations of herbage mass, as well as trampling, defoliation by insects, and senescence, make the herbage disappearance technique not reliable enough to be recommended for routine estimates of pasture intake (Moore and Sollenberger, 1997).

The animal performance technique, also called "reverse energy calculations", is the calculation of intake by using, in reverse, accepted energy requirements for maintenance, growth, and lactation (McMeniman, 1997). For a given rate of performance, the daily

amount of energy that must be consumed in order to achieve that level of performance can be obtained from tables and equations. Accurate determinations of changes in body weight are required when using this technique. Digestibility is the main determinant of forage energy concentration and efficiency of energy utilization (Moore and Sollenberger, 1997). Digestibility of the forage can be obtained by the methods reported before, and concentration of digestible energy (DE) is calculated by assuming 4.4 Mcal DE kg<sup>-1</sup> DOM. Concentration of metabolisable energy (ME) is calculated by multiplying DE concentration by 0.82 and net energy for maintenance and for gain are calculated from ME concentration by (NRC, 1996). The main constraint of this technique is that factors other than forage energy concentration, such as nutrient imbalances and environmental effects may influence the efficiency of conversion of net energy for gain to animal product.

### **N Fractioning and in situ Methodology**

Diet formulation systems have been developed that attempt to balance diets for both ruminal protein degradability and carbohydrate availability with the goals of maximizing microbial protein synthesis and minimizing protein wastage as ammonia (Nocek and Russell, 1988). Rumen protein degradability is one of the most important qualitative factors determining the protein value of a feed. Protein degradability determines the supply to the rumen microbes of both ammonia and branched-chain amino acids, as well as the supply to the small intestine of the rumen-undegraded feed protein as a potential source for amino acid absorption.

The protein concentration in feeds may be expressed on a CP basis. The CP is composed of two fractions: rumen degradable protein (RDP) and rumen undegradable protein (RUP). The RDP consists of non-protein N and true protein while the RUP is

formed only by true protein. The protein degradation rate will vary depending on the proportions of NPN, true protein that degrades at variable rates, and unavailable protein (Pichard and Van Soest, 1977).

### **In situ Procedure**

Numerous methods currently are available for estimating ruminal DM and N disappearance of feedstuffs. The in situ technique involves the placement of indigestible bags containing a feedstuff into the rumen of a fistulated animal for various time intervals and the measurement of the amount of DM and N that disappears from the bags over time (Stern and Satter, 1984). According to Nocek (1988) there is no better way to simulate the rumen environment within a given feeding regime, although in the ruminal environment, the feed sample in the bag is not subject to the total ruminal experience: i.e.; mastication, rumination, and passage.

The in situ procedure can be used to quantify the protein fractions, the instantly degradable Fraction A; the undegradable fraction after an extended rumen incubation, Fraction C; and Fraction B, the slowly degradable fraction, obtained by difference ( $\% \text{Fraction B} = 100 - \% \text{Fraction A} - \% \text{Fraction C}$ ). Although the technique allows the quantification of the different N fractions of the forage as well as the rate of digestion of B, it cannot be used to quantify the rate at which A is degraded. Nocek (1985) demonstrated that a certain portion of the test feed escapes the bag prior to ruminal degradation. This fraction is generally assumed to be readily available to rumen microbes and digested at a rapid rate. Potentially degradable nutrient fractions have been described by first-order kinetic rate constants (Mertens, 1973). Primary assumptions are that the pools in question are homogeneous and that the substrate remaining will be degraded as a linear function of time in the rumen. Orskov and McDonald (1979) and other researchers

have developed mathematical models to fit the estimated ruminal degradability of feedstuffs. The most common approach included the use of non-linear regression. Mertens and Lofton (1980) proposed the inclusion of lag time for protein degradation in the models used for fitting N disappearance. If a delay appears at the beginning of the disappearance of Fraction B, a lag component should be included in the model (McDonald, 1981).

Various aspects of the in situ technique interact and can influence the interpretation of the results. Bag porosity is a compromise between limiting the influx of rumen contents not associated with the test feed and allowing influx of microbes to degrade the test feed, while at the same time limiting the efflux of undegradable feed particles (Nocek, 1988). Uden and Van Soest (1984) showed cell wall digestion of timothy (*Phleum pratense L.*) increased with increasing bag pore size (20, 37, and 53 µm). Digestion of DM was similar for pore size ranging from 40 to 102 µm, and estimated rumen N availability was greater for bags with pore size of 6 or 20 µm (Uden and Van Soest, 1984).

Feed particle size is another important aspect in the in situ disappearance determination. Generally, longer and coarser material is associated with slower rates of digestion and greater variation. However, finely ground materials are subject to greater mechanical losses from the bags (Nocek, 1988). The same author states different feedstuffs can require different particle sizes, and the particle size for cereal grains, fibrous products, forage, and silages ranges from 2 to 5 mm.

Sample weight is also an important consideration. The optimum sample weight is that which provides enough residue at the end of the extended rumen incubation for

chemical analysis without over-filling the bag so as delay bacterial attachment, increase lag time, and underestimate digestion rates (Nocek, 1988). For forages, Van Hellen and Ellis (1977) recommends  $10 \text{ mg cm}^{-2}$  of bag surface area, whereas Uden and Van Soest (1984) recommend  $\leq 6$  to  $7 \text{ mg cm}^{-2}$ .

The host animal diet is the major factor determining quantity and types of microbes and therefore the rate and extent of digestion of dietary nutrients. de Faria and Huber (1984) evaluated in situ DM digestion of corn silage, alfalfa (*Medicago sativa* L.) silage, and grass hay in diets containing three different protein ( $81, 113, 133 \text{ g kg}^{-1}$ ) and three different acid detergent fiber (ADF) concentrations ( $390, 299$ , and  $210 \text{ g kg}^{-1}$ ). Neither protein nor ADF of the host animals' diet had a significant effect on DM digestibility for any forage tested, however, specific sampling time by forage interaction was noted.

The animal species most commonly used for in situ experiments are cattle and sheep. Siddons and Paradine (1983) compared sheep and steers fed similar diets at maintenance. Sheep had higher ruminal ammonia N than steers, lower VFA, and similar ruminal pH and rumen dilution rate.

### **In situ Disappearance of Warm- and Cool-season Grasses**

High quality cool-season pastures and many tropical legumes would be expected to have high ruminal ammonia losses when their CP concentrations exceeded  $150 \text{ g kg}^{-1}$  because of the high concentration of ruminal degradable protein (Poppi and McLennan, 1995). According to Beever (1984),  $800$  to  $900 \text{ g kg}^{-1}$  of ryegrass CP can be degradable in the rumen. Van Vuuren et al. (1991) stated that OM and CP in situ total degradability decreased with increasing ryegrass sward maturity and with decreasing rate of N application. Salaun et al. (1999) studied the relation between N fertilization and rumen CP degradability of perennial ryegrass. They concluded that reducing N fertilizer

application decreased the theoretical degradability in the rumen due to decrease in the NPN. The total N disappearance was 600 and 710 g kg<sup>-1</sup> for plots fertilized with 250 and 550 kg N ha<sup>-1</sup>. Assis et al. (1999) did not find significant difference of CP Fraction A in Tifton 85 bermudagrass with levels of N fertilization from 0 to 400 kg ha<sup>-1</sup>. Yan and Agnew (2004) tested the effective degradability of perennial ryegrass N assuming a ruminal outflow rate of 0.02, 0.05, or 0.08 % h<sup>-1</sup>. The objective was to use these data to develop prediction equations for N degradability in C3 grass silages. At 0.02 % h<sup>-1</sup> ruminal outflow, total N degradability was 934 g kg<sup>-1</sup>. The N degradability was negatively related to ADF, NDF, and lignin concentrations but positively related to CP concentration.

Warm-season grass CP tends to be more slowly degraded in the rumen than that of cool-season grasses (Minson, 1990). Akin and Burdick (1975) concluded that digestibility differences between C3 and C4 grasses were associated with the parenchyma bundle sheath (PBS) of C4 grasses. The C4 plants have a lower soluble protein concentration (260 to 300 g kg<sup>-1</sup>) than C3 plants (330 to 480 g kg<sup>-1</sup>), which is thought to be mainly due to differences in Rubisco concentration and location. Further, PBS tissue from C4 plants, the primary location for Rubisco, is slowly or incompletely digested in the rumen (Akin and Burdick, 1975).

Redfearn et al. (1995) studied the rates of ruminal protein disappearance for switchgrass (*Panicum virgatum* L.), big bluestem (*Andropogon gerardii* Vitman), and smooth bromegrass (*Bromus inermis* Leyss.) and suggested that generalizations regarding ruminal protein degradability should not be made among forage species. The total protein disappearance was 847, 795, and 974 mg g<sup>-1</sup> for switchgrass, big bluestem, and smooth

bromegrass, respectively. Mandebvu et al. (1999) compared in situ disappearance of Tifton 85 and coastal bermudagrass. There was no difference in the potentially digestible fractions (A+B) among the cultivars with approximate values of  $600 \text{ g kg}^{-1}$ . Assis et al. (1999) evaluated the in situ N disappearance of *Cynodon spp*, Tifton 44 and Tifton 85 bermudagrasses, and ‘Puerto Rico’ stargrass. Tifton 85 had the smallest concentrations of the potentially digestible CP fractions (A+B), but it had the largest B fraction concentration. Johnson et al. (2001b) reported that with no fertilization, the Fraction A concentration was 212 (bahiagrass), 310 (bermudagrass), and  $279 \text{ g kg}^{-1}$  (stargrass) of the total N, but upon application of  $160 \text{ kg N ha}^{-1}$  per cutting, Fraction A represented 285 (bahiagrass), 400 (bermudagrass), and  $421 \text{ g kg}^{-1}$  (stargrass) of the total N. Newman et al. (2002a) fractionated the N content of limpograss at different grazing heights. Pastures grazed to 20 cm had the greatest proportion of soluble N and the least portion of undegradable CP. They concluded that low total CP in the DM, resulting in low concentrations of CP Fractions A and B in the rumen, and the long lag phase for degradation of the B fraction, may contribute to reported protein deficiencies of cattle grazing limpograss.

### **Other Methods to Estimate Ruminal Protein Degradation**

Although in vivo and in situ procedures for estimating degradability of protein are not without drawbacks, they are typically considered to most accurately reflect reality. However, labor requirements, cost, time, variability, and the need for access to fistulated ruminants limit the feasibility of widespread use of these procedures for routine analysis (Mathis et al., 2001). In vitro estimation of rumen-degradable protein is appealing because it addresses many of the limitations of in situ and in vivo procedures and would be relatively easy to standardize (Stern et al., 1997). While numerous in vitro methods are

currently available for estimating ruminal protein degradation of feedstuffs, assays based on *Streptomyces griseus* are probably the most commonly used (Roe et al., 1991).

In the *Streptomyces griseus* method, feeds are incubated in a borate-phosphate buffer at pH 7.8 to 8.0 to facilitate optimum enzyme activity, and enzyme is added at a level of 6.6 units of enzyme g<sup>-1</sup> sample DM (Krishnamoorthy et al., 1983). *Streptomyces griseus* is a broad spectrum, commercially available protease that has both exopeptidase and endopeptidase activity, as in the rumen.

Ruminal protein degradation also has been estimated by the ficin method, which breaks down protein by proteolytic ficin (*Ficus glabrata*) used at 8.24 units g<sup>-1</sup> of sample DM in a phosphate buffer at pH 6.5 (Poos-Floyd et al., 1985). Finally, the neutral protease with amylase method makes use of an endopeptidase, *Bacillus subtilis*, at 9.6 units g<sup>-1</sup> sample DM, in a sodium citrate buffer, in addition to an enzyme that contains endo-β-glucanase and α-amylase activities (Assounami et al., 1990).

Roe et al. (1991) compared the three in vitro methods of ruminal protein degradability with the in situ methodology. None of them resulted in feed protein degradation curves that had a consistent relationship with those generated by the in situ technique. However, relationships were found between protein degradability estimates obtained by the neutral proteases with the amylase method at specific time points and those measured in situ.

## CHAPTER 3

### SUPPLEMENTATION EFFECTS ON FORAGE CHARACTERISTICS AND PERFORMANCE OF EARLY WEANED CALVES GRAZING RYE-RYEGRASS PASTURES

#### **Introduction**

Grassland covers ~ 4.5 million ha in Florida and most of this area is utilized by beef cattle. Florida's beef cattle industry is based on cow-calf enterprises with a total of 950 000 beef cows. Sales of cows and calves accounted for \$348 million of income to Florida farmers and ranchers in 2003 (Florida Agriculture Statistics, 2004).

The profitability of the Florida cow-calf enterprise is largely dependent on the cow's productivity. The combination of low quality warm-season forages and forage quantity limitations during winter reduce cow reproductive performance. Early weaning the calves of young cows and first-calf heifers is a management strategy that has potential to address this problem. At early weaning, cow requirements for total digestible nutrients (TDN) decreases by as much as 49%. As a result they are able to restore body condition rapidly (Arthington and Kalmbacher, 2003). Heifers whose calves were weaned early had higher pregnancy rates (94%) than those whose calves were weaned at the normal time (65%) during a 2-yr study in South Florida (Arthington and Kalmbacher, 2003).

Although the benefits of early weaning, i.e., improving reproduction and reducing nutrient requirements of the cow, have been recognized for many years, the factor limiting practical application of early weaning has been management of the early weaned calves. Mild winters in the southern USA offer an opportunity to raise calves on pasture systems that include high nutritive value winter-annual forages (Arthington and

Kalmbacher, 2002). Annual ryegrass (*Lolium multiflorum* Lam.), a high-yielding, high quality grass, is the most commonly grown cool-season pasture forage in the southern and southeastern USA (Evers et al., 1997). The use of small grains such as oat (*Avena sativa* L.), wheat (*Triticum aestivum* L.), and rye (*Secale cereale* L.) in mixtures with ryegrass generally extends the grazing season (Rouquette et al., 1997). Small grains grow better from late December to mid-February, and ryegrass is most productive during March to late May.

The practice of raising early weaned calves on winter pastures is a feasible alternative, especially if pasture quality and quantity are superior to hay available for winter feeding (Barnes et al., 1996). Weder (1997) reported average daily gain of 0.8 kg d<sup>-1</sup> for early weaned calves grazing annual ryegrass, however, the limited ruminal capacity of early weaned calves at young ages may limit forage intake and result in low animal performance. Early weaned calves grazing wheat pastures consumed 27% less forage dry matter (DM) during the first 20 d exposed to pastures than during the subsequent 50 d (Paisley et al., 1998). The authors suggested that initial performance of early weaned calves was limited by low forage intake. Moreover, calves grazing high quality cool-season pasture may have high ruminal ammonia losses, if forage crude protein (CP) concentrations exceed 150 g kg<sup>-1</sup> (Poppi and McLennan, 1995). Loss of N from the rumen is costly due to significant energetic expenditure associated with urea synthesis and excretion. Non-structural carbohydrates are needed to utilize the forage N, to reduce energy cost of excreting N, and to supply nutrients to the small intestine. Microbial protein synthesis can become a performance-limiting factor for ruminants consuming ryegrass diets. Rocha et al. (2003) evaluated beef heifers grazing oat-annual

ryegrass with and without ground maize (*Zea mays* L.) supplement. Supplementation resulted in higher average daily gain, stocking rate, and production per unit of land area.

An effective supplementation program is necessary to overcome potentially low forage intake and maximize the efficiency of utilization of cool-season grasses in early weaned calf systems. The objective of this study was to evaluate the effect of different levels of concentrate on performance, stocking rate, gain per hectare, and forage intake of early weaned calves grazing rye-ryegrass pastures in North-Central Florida.

### **Material and Methods**

The study was located at the Beef Research Unit, 18 km northeast of Gainesville, FL (30° N). Data were collected during the 2003 and 2004 winter-spring seasons. The soils at the research site are Adamsville fine sand (Aquic Quartzipsammets, hyperthermic, uncoated) and Pomona sand (sandy, siliceous, hyperthermic Ultic Alaquod). These soils have from poor to somewhat poor drainage with rapid permeability. Prior to initiation of winter grazing, mean soil pH (1:2 soil:deionized H<sub>2</sub>O ratio) was 6.5, and Mehlich-I (0.05 M HCl + 0.0125 M H<sub>2</sub>SO<sub>4</sub>) extractable P, K, Mg, and Ca in the Ap1 horizon (0- to 15-cm depth) were 52, 19, 117, 761 mg kg<sup>-1</sup>, respectively.

Starting dates for the trial were 28 Jan. 2003 and 15 Jan. 2004. Grazing ended on 14 May 2003 and 29 Apr. 2004. Monthly rainfall totals and temperature data during the trial are presented in Table 1 (Appendix A).

In early October 2003 and 2004, the area was sprayed with 3.0 L ha<sup>-1</sup> of glyphosate (Monsanto Co., St. Louis, MO; isopropylamine salt [10 g kg<sup>-1</sup>] of N-phosphonomethyl glycine) to kill bahiagrass (*Paspalum notatum* Flügge). Three weeks later, the cool-season forages were planted using a no-till drill. The seeding rates were 20 kg ha<sup>-1</sup> of 'Jumbo' ryegrass and 80 kg ha<sup>-1</sup> of a mixed-blend rye ('Grazemaster'). All pastures

received an initial application of 40 kg N ha<sup>-1</sup>, 17 kg P ha<sup>-1</sup>, and 66 kg K ha<sup>-1</sup>, 3 wk after planting. Additional applications of 40 kg N ha<sup>-1</sup> were made in late December, early February, and early March in both years.

Calves were weaned on 2 Jan. 2003 and 5 Jan. 2004 at ~90 d of age and 100 kg of body weight (BW). They were held in dry lot for 7 d with access to bermudagrass [*Cynodon dactylon* L. (Pers.)] hay (ad libitum), 1 kg of pre-conditioning medicated concentrate d<sup>-1</sup>, and water. Early weaned calves were Angus-sired (crossbred-cows sired by Angus bulls) products from primiparous and multiparous cows in 2003 and 2004, respectively. Calves were dewormed with Ivermectin 10 g kg<sup>-1</sup> concentration (Ivomec, Merck & Company, Rahway, New Jersey, USA) on 10 Apr. 2003, and 12 Feb. and 29 Apr. 2004.

Pasture size was 0.2 ha, and each pasture was subdivided into four paddocks. Pastures were rotationally stocked with a 7-d grazing and 21-d resting period. Two early weaned calves (1 steer and 1 heifer) were assigned as testers to each experimental unit such that BW was equal ( $\pm 5$  kg) across all experimental units. "Put and take" early weaned calves of comparable age and weight to the testers were used to maintain similar herbage allowance across experimental units. The literature does not define specific herbage allowance targets for the species in this study, thus our primary objectives in managing pasture quantity were to avoid i) low herbage allowances that would limit calf ADG and ii) variation among experimental units in herbage allowance within a year that could be confounded with the responses to supplement treatment. It was also recognized that variable growth conditions, especially due to rainfall, could result in year differences in herbage allowance.

Treatments were three levels of a commercial pelleted concentrate, 10, 15, and 20 g kg<sup>-1</sup> of calf BW, offered daily. Each treatment was replicated three times in a completely randomized design, so there were a total of nine experimental units in the study. In 2004, for observation purposes, two experimental units were added to the study in which the EWC did not receive concentrate supplementation. The concentrate composition is described in Table 3.1. A salt-based trace mineral mix was supplied free choice throughout the grazing season.

### **Pasture Sampling**

In each 28-d grazing cycle, herbage mass was determined twice using a double-sample technique (on Paddocks 1 and 3). Indirect estimates of herbage mass were done using a 0.25-m<sup>2</sup> aluminum disk plate meter, and direct measures were done by clipping herbage in the same area to a 3-cm stubble. Twenty disk settling height measures were taken the day before the paddock was grazed and twenty were taken at the end of the grazing period. Twenty, 0.25-m<sup>2</sup> sites, representing the range of herbage mass on the nine pastures, were selected for disk calibration once a month. Disk height was measured and the herbage at these sites was then clipped to a stubble height of 3 cm, dried at 60°C in a forced-air drier to constant weight, and weighed. A calibration equation was developed using these double sampling data by regressing actual herbage mass on disk height. To predict herbage mass for any given pre- or post-graze sampling date, the average of the 20 disk heights measurements was calculated and entered into the calibration equation. The regression equations and r<sup>2</sup> for each double sampling date are shown in Table 2 (Appendix A).

Table 3-1. Ingredient and chemical composition of supplement fed to early weaned calves on pasture (DM basis).

Ingredients	Concentration ( $\text{g kg}^{-1}$ )
Corn meal	25.0
Wheat middling	400.0
Soybean meal (48% CP)	25.0
Cottonseed meal (41% CP)	50.0
Soybean hulls	392.5
Cottonseed hulls	32.5
Calcium carbonate	12.5
Salt	6.3
Quadra-plex	1.3
Molasses	50.0
Chemical composition <sup>†</sup>	( $\text{g kg}^{-1}$ DM)
Dry matter	900.0
Ash	62.3
Crude protein	146.9
TDN	700.0
Calcium	7.6
Phosphorus	5.7
Salt	6.3
Sodium	3.7
Magnesium	2.5
Potassium	12.6
Sulfur	1.4
Cobalt ( $\text{mg kg}^{-1}$ )	3.36
Cooper ( $\text{mg kg}^{-1}$ )	30.48
Iodine ( $\text{mg kg}^{-1}$ )	0.12
Iron ( $\text{mg kg}^{-1}$ )	200.12
Manganese ( $\text{mg kg}^{-1}$ )	111.84
Selenium ( $\text{mg kg}^{-1}$ )	0.15
Zinc ( $\text{mg kg}^{-1}$ )	103.13

<sup>†</sup>Provided by the manufacturer (Lakeland Animal Nutrition)

Pregraze herbage mass during a grazing cycle was calculated as the average of

Paddocks 1 and 3. Herbage accumulation for a given paddock was calculated by

subtracting postgraze herbage mass of cycle  $n-1$  from pregraze herbage mass of cycle  $n$ .

Average herbage allowance was computed as the ratio of average herbage mass

$[(\text{pregraze} + \text{postgraze}) / 2]$  to early weaned calf liveweight exposed to the experimental

unit during the grazing period (Sollenberger et al., 2005). Stocking rate (SR) was a response variable (variable SR study) and was expressed as animal units (AU; 1 AU = 500 kg of liveweight  $^{0.75}$ ) ha $^{-1}$ .

Hand-plucked samples were used to estimate nutritive value of the grazed portion of the canopy. Samples were taken at 20 locations per paddock on the day prior to grazing and herbage was removed to the stubble height at which the previous paddock was grazed. These samples were dried at 60°C in a forced-air drier to constant weight, ground in a Wiley mill to pass a 1-mm stainless steel screen, and taken to the laboratory for analyses. Nitrogen concentration was measured using a modification of the aluminum block digestion technique (Gallaher et al., 1975). Concentration of CP in herbage DM was calculated as N x 6.25. In vitro digestible organic matter (IVDOM) concentration was determined by the two-stage procedure of Tilley and Terry (1963) modified by Moore and Mott (1974).

Rumen degradable protein and rumen undegradable protein were estimated by the in vitro method proposed by Roe et al. (1991). Hand-plucked samples from 15 g kg $^{-1}$  BW supplement treatment pastures were analyzed. Samples were incubated in a buffer/protease solution for 48 h, the residue recovered through filtering, and it was analyzed for CP concentration. Rumen degradable protein is that which was digested during 48 h, and rumen undegradable protein is the difference between the original CP content and the rumen degradable protein.

### **Animal Response Variables**

Total organic matter intake (OMI) was computed based on fecal output and diet digestibility, viz., total OMI= OM output of feces / (1- [OM digestibility/ 100]). Fecal output was estimated using a controlled release Cr marker (Captec New Zealand Limited,

Auckland, New Zealand). The devices were administered orally to tester calves on 25 Mar. 2003 and 26 Feb. 2004. Four fresh fecal samples were obtained during the morning on Days 11, 13, 15, and 17 after administration.

In addition, four early weaned calves fitted with the controlled release chromium marker were used for total fecal collection from Days 11 to 17 after dosing. These four calves were confined in metabolic crates and fed freshly harvested rye-ryegrass ad libitum and were supplemented with 15 g kg<sup>-1</sup> BW concentrate. The total daily fecal output from each calf was collected, weighed, mixed and a subsample analyzed for DM and Cr concentration. Total Cr output was calculated by multiplying the fecal Cr concentration by total daily fecal weight. The total daily Cr output was used to estimate total fecal output of the tester calves by relating total daily Cr output and Cr concentration in the feces OM. Individual daily total Cr output is described in Tables 3 and 4 (Appendix A).

Fecal samples were dried at 60°C in a forced-air oven and ground in a Wiley mill to pass a 4-mm stainless steel screen. Chromium concentration in the feces was assayed by atomic absorption spectrophotometry following the procedure described by Williams et al. (1962). The samples were analyzed by d of collection in duplicate and analyses were repeated for samples where the difference of Cr concentration between duplicates exceeded 100 g kg<sup>-1</sup>.

Total OMI was calculated based on fecal output estimations and IVDOM of the respective pasture herbage. Forage OMI was the difference between total OMI and the known amount of concentrate OM fed. The fecal output estimated with the marker did not equal the fecal output predicted based on estimated forage and supplement

digestibilities. For this reason, an interactive SAS Institute Inc. (1991) program was used to adjust the total OMI based on the equations developed by Moore et al. (1999). This adjustment accounted for the differences in total diet digestibility due to associative effects from concentrate and forage (Appendix A).

To calculate the forage intake, the following assumptions were made:

1) Digestibility of forage and supplement were determined by IVDOM

2) Digestibility of forage was affected by the level of supplement intake, as

determined by the equations described by Moore et al. (1999)

Diurnal grazing time of calves was evaluated on a 28-d interval. Calves were observed and actual grazing time recorded from 0700 to 1800 h. These observations were performed on the first day of the grazing period in Paddock 2 of each grazing cycle.

The weight of the animals was recorded on a 28-d interval at 0900 h. The change in unshrunk weight of the tester animals was used to calculate average daily gain (ADG). Liveweight (LWG) per ha in each 28-d period was determined based on the ADG of the testers multiplied by the number of calves within the pasture during that period and adjusted to a hectare basis.

In 2004 only, blood was collected from the jugular vein on a 28-d interval. Samples were collected into 9-mL, Na-heparinized syringes (Luer Monovette, ® LH, Sarstedt, Inc., Newton, NC) and placed on ice. Blood was centrifuged (2000 xg rcf for 30 min) and plasma was separated and frozen at -20°C on the same day. Blood urea N (BUN) was determined using a kit (Kit B-7551-120, Pointe Scientific, Inc., Detroit, MI) and read on a plate reader at 620 nm.

### **Economic Analysis**

The data and assumptions used in the economic analysis were:

- Concentrate cost = \$0.22 kg<sup>-1</sup>
- Calf price = \$2.2 kg<sup>-1</sup>
- Days of grazing = 100 d

Where LW = calf liveweight per hectare, formulas used to calculate the results were:

$$\text{Concentrate cost ha}^{-1} = \text{LW} * \text{Concentrate level} * \text{Days of grazing} * \text{Concentrate cost}$$

$$\text{Income ha}^{-1} = \text{gain ha}^{-1} * \text{calf price}$$

The return was the difference between concentrate cost ha<sup>-1</sup> and income ha<sup>-1</sup>.

The objective of the economic analysis was to compare the specific treatments used in this study; it should not be extrapolated to a wide range of production systems.

### **Statistical Analysis**

All responses were analyzed by fitting mixed effects models using the PROC MIXED procedure of SAS (SAS Institute Inc., 1996). Replicate and its interactions were considered random effects. Single degree of freedom orthogonal polynomial contrasts were used to test concentrate effects. Treatments were considered different when  $P < 0.05$ . Interactions not discussed in the Results and Discussion section were not significant ( $P > 0.05$ ). The means reported in this text are least squares means.

For pasture and pasture-animal interface variables, the model used was:

$$Y_{ijk} = \mu + A_i + T_j + P_k + (AT)_{ij} + (AP)_{ik} + (TP)_{jk} + (ATP)_{ijk} + e_{ijk}$$

Where  $Y_{ijk}$  is the dependent variable

$\mu$  is the overall mean

$T_j$  is the concentrate effect (main plot)

$A_i$  is the year effect (sub-plot)

$P_k$  is the period effect (sub-sub-plot)

$(AT)_{ij}$  is the year\*concentrate interaction

$(AP)_{ik}$  is the year\*period interaction

$(TP)_{jk}$  is the concentrate\*period interaction

$(ATP)_{ijk}$  is the year\*concentrate\*period interaction

$e_{ijk}$  is the error

Main plot (concentrate) error was replicate\*concentrate; sub-plot (year) error was replicate\*year; sub-sub-plot (period) error was the residual.

For the animal variables, the model used was:

$$Y_{ijkl} = \mu + A_i + T_j + P_k + S_l + (AT)_{ij} + (AP)_{ik} + (PS)_{kl} + (AS)_{il} + (TP)_{jk} + (TS)_{jl} \\ + (ATP)_{ijk} + (ATS)_{ijl} + (TPS)_{jkl} + (ATPS)_{ijkl} + e_{ijkl}$$

Where  $Y_{ijkl}$  is the dependent variable

$\mu$  is the overall mean

$T_j$  is the concentrate effect (main plot)

$A_i$  is the year effect (sub-plot)

$S_l$  is the sex effect (sub-sub-plot)

$P_k$  is the period effect (sub-sub-sub-plot)

$(AT)_{ij}$  is the year\*concentrate interaction

$(AP)_{ik}$  is the year\*period interaction

$(AS)_{il}$  is the year\*sex interaction

$(TP)_{jk}$  is the concentrate\*period interaction

$(TS)_{jl}$  is the concentrate\*sex interaction

$(PS)_{kl}$  is the concentrate\*sex interaction

$(ATP)_{ijk}$  is the year\*concentrate\* period interaction

$(ATS)_{ijl}$  is the year\*concentrate\*sex interaction

$(TPS)_{jkl}$  is the concentrate\*period\*sex interaction

$(ATPS)_{ijkl}$  is the year\*concentrate\*period\*sex interaction

$e_{ijkl}$  is the error

Main plot (concentrate) error was replicate\*concentrate; sub-plot (year) error was replicate\*year; sub-sub-plot (sex) error was replicate\*sex; sub-sub-sub-plot (period) error was the residual.

## **Results and Discussion**

### **Pasture Responses**

There were no differences in pregraze herbage mass among the different levels of concentrate (Table 3-2). There was a significant year\*period interaction that occurred because herbage mass was greater during January to March 2004 than in 2003, but there was no year effect for April (Fig. 3-1). The greater rainfall from November 2002 to March 2003 (Fig. 3-2) resulted in pastures with excessive soil moisture and likely reduced the efficiency of utilization of N fertilizer causing lesser herbage mass during the first 3 mo of the 2003 experimental period. The soils at the research site are characterized by poor to somewhat poor drainage and are susceptible to flooding under conditions of excessive rainfall. In contrast, limited rainfall in March and April 2004 likely resulted in lesser mass during April than in January through March.

Macoon (1999) reported average herbage mass on rye-ryegrass pastures of  $1.4 \text{ Mg ha}^{-1}$  for dairy cows at a SR of five cows  $\text{ha}^{-1}$ . In that study, there was a significant effect of month of sampling. Herbage mass was greater ( $1.3 \text{ Mg ha}^{-1}$ ) in March than in January ( $0.8 \text{ Mg ha}^{-1}$ ). According to Rouquette et al. (1997), small grains grow better from late

December to mid-February and ryegrass has rapid forage growth during March to late May, and as a result stocking rate often needs to be increased to efficiently use ryegrass pastures. In the current study, this type of response was observed only in 2003.

Table 3-2. Pregraze herbage mass and herbage accumulation of rye-ryegrass pastures grazed by early weaned calves supplemented with three levels of concentrate. (BW=body weight)

Concentrate g kg <sup>-1</sup> BW	Herbage mass Mg ha <sup>-1</sup>	Herbage accumulation kg ha <sup>-1</sup> d <sup>-1</sup>
10	1.6	31
15	1.5	27
20	1.7	35
Polynomial contrast	NS <sup>†</sup>	NS
P value	≥ 0.18	≥ 0.44
SEM	0.1	3.0

<sup>†</sup>NS = not significant

Herbage accumulation was similar among treatments, with an average of 31 kg DM ha<sup>-1</sup>d<sup>-1</sup> (Table 3-2). These rates are comparable to those reported by Assmann et al. (2004). In their study in southern Brazil, ryegrass pastures were grazed by beef steers (3 AU ha<sup>-1</sup>), fertilized with 100 kg N ha<sup>-1</sup>, and herbage accumulation was 37 kg DM ha<sup>-1</sup>d<sup>-1</sup>. For heavily-stocked (5 cows ha<sup>-1</sup>) rye-ryegrass pastures grazed by lactating dairy cows, Macoon (1999) observed 22 kg DM ha<sup>-1</sup>d<sup>-1</sup>.

There was a significant year\*period interaction for herbage accumulation (Fig. 3-3). This interaction occurred because herbage accumulation in April 2003 was much greater than in 2004, while in other months there were no differences. Excessive rainfall during November and December 2002 (220 mm vs. 30-yr average of 133 mm) resulted in standing water in some pastures and decreased herbage accumulation during the first 2 mo after planting. In April and May 2003, soils retained sufficient moisture despite fewer

rainfall events to provide a better growth environment for the plants. In contrast, the decreased herbage accumulation in April 2004 reflects lower than normal rainfall in March (51 vs. 30-yr average of 93 mm) and April (26 vs. 30-yr average of 75 mm) of that year (Fig. 3-2).

Table 3-3. Herbage crude protein (CP) and in vitro digestible organic matter (IVDOM) concentrations of rye-ryegrass pastures grazed by early weaned calves supplemented with three levels of concentrate. (BW=body weight)

Concentrate g kg <sup>-1</sup> BW	CP g kg <sup>-1</sup> DM	IVDOM g kg <sup>-1</sup> OM
10	273	841
15	282	837
20	283	838
Polynomial contrast	NS <sup>†</sup>	NS
P value	≥ 0.13	≥ 0.51
SEM	4.0	3.0

<sup>†</sup>NS = not significant

There was no concentrate level effect on herbage CP and IVDOM (Table 3-3). The CP concentrations were greater in 2004 (302 g kg<sup>-1</sup>) than 2003 (257 g kg<sup>-1</sup>) in all periods likely because the very high rainfall during parts of the 2003 season. An anaerobic root environment caused by excess rain can decrease absorption of N, resulting in lesser N concentration in the plants (Salisbury and Ross, 1991). Also, heavy rain likely leached some N out of the root zone.

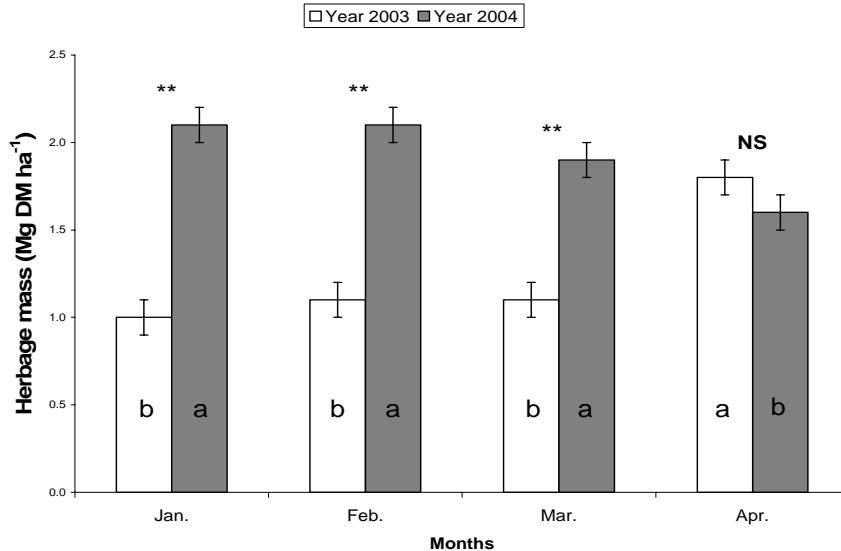


Fig. 3-1. Year\*period interaction effect on pregraze herbage mass of rye-ryegrass pastures grazed by early weaned calves supplemented with different levels of concentrate. Year effect within period; \*\*,  $P \leq 0.01$ ; NS= not significant. Period effect within year; means are different if followed by different letters ( $P \leq 0.05$ ).

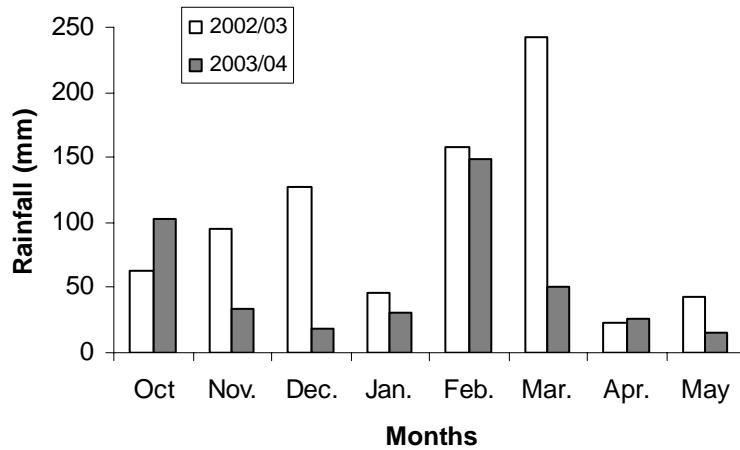


Fig. 3-2. Rainfall distribution from October to May 2002/03 and 2003/04.

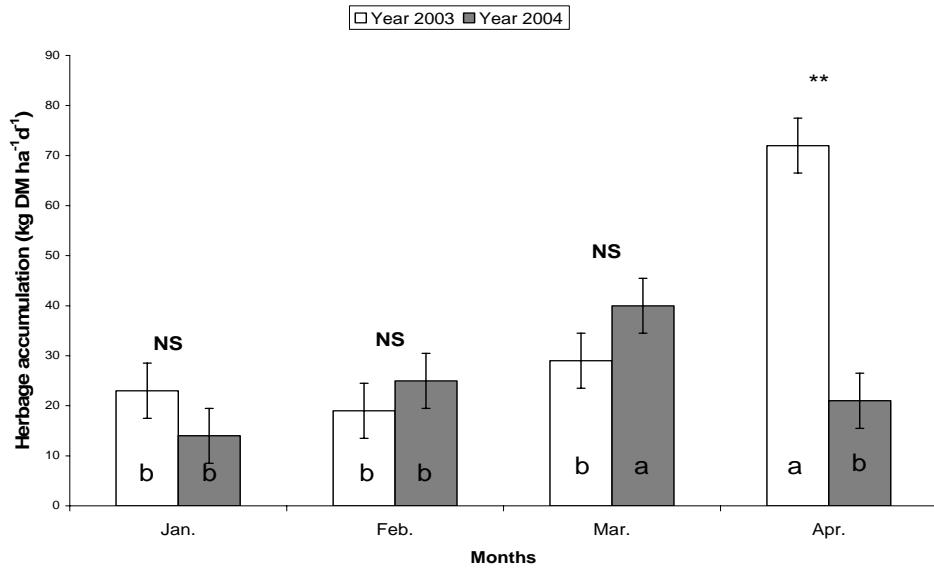


Fig. 3-3. Year\*period interaction effect on average herbage accumulation of rye-ryegrass pastures grazed by early weaned calves supplemented with different levels of concentrate. Year effect within period; \*\*,  $P \leq 0.01$ ; NS= not significant. Period effect within year; means are different if followed by different letters ( $P \leq 0.05$ ).

There was a year\*period interaction for CP concentration (Fig. 3-4). The herbage CP concentration was least in January compared to other months because of maturity. There was greater length of growth period of this forage herbage (~80 d from planting) relative to regrowth grazing (21 d). Additionally, the lowest CP observed in this study was in January 2003 following very heavy November and December rains. The greater CP concentrations in February and March are associated with the dates of N fertilization on the pastures (early February and early March).

There also was year\*period interaction for IVDOM (Fig. 3-5). There was a significant year effect on IVDOM concentration in January only. The IVDOM was not affected by climatic conditions to the same degree as herbage mass, accumulation, and CP concentrations were. The IVDOM decreased in both years, from January to April, primarily because of the presence of reproductive tillers after February. Highest IVDOM,

unlike CP, occurred in January. Other studies (Chapter 5) have shown cool-season grass IVDOM to be relatively insensitive to length of regrowth period during winter.

The CP and IVDOM concentrations were similar to the average CP ( $285 \text{ g kg}^{-1}$ ) and IVDOM ( $756 \text{ g kg}^{-1}$ ) values reported by Arthington and Kalmbacher (2002) for ryegrass pastures grazed by early weaned calves. Redfearn et al. (2002) showed CP and IVDMD concentrations to be 232 and  $846 \text{ g kg}^{-1}$ , respectively, for ryegrass pastures grazed by beef steers.

Fractionation of CP showed ruminal-degradable protein concentration to be  $730 \text{ g kg}^{-1}$  CP and ruminal-undegradable protein concentration to be  $270 \text{ g kg}^{-1}$  CP (data not shown). These very high concentrations of ruminal degradable protein have the potential to result in significant loss of N in ruminants. Excessive ruminal-degradable protein consumed by the animal is absorbed by the rumen epithelium and excreted as urea in the urine. The NRC (1996) reported lower values for the ruminal degradable protein of ryegrass hay ( $650 \text{ g kg}^{-1}$ ). Using the in situ methodology, Michalet-Douren and Ould-Bah (1992) observed similar ruminal degradable protein concentration of  $740 \text{ g kg}^{-1}$  on ryegrass hay.

Herbage allowance was similar among the treatments (Table 3-4). This was achieved by increasing SR on high concentrate treatment pastures to account for substitution of concentrate for forage. The average herbage allowance through the experimental period was greater in 2004 (0.8) than in 2003 (0.4) due to superior fall growth preceding the initiation of grazing in the second year.

Table 3-4. Herbage allowance and SR of rye-ryegrass pastures grazed by early weaned calves supplemented with three levels of concentrate. (BW=body weight)

Concentrate g kg <sup>-1</sup> BW	Herbage allowance kg DM kg <sup>-1</sup> BW	SR <sup>†</sup> AU ha <sup>-1</sup>
10	0.62	5.5
15	0.59	5.9
20	0.66	6.5
Polynomial contrast	NS <sup>‡</sup>	L
P value	≥ 0.38	< 0.01
SEM	0.02	0.13

<sup>†</sup>AU = 500 kg BW<sup>0.75</sup>

<sup>‡</sup>NS = not significant, L = linear

Phillips (1989) reported that to prevent a decline in individual dairy cow performance, herbage allowance should allow for dry matter intake of at least 40 g OM kg<sup>-1</sup> BW d<sup>-1</sup>. McCartor and Rouquette (1977) studied the effect of different levels of herbage allowance on performance of beef calves grazing pearl millet [*Pennisetum glaucum* (L.) R. Br.] and concluded that animal performance declines as herbage allowance levels fall below 1 kg DM kg<sup>-1</sup> BW. According to Le Du et al. (1979), the maximum intake of cool-season grasses occurs when herbage allowance is at least twice the herbage intake. The average herbage allowance observed in this study was always more than twice the early weaned calves' forage intake.

There was no correlation ( $r^2 = 0.03$ ) between herbage allowance and ADG (Table 3-5) of the calves implying that factors other than herbage allowance were influencing animal performance.

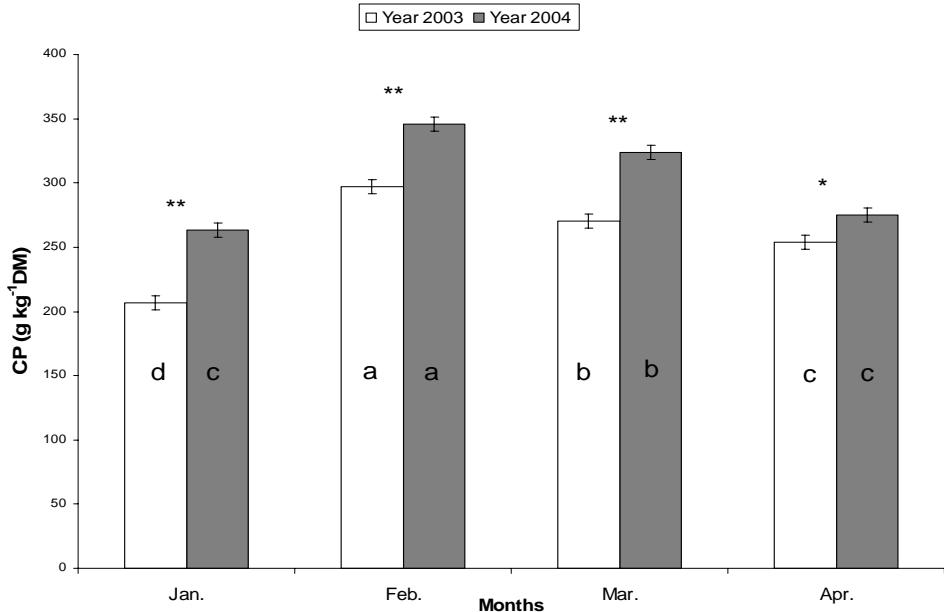


Fig. 3-4. Year\*period interaction effect on crude protein (CP) concentration of rye-ryegrass pastures grazed by early weaned calves supplemented with different levels of concentrate. Year effect within period; \*\*,  $P \leq 0.01$ ; \*,  $P \leq 0.05$ ; NS= not significant. Period effect within year; means are different if followed by different letters ( $P \leq 0.05$ ).

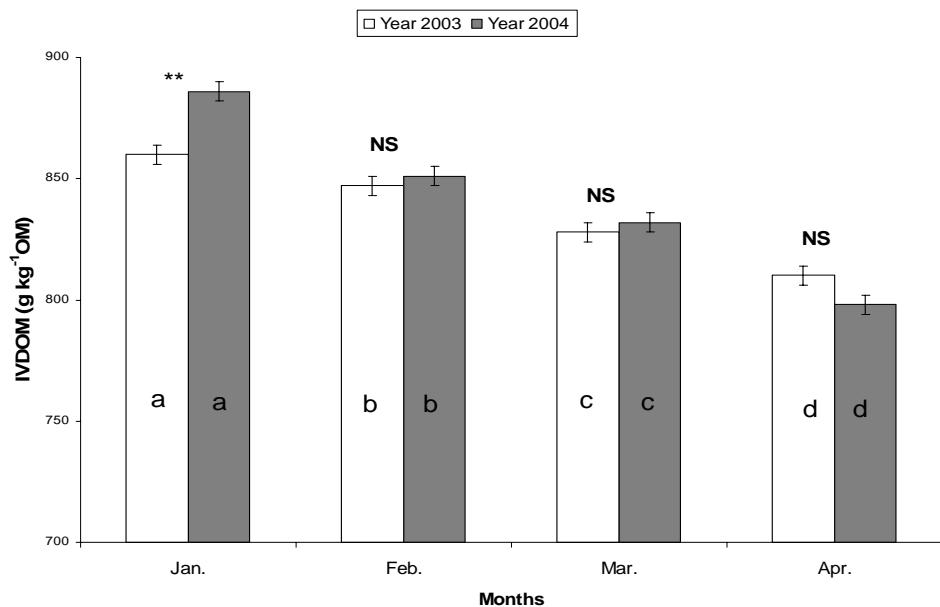


Fig. 3-5. Year\*period interaction effect on in vitro digestible organic matter (IVDOM) concentration of rye-ryegrass pastures grazed by early weaned calves supplemented with different levels of concentrate. Year effect within period; \*\*,  $P \leq 0.01$ ; NS= not significant. Period effect within year; means are different if followed by different letters ( $P \leq 0.05$ ).

There was a significant year\*period interaction on herbage allowance (Fig. 3-6).

There was no difference in herbage allowance during January and February 2003.

Herbage allowance was less in March than January, but there was no difference between February and March. During April, herbage allowance was greater than in the other months. This was a result of the greater herbage accumulation (Fig. 3-1) during that month. In 2004, herbage allowance was greatest in January and decreased through April. High herbage allowance in January 2004 was due to excellent forage growth during fall 2003 and conservative stocking decisions to start the experiment in 2004.

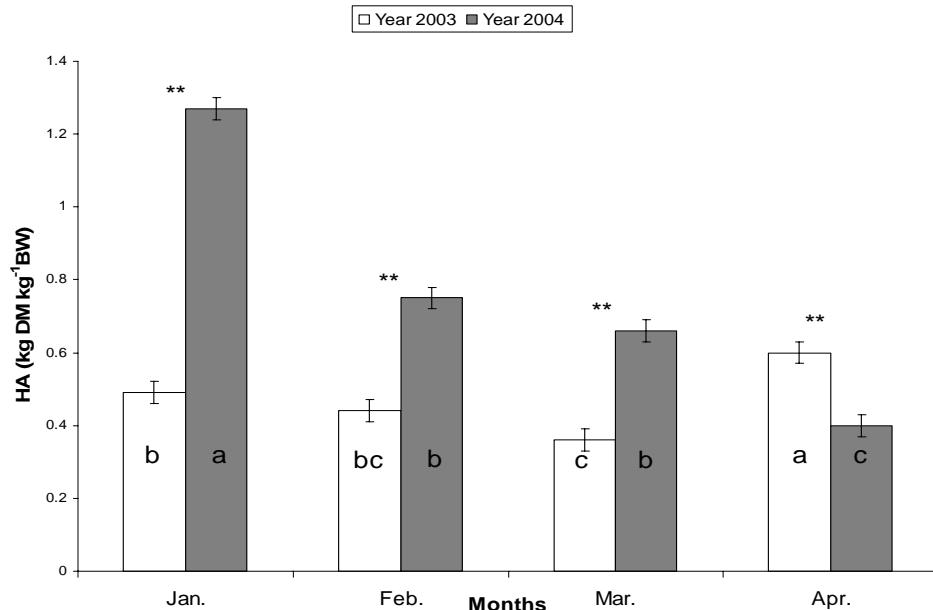


Fig. 3-6. Year\*period interaction effect on herbage allowance of rye-ryegrass pastures grazed by early weaned calves supplemented with different levels of concentrate. Year effect within period; \*\*,  $P \leq 0.01$ ; NS= not significant. Period effect within year; means are different if followed by different letters ( $P \leq 0.05$ ).

Horn et al. (1995) conducted a 3-yr experiment to evaluate the influence of energy supplements on performance of stocker cattle grazing wheat pasture. They concluded that energy supplements, such as maize and soybean [*Glycine max* (L.) Merrill] hulls, when fed at  $7.5 \text{ g kg}^{-1}$  BW allowed a 33% increase in stocking rate compared to

unsupplemented calves. In this study, there was 18% increase in SR when the supplement level was increased from 10 to 20 g kg<sup>-1</sup> BW (Table 3-5).

### **Animal Response Variables**

There was a linear increase in ADG and LWG as supplementation level increased (Table 3-5). The average daily gain reported for calves supplemented at the 10 g kg<sup>-1</sup> BW concentrate level in this study was the same as that reported by Arthington and Kalmbacher (2003) for calves grazing ryegrass in south Florida. There were no effects due to sex or year on ADG, however, there was a year\*period interaction (Fig. 3-7). The decrease in ADG during February and March 2003 was associated with an infestation of endoparasites that was not detected by visual examination. After the depression in ADG was observed in March, feces samples were collected, examined, and a high incidence of parasites detected. Calves were individually treated with 6 ml of Ivermectin (10 g kg<sup>-1</sup>) and a large increase in ADG was observed during April.

The ADG and LWG of calves that did not receive concentrate supplementation were 0.3 kg d<sup>-1</sup> and 650 kg ha<sup>-1</sup>, respectively. These values were well below the ADG and gain per ha of calves supplemented with 10 g kg<sup>-1</sup> BW in concentrate, 0.74 kg d<sup>-1</sup> and 950 kg ha<sup>-1</sup>, respectively. Although the forage had nutritive value similar to the concentrate, the low DM concentration (150-180 g kg<sup>-1</sup>) of the forage may be limited the total OMI of the animals resulting in decreased performance.

The linear increase in LWG was a function of the linear increase in both SR and ADG as concentrate level increased. Horn et al. (1995) observed greater LWG on steers grazing wheat pastures supplemented with concentrate at 7.5 g kg<sup>-1</sup> BW (153 kg ha<sup>-1</sup>) than for the unsupplemented calves (103 kg ha<sup>-1</sup>). Restle et al. (2000) studied beef heifers grazing oat-ryegrass pastures fertilized with 200 kg N ha<sup>-1</sup> under continuous stocking.

Average daily gain and LWG were  $0.58 \text{ kg d}^{-1}$  and  $429 \text{ kg ha}^{-1}$ , respectively, less than the values in our study. The results of the current study agree with the literature on the effects of supplementation on beef calves grazing cool-season grass pastures, i.e., energy supplementation leads to substitution of forage by concentrate, allowing higher stocking rates and gains per unit land area.

There was no difference in total OMI among treatments; however, there was a linear decrease in forage OMI with increasing levels of supplement (Table 3-6). Total OMI was similar to that reported by Paisley et al. (1998) for early weaned calves grazing wheat pastures ( $28 \text{ g kg}^{-1}$  BW). In general, forage intake is decreased by feeding concentrate when forage quality is high, other nutrients are in balance with energy, and concentrate is fed in large amounts (Moore, 1994). Carey et al. (1993) supplemented beef steers grazing tall fescue (*Festuca arundinacea* Schreb.) pastures with different sources of energy. Forage intake was less for steers supplemented with energy than for control steers, but total intake (forage + supplement) did not differ among treatments. Cravey (1993) reported substitution ratios of 1:0.93 (forage:concentrate) when steers grazing wheat pastures were fed energy concentrate at  $10 \text{ g kg}^{-1}$  BW. The substitution rate of concentrate OM (0.8, 1.2, and 1.6 for 10, 15, and  $20 \text{ g kg}^{-1}$  treatment respectively) for forage OM in the current study was 1:1 and consistent across treatments, confirming observations in the literature of substitution of forage by concentrate intake at similar proportions by calves receiving high amounts of energy supplement and grazing high nutritive value cool-season pastures.

Table 3-5. Average daily gain (ADG) and liveweight gain (LWG) of early weaned calves grazing rye-ryegrass pastures and supplemented with three levels of concentrate. (BW=body weight)

Concentrate g kg <sup>-1</sup> BW	ADG kg d <sup>-1</sup>	LWG <sup>†</sup> kg ha <sup>-1</sup>
10	0.74	950
15	0.81	1080
20	0.89	1320
Polynomial contrast	L <sup>‡</sup>	L
P value	≤ 0.01	≤ 0.01
SEM	0.03	42

<sup>†</sup>Gain per ha during a 106-d period.

<sup>‡</sup>L = linear

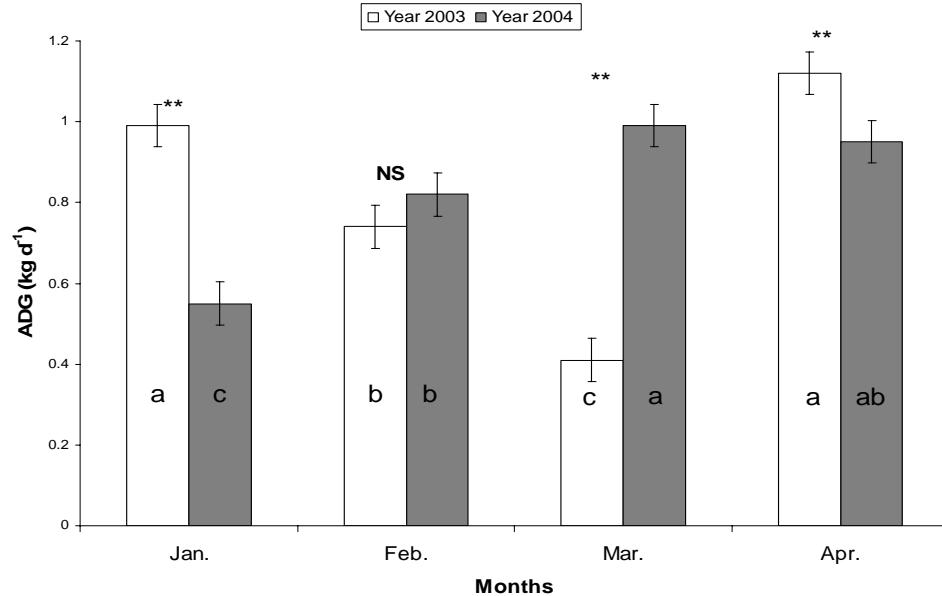


Fig. 3-7. Year\*period interaction effect on average daily gain of early weaned calves grazing rye-ryegrass pastures and supplemented with different levels of concentrate. Year effect within period; \*\*,  $P \leq 0.01$ ; NS= not significant. Period effect within year; means are different if followed by different letters ( $P \leq 0.05$ ).

The greater ADG at higher concentrate levels despite similar total intake may be a function of the different sources of nutrients provided by the concentrate that resulted in

better N and energy synchronization in the rumen and increased microbial protein production. In addition concentrate had more rumen-undegradable protein than the forage, potentially leading to more amino acids being absorbed post rumen and decreasing the levels of ammonia absorbed by the rumen epithelium. Absorption and excretion of excess ammonia is a process that spends energy that otherwise could be used to improve animal performance. Calves that received greater concentrate rates spent less time grazing during daylight (Table 3-7) likely reducing their energy requirement for maintenance. This could also be a factor contributing to greater ADG for calves receiving greater levels of concentrate, despite total OMI being the same across treatments..

Table 3-6. Total organic matter intake (OMI) and forage OMI of rye-ryegrass pastures grazed by early weaned calves supplemented with three levels of concentrate. (BW=body weight)

Concentrate -----g kg <sup>-1</sup> BW-----	Total OMI <sup>†</sup> ----- (% BW)-----	Forage OMI
10	2.6	1.8
15	2.4	1.3
20	2.7	1.1
Polynomial contrast	NS <sup>‡</sup>	L
P value	≥ 0.68	< 0.01
SEM	0.01	0.01

<sup>†</sup>Total OMI intake data adjusted according to Moore et al. (1999).

<sup>‡</sup>NS = not significant, L = linear

Grazing time differed among the calves receiving different levels of concentrate.

Calves supplemented with 10 g kg<sup>-1</sup> BW concentrate spent more time grazing during daylight hours than calves receiving 15 and 20 g kg<sup>-1</sup> BW (Table 3-7). There was no sex effect on grazing time.

In research with yearling beef steers grazing ryegrass, Adams (1985) reported that although there was an 11% decrease in forage intake by supplemented calves compared with control calves, total daily grazing time was not altered. Macoon (1999) observed that dairy cows supplemented with high levels of concentrate spent less time grazing (135 min) than cows that received low rates of concentrate (180 min). Cowan et al. (1977) observed decreased grazing time of 23 min d<sup>-1</sup> for each additional kg of concentrate fed to cows grazing grass-legume pastures. Increased grazing time in the current study suggests that calves supplemented with lower rates of concentrate grazed longer during the day in an attempt to meet their nutritional requirements. According to Macoon (1999), lactating cows receiving low levels of concentrate tended to increase the night-time grazing as well.

Table 3-7. Grazing time during daylight hours of early weaned calves grazing rye-ryegrass pastures and supplemented with different levels of concentrate.

Concentrate g kg <sup>-1</sup> BW	Grazing time min
10	284
15	230
20	234
Polynomial contrast	Q <sup>†</sup>
P value	< 0.08
SEM	17

<sup>†</sup> Q = quadratic.

There was no effect of three levels of concentrate supplementation on calf BUN concentrations (Table 3-8). Blood urea N levels between 11 and 15 mg dL<sup>-1</sup> were associated with maximum rates of gain for growing steers (Byers and Moxon, 1980), thus it is likely that the calves had an adequate protein supply during the entire experimental

period. Increased solubility and degradability of dietary protein can lead to increased ruminal ammonia concentrations resulting in increased BUN concentrations (Hammond et al., 1994). Protein in intensively fertilized cool-season grasses is highly degradable and thus easily fermented to volatile fatty acids and ammonia in the reticulo-rumen. Ammonia that is not captured is absorbed and excreted in the urine (Van Vuuren et al., 1991). It was expected that calves receiving greater amounts of concentrate would have a lesser BUN concentration because the concentrate had lower CP and ruminal degradable protein concentrations than the rye-ryegrass pastures. There was a numerical suggestion of lesser blood urea N for calves receiving the 20 g kg<sup>-1</sup> BW concentrate compared to the 15 g kg<sup>-1</sup> level, however, no statistical difference was observed.

Table 3-8. Blood urea nitrogen (BUN) concentrations of early weaned calves grazing rye-ryegrass pastures supplemented with three levels of concentrate. (BW=body weight)

Concentrate g kg <sup>-1</sup> BW	BUN mg dL <sup>-1</sup>
10	14.1
15	15.1
20	13.0
Polynomial contrast <sup>†</sup>	NS <sup>†</sup>
P value	≥ 0.26
SEM	1.0

<sup>†</sup> NS = not significant

According to the NRC (1996), the ruminal-degradable protein requirement for 120 kg calves is 300 g d<sup>-1</sup>. Based on the estimations of forage and concentrate intake for calves receiving the 10 g kg<sup>-1</sup> BW supplement and the data for CP fractionation, ryegrass provided ~ 380 and concentrate 100 g of ruminal degradable protein d<sup>-1</sup>. Therefore, the estimated ruminal degradable protein consumed was 60% greater than the requirement.

The excessive rumen degradable protein consumed by the calves was not expressed in increased BUN concentrations that were in the range considered adequate for growing calves.

### **Economic Analysis**

There was a linear increase in supplement cost and income with increasing supplement levels; however, there was no difference in return among the treatments (Table 3-9). Provided that there are no economic incentives to producing heavier calves, these data do not justify use of supplement levels above 10 g kg<sup>-1</sup> BW.

Table 3-9. Economic analysis of three concentrate levels on early weaned calves grazing rye-ryegrass pastures.

Concentrate	Concentrate cost	Income	Return
-----g kg <sup>-1</sup> BW-----	-----\$ ha <sup>-1</sup> -----		
10	600	2100	1500
15	970	2370	1400
20	1430	2900	1470
Polynomial contrast <sup>†</sup>	L	L	NS
P value	< 0.01	< 0.01	≥ 0.86
SEM	25	91	92

<sup>†</sup> L = linear; NS = not significant

### **Summary and Conclusions**

Herbage mass, accumulation, allowance, and nutritive value of rye-ryegrass pastures did not differ among levels of concentrate. Seasonal variation in forage responses were the result of the climatic conditions during the trial, especially the very high rainfall that occurred during the 2002/03 season. It resulted in lower herbage mass and CP during that year.

Total OMI did not vary among the three supplementation levels, but forage OMI decreased linearly as supplement level increased. Concentrate substituted for forage intake in ~ a 1:1 ratio. To enable greater forage intake, calves receiving the 10 g kg<sup>-1</sup> BW concentrate level spent more time grazing during daylight hours than calves receiving the 15 and 20 g kg<sup>-1</sup> BW treatments.

Average daily gain, SR, and LWG increased linearly with increasing levels of concentrate. Increased ADG at the same level of intake implies better synchronization of energy and N in the rumen, and possibly an effect associated with the greater amounts of ruminal undegradable protein provided by the concentrate. Stocking rate increased because of the substitution of concentrate for forage in the 15 and 20 g kg<sup>-1</sup> BW treatments.

There was a trend for BUN concentration to be lower for the 20 than 15 g kg<sup>-1</sup> BW treatment, likely the result of the lower CP and ruminal degradable protein concentration in the concentrate compared to the forage. The BUN concentrations of all treatments were in the range considered adequate for growing cattle.

The economic analysis implies that there is no economic benefit of increasing the supplementation levels above 10 g kg<sup>-1</sup> BW, unless a greater price is paid for heavier weight calves. In practice, the optimum supplementation level will be dependent upon forage availability, cost of the concentrate, and calf price. Given the pasture conditions, and the concentrate and calf pricing in this study, the 10 g kg<sup>-1</sup> BW supplement level is recommended. Future studies should evaluate lesser levels, e.g., 5 g kg<sup>-1</sup>, to determine if more economical gains can be achieved with less supplement.

CHAPTER 4  
SUPPLEMENTATION EFFECTS ON FORAGE CHARACTERISTICS AND  
PERFORMANCE OF EARLY WEANED CALVES GRAZING TIFTON 85  
BERMUDAGRASS PASTURES

**Introduction**

There are 39 million ha of perennial pastures grown in the eastern USA and almost 30 million ha are located in the South. These pastures are mainly used for beef cows and calves and stockering of weaned calves (Hoveland, 1992). Among several species found in the southeastern USA, bermudagrass [*Cynodon dactylon* (L.) Pers.] is one of the most important with ~ 10 to 12 million ha of planted for livestock grazing and hay.

Johnson et al. (2001b) compared different species of warm-season grasses in Florida and showed that bermudagrass produced more forage DM ( $1540 \pm 43 \text{ kg ha}^{-1}$ ) cutting $^{-1}$ ) than stargrass (*Cynodon nemfuensis* Vanderyst) ( $1400 \pm 43 \text{ kg ha}^{-1}$  cutting $^{-1}$ ) or bahiagrass (*Paspalum notatum* Flügge) ( $1300 \pm 43 \text{ kg ha}^{-1}$  cutting $^{-1}$ ). Moreover, bermudagrass was more digestible ( $575 \pm 4 \text{ g kg}^{-1}$ ) than stargrass ( $546 \pm 4 \text{ g kg}^{-1}$ ) and bahiagrass ( $519 \pm 4 \text{ g kg}^{-1}$ ). In 1993, ‘Tifton 85’, a hybrid between a South African bermudagrass and ‘Tifton 68’ stargrass was released. Burton et al. (1993) described it as taller, with larger culms, broader leaves, and darker color than other bermudagrass hybrids. Compared with ‘Coastal’, Tifton 85 yielded 26% more dry matter, was  $110 \text{ g kg}^{-1}$  more digestible, and more succulent at harvest.

Warm-season grasses have relatively larger proportions of cell-wall material. Cell wall is potentially digestible, but because of the chemical composition and anatomical structure of warm-season grasses the rate of degradation and fermentation is relatively

slow (Coleman et al., 2004). Although forage nutritive value of C4 grasses is generally inferior to that of C3 grasses, animal production can be high on C4 grasses because of their high DM production potential. Pedreira et al. (1998) studied Tifton 85 bermudagrass in a 3-yr grazing trial. The pastures were continuously stocked with a fertilization program of  $210 \text{ kg N ha}^{-1} \text{ yr}^{-1}$ . Tifton 85 pastures supported six heifers  $\text{ha}^{-1}$ , resulting in live weight gain (LWG)  $648 \text{ kg ha}^{-1}$  during spring-summer in North-Central Florida.

The use of supplementary feed is a management practice to overcome the nutritional shortfalls of the forage component of the diet. When energy and protein requirements are high, e.g., for lactation, pregnancy, and growth, part of the roughage component may need to be replaced by feeding of concentrates (Fontaneli, 1999). Rouquette et al. (2003) reported that stocker steers gained  $1.03 \text{ kg d}^{-1}$  on Tifton 85 compared to  $0.75 \text{ kg d}^{-1}$  on Coastal bermudagrass without supplementation. With supplementation of  $1.4 \text{ kg d}^{-1}$  of a 3:1 maize (*Zea mays* L.):soybean [*Glycine max* (L.) Merr.] meal concentrate, steers grazing Tifton 85 gained  $1.25 \text{ kg d}^{-1}$ .

According to Galloway et al. (1992), moderate dietary levels of supplement (200–300 g  $\text{kg}^{-1}$  of the diet DM) can improve nutrient intake and performance by cattle consuming bermudagrass. At greater amounts, nutrient digestion, intake, or both of the forage portion of the diet can be affected negatively. Wheeler et al. (2002) tested the effects of increasing supplement protein concentration on performance and forage intake of beef steers consuming bermudagrass forage. Treatments were no supplement or daily equivalents of 0.2, 0.4, and 0.6 g of supplemental protein  $\text{kg}^{-1}$  of body weight (BW). Forage intake increased 16% and organic matter (OM) intake increased 30% in supplemented compared to unsupplemented steers. Diet OM digestibility increased 145 g

$\text{kg}^{-1}$  and total digestible OM intake increased  $490 \text{ g kg}^{-1}$  in supplemented compared to unsupplemented steers.

The success of the Florida cow-calf enterprise depends upon maintaining high calving percentage. First-calf heifers and other young cows may experience low conception rates due to stress of lactation. Early weaning of calves of young cows is one approach to reduce cow nutrient requirement, increase body condition, and increase the likelihood of rebreeding. Management practices for raising the early weaned (EW) calf have not been widely studied. In particular there is little information to guide supplementation programs for EW calves grazing C4 grass pastures. In a study done in south Brazil, Muehlmann et al. (1997) reported average daily gains (ADG) of  $0.2 \text{ kg d}^{-1}$  for EW calves grazing a bermudagrass-native warm-season grasses mixture. Vendramini et al. (2003) observed that supplementing EW calves with concentrate at  $10 \text{ g kg}^{-1}$  BW of body weight resulted in gains of  $0.59$  and  $0.44 \text{ kg d}^{-1}$  on stargrass and atrapaspalum (*Paspalum atratum* Swallen), respectively. Additional information is needed regarding the amount of supplement required by EW calves grazing C4 grass pastures. The objective of this study was to evaluate the effect of different levels of concentrate on ADG, stocking rate (SR), LWG, and forage intake of EW calves grazing Tifton 85 bermudagrass pastures in North-Central Florida.

### **Material and Methods**

The research site was the Florida Beef Research Unit, 18 km northeast of Gainesville, FL ( $30^{\circ}$  N). Dates for the trial during the 2 yr were 14 May through 13 Aug. 2003 (86 d) and 18 May through 10 Aug. 2004 (86 d). Monthly rainfall and temperature data during the trial are presented in Table 1 (Appendix A).

The soils at the research site are Adamsville fine sand (Aquic Quartzipamments, hyperthermic, uncoated) and Sparr fine sand (Grossarenic Paleudult, hyperthermic, loamy siliceous). These soils are moderately well drained with rapid permeability. Prior to initiation of summer grazing at the site, mean soil pH (1:2 soil:deionized H<sub>2</sub>O ratio) was 5.5, and Mehlich-I (0.05 M HCl + 0.0125 M H<sub>2</sub>SO<sub>4</sub>) extractable P, K, Mg, and Ca in the Ap1 horizon (0- to 15-cm depth) were 44, 17, 40, 328 mg kg<sup>-1</sup>, respectively.

Bermudagrass pastures were established in August 2002 and fertilized with 40 kg ha<sup>-1</sup> of N, 17 kg ha<sup>-1</sup> of P, and 66 kg ha<sup>-1</sup> of K 1 mo after establishment. In April 2003 and 2004, the pastures received 40 kg N ha<sup>-1</sup>, 17 kg P ha<sup>-1</sup>, and 66 kg K ha<sup>-1</sup>. An additional 80 kg N ha<sup>-1</sup> was split in two applications of 40 kg ha<sup>-1</sup> in early June and early July of both years.

Treatments were three levels of a commercial pelleted concentrate, 10, 15, and 20 g kg<sup>-1</sup> of the calves body weight (BW), offered daily. The concentrate composition was described in Table 3.2 (Chapter 3). Each treatment was replicated three times in a completely randomized design so there were a total of nine experimental units in the study. In 2004, for observation purposes, two experimental units were added to the study in which the EWC did not receive concentrate supplementation.

The EWC were described in Chapter 3. At the start of this trial, they were ~200-d old with an average liveweight of 190 kg. Calves grazed rye (*Secale cereale* L.)-annual ryegrass (*Lolium multiflorum* Lam.) pastures from January to April. Calves received the same supplement treatment in summer as they did during the winter-spring period. At the initiation of grazing of the Tifton 85 pastures, calves within a supplement level were randomly allocated to the three replicates of that treatment. They were vaccinated with

Ultrabac 8 and Bovashield 4 (Pfizer Animal Health New York, NY) and dewormed with ivermectin (Ivomec, Merck & Company, Rahway, New Jersey, USA) 10 g kg<sup>-1</sup> concentration on 23 July 2003 and 14 July 2004.

Pasture size was 0.15 ha subdivided in three paddocks for rotational stocking. The grazing period was 7 d and the rest period was 14 d. Two EW calves (1 steer and 1 heifer) were assigned as testers to each pasture and “put and take” EW calves were used to maintain herbage allowance at ~1 kg forage DM kg<sup>-1</sup> of calf BW.

### **Pasture Sampling**

In each grazing cycle (21 d), herbage mass was determined on Paddock 2 using a double sampling technique. The procedure of herbage sampling was similar to the one described in Chapter 3. A total of 40, double-samples were taken every 3 wk to calibrate the disk meter. This greater number than used during the winter was necessary because C4 grasses usually have a greater heterogeneity of herbage bulk density through the different heights of the canopy (Sollenberger and Burns, 2001). Thus, separated pre- and post-graze calibration equations resulted in more precision of the height/weight relationship than combining them into one. The regression equations and r<sup>2</sup> of the pre- and post-graze double sampling technique are shown in Table 1 (Appendix B).

The methodology used to determine herbage allowance, stocking rate, and forage nutritive value were the same as those described in Chapter 3.

### **Animal Response Variables**

Total organic matter intake (OMI) and forage OMI were estimated only in 2003. The controlled-release devices used in the trial were designed for sheep or small calves. When used by 200-kg calves, most of the calves regurgitated the device before the fecal collection period. The data are presented only for 2003 and reflect results from only 8 out

of 18 calves dosed with the controlled-release device. The total Cr output calculated from total fecal collection from three calves is presented in Table 2 (Appendix B). The Cr analyses procedure and total and forage OMI determinations were described in Chapter 3.

Grazing time of EW calves during daylight hours was evaluated every 21 d. Calves were observed and time spent grazing was recorded from 0700 to 1900 h. These observations were performed on the first day of the grazing period in Paddock 2 in each grazing cycle.

The weight of the animals was recorded on a 21-d interval at 0900 h. The change in unshrunk weight of the tester animals was used to calculate ADG. The LWG in each 21-d period was determined based on the ADG of the testers multiplied by the number of calves within the pastures during that period and adjusted to a hectare basis. Blood urea N (BUN) sampling and determination were conducted as described in Chapter 3.

### **Economic Analysis**

The assumptions used in the economic analysis were:

- Concentrate cost = \$0.22 kg<sup>-1</sup>
- Calf price = \$2.20 kg<sup>-1</sup>
- Live weight (LW) = SR\*500 kg
- Days of grazing = 90 d

The formulas used to calculate the results were described in Chapter 3.

### **Statistical Analysis**

The models, procedure, and software used for statistical analyses were described in Chapter 3.

## Results and Discussion

### Pasture Responses

There was no difference in pregraze herbage mass and herbage accumulation among the treatments (Table 4-1).

Table 4-1. Pregraze herbage mass and herbage accumulation of Tifton 85 pastures grazed by early weaned calves supplemented with three levels of concentrate.  
(BW=body weight)

Concentrate g kg <sup>-1</sup> BW	Herbage mass Mg ha <sup>-1</sup>	Herbage accumulation kg ha <sup>-1</sup> d <sup>-1</sup>
10	4.9	101
15	4.8	95
20	4.7	84
Polynomial contrast	NS <sup>†</sup>	NS
P value	0.20	0.11
SEM	0.1	15

<sup>†</sup> NS = not significant

Using continuous stocking, Pedreira et al. (1998) reported greater yields of Tifton 85 than Florakirk bermudagrass early in the grazing season. Herbage accumulation was 73 kg DM ha<sup>-1</sup>d<sup>-1</sup> for Tifton 85 vs. 44 kg DM ha<sup>-1</sup>d<sup>-1</sup> for Florakirk. Under continuous stocking, average herbage mass during a 3-yr study with Tifton 85 grazed by beef steers in Georgia was 2.8 Mg ha<sup>-1</sup>, and ADG decreased when herbage mass was below 2.5 Mg ha<sup>-1</sup> (Hill et al., 1993). Greater average herbage mass was maintained in our study to provide opportunity for the calves to select forage that was high in nutritive value and maximize animal performance.

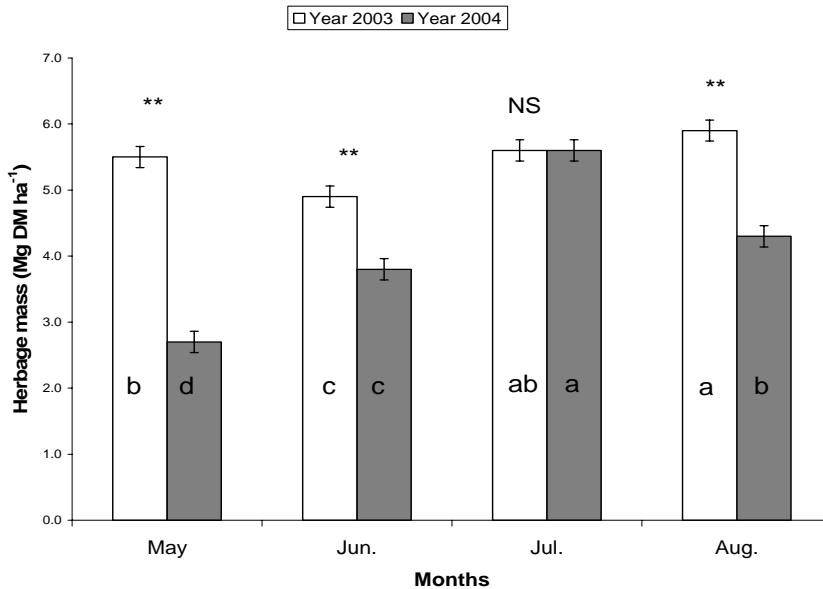


Fig. 4-1. Year\*period interaction effect on pregraze herbage mass of Tifton 85 pastures grazed by early weaned calves supplemented with different levels of concentrate. Year effect within period; \*\*,  $P \leq 0.01$ ; NS= not significant. Period effect within year; means are different if followed by different letters ( $P \leq 0.05$ ).

There was a significant year \* period interaction effect on herbage mass (Fig. 4-1).

The lesser herbage mass present in the first 2 mo of 2004 can be attributed to very low rainfall that occurred during May (15 mm vs. the 30-yr average of 106 mm).

Herbage accumulation also varied throughout the grazing season ranging from 45 to 121 kg ha<sup>-1</sup> d<sup>-1</sup> in 2003 and from 51 to 133 kg ha<sup>-1</sup> d<sup>-1</sup> in 2004 (Fig. 4-2). According to Dubeux et al. (2003), rotationally stocked pastures of bahiagrass had greater herbage accumulation than continuously stocked pastures. The use of a rotational stocking may be one of the factors responsible for greater herbage accumulation in this study compared to those of Hill et al. (1993) and Pedreira et al. (1998) who stocked their pastures continuously.

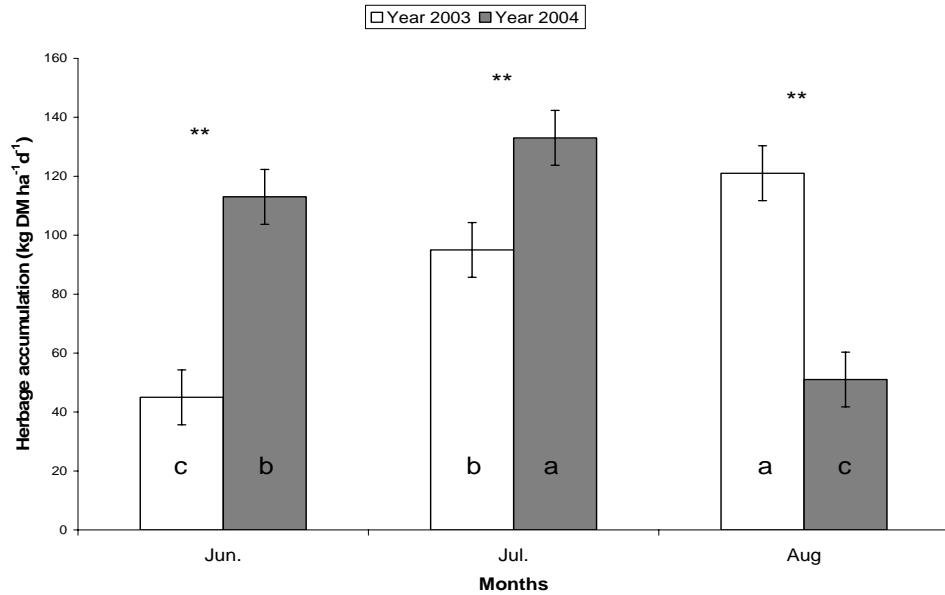


Fig. 4-2. Year\*period interaction effect on average herbage accumulation of Tifton 85 pastures grazed by early weaned calves supplemented with different levels of concentrate. Year effect within period; \*\*,  $P \leq 0.01$ ; NS= not significant. Period effect within year; means are different if followed by different letters ( $P \leq 0.05$ ).

Herbage CP and IVDOM concentrations were not affected by treatment and averaged  $184 \text{ g kg}^{-1}$  and  $624 \text{ g kg}^{-1}$ , respectively (Table 4-2). These concentrations are greater than those reported by Pedreira et al. (1998) ( $120 \text{ g kg}^{-1}$ ) and Hill et al. (1993) ( $140 \text{ g kg}^{-1}$ ) for Tifton 85 pastures stocked continuously. Fike et al. (2002) used rotational stocking with similar resting period (21 d) and N fertilization program ( $45 \text{ kg N ha}^{-1}$  on 21 May, 8 June, and 7 August) on Tifton 85 pastures. They reported CP and IVDOM values ( $140$  and  $600 \text{ g kg}^{-1}$ , respectively) lower than those observed in this study. Masticate samples from Tifton 85 pastures had CP and IVDMD concentrations of  $180$  and  $650 \text{ g kg}^{-1}$  (Hill et al., 1998). With a 35-d regrowth interval, Mislevy and Martin (1998) reported CP of  $170 \text{ g kg}^{-1}$  DM for hand-plucked samples of stargrass pastures grazed by beef steers.

Table 4-2. Crude protein (CP) and in vitro digestible organic matter (IVDOM) concentration of Tifton 85 pastures grazed by early weaned calves supplemented with three levels of concentrate. (BW=body weight)

Concentrate	CP	IVDOM
-----g kg <sup>-1</sup> BW-----	-----g kg <sup>-1</sup> DM-----	-----g kg <sup>-1</sup> OM-----
10	182	626
15	181	610
20	189	636
Polynomial contrast	NS <sup>†</sup>	NS
P value	0.49	0.44
SEM	6	8

<sup>†</sup>NS = not significant

There was a year\*period interaction for CP concentration (Fig. 4-3). In both years, the lower CP during the first month of grazing was attributed to a longer growth period preceding the first grazing cycle than subsequent cycles. At initiation of grazing in May, the herbage present reflected growth that had occurred during the spring and not from the most recent 14 d. Thus, hand-plucked samples included older herbage with more stem material resulting in lesser CP and IVDOM concentrations. Pedreira (1995) reported similar results from bermudagrasses pastures grazed by beef heifers. Herbage CP was 70 g kg<sup>-1</sup> in June while the average for June through August was 125 g kg<sup>-1</sup>. Similar results were presented by Hill et al. (1993), with CP concentrations of 114 (May) and 156 g kg<sup>-1</sup> (September) in the first and last month of the grazing study with Tifton 85.

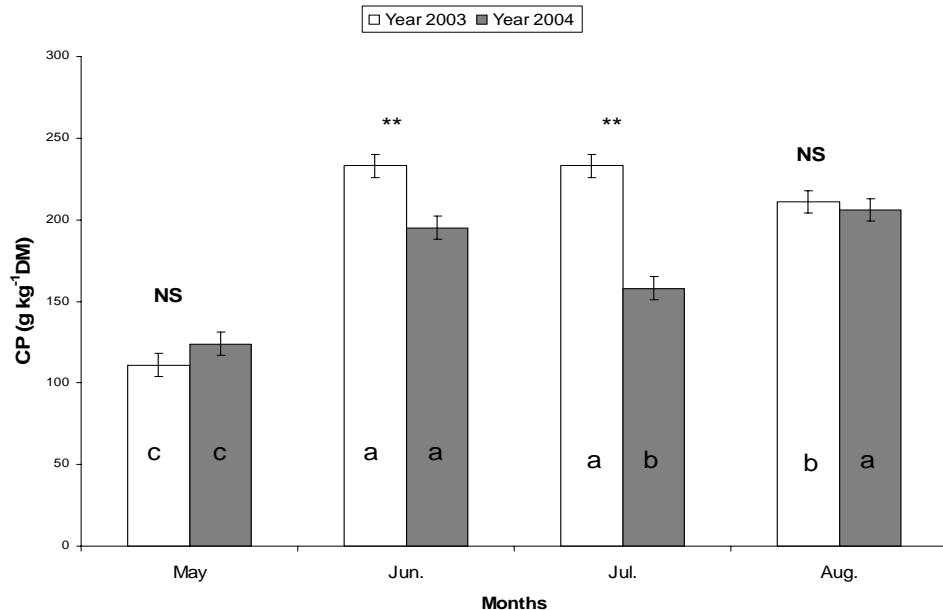


Fig. 4-3. Year\*period interaction effect on crude protein (CP) concentration of Tifton 85 pastures grazed by early weaned calves supplemented with different levels of concentrate. Year effect within period; \*\*,  $P \leq 0.01$ ; NS= not significant. Period effect within year; means are different if followed by different letters ( $P \leq 0.05$ ).

There was no year\*period interaction effect on herbage IVDOM, but there were year and period (Fig. 4-4) effects. Mean herbage IVDOM was greater in 2004 ( $640 \text{ g kg}^{-1}$ ) than in 2003 ( $580 \text{ g kg}^{-1}$ ). The herbage IVDOM period response was similar to that of CP concentration, with the lowest values occurring during the first month of grazing because of the longer regrowth period of the forage. Herbage IVDOM was greater in June and decreased in July and August.

The estimated rumen-degradable and rumen-undegradable protein concentrations were  $550$  and  $450 \text{ g kg}^{-1}$  CP, respectively (data not shown). Similar values for bermudagrass rumen-degradable protein ( $570 \text{ g kg}^{-1}$ ) were found by Basurto et al. (2001). Mathis et al. (2001) measured bermudagrass ruminal degradable protein from seven different locations using the enzymatic methodology proposed by Roe et al. (1991). The average across locations was  $610 \text{ g kg}^{-1}$  CP.

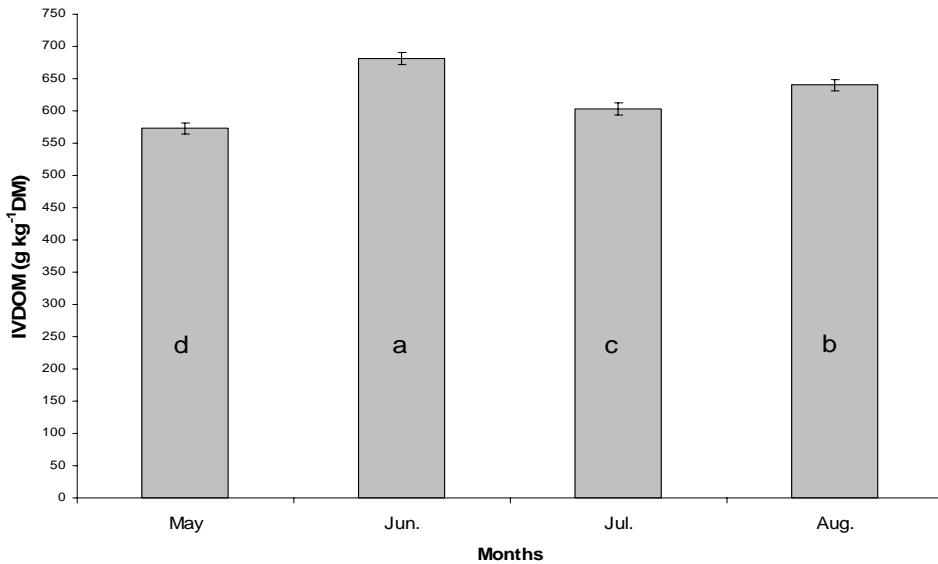


Fig. 4-4. Period effect on IVDOM concentration of Tifton 85 herbage grazed by early weaned calves supplemented with different levels of concentrate. Means are different if followed by different letters ( $P \leq 0.05$ ).

There was a linear decrease in average herbage allowance with increased supplementation levels, although the magnitude of the change was small (Table 4-3). Put and take animals were used to maintain similar herbage allowance among treatments. Even though herbage mass was not different among treatments, the greater SR for the 20 g kg<sup>-1</sup> BW treatment caused herbage allowance to be slightly reduced. There was no period or period \* year interaction on herbage allowance, however, a year effect was observed with averages across treatments of 1.0 and 0.8 kg DM kg<sup>-1</sup> BW for 2003 and 2004, respectively. Herbage allowance of at least 1.0 kg DM kg<sup>-1</sup> BW was associated with highest gains of unsupplemented yearling beef heifers on continuously-stocked Tifton 85 bermudagrass (Pedreira, 1995). Although the herbage allowance in this study was below 1 kg DM kg<sup>-1</sup> BW in 2004, it is important to consider that calves were supplemented with at least 10 g kg<sup>-1</sup> BW concentrate. This amount of concentrate

accounts for 33% of the daily energy requirement of these animals, likely resulting in lower forage allowance requirements.

Table 4-3. Herbage allowance and stocking rate of Tifton 85 pastures grazed by early weaned calves supplemented with three levels of concentrate. (BW=body weight)

Concentrate g kg <sup>-1</sup> BW	Herbage allowance kg DM kg BW <sup>-1</sup>	Stocking rate AU <sup>†</sup> ha <sup>-1</sup>
10	0.97	11.1
15	0.95	11.2
20	0.81	13.7
Polynomial contrast	L <sup>‡</sup>	L
P value	<0.01	<0.01
SEM	0.02	0.4

<sup>†</sup>AU = 500 kg LW<sup>0.75</sup>

<sup>‡</sup>L=linear

Hernandez Garay et al. (2004) studied the effect of N fertilization and stocking rate on weanling bulls grazing stargrass. Animal ADG decreased quadratically with increasing stocking rate from 1.3 to 3.8 AU (500 kg LW) ha<sup>-1</sup>. The LWG was maximized at stocking rates of ~ 2.5 AU ha<sup>-1</sup> for N fertilization rates of 112 and 224 kg ha<sup>-1</sup> over a 280-d grazing season. Pedreira (1995) verified a mean seasonal stocking rate of 5.9 AU ha<sup>-1</sup> on Tifton 85 pastures with maximum stocking rate of 9 AU ha<sup>-1</sup> in July 1994.

The greater stocking rates in this study are the result of supplementation of the calves. The substitution of forage by concentrate resulted in more forage available for grazing, resulting in a linear increase in stocking rates with increased level of concentrate.

### **Animal Response Variables**

There was linear increase in ADG and LWG as level of supplement fed increased (Table 4-4). The performance of early weaned calves grazing Tifton 85 and receiving 10 g kg<sup>-1</sup> BW in concentrate was similar to the results presented by Vendramini et al. (2003) for early weaned calves grazing stargrass (0.59 kg d<sup>-1</sup>) and receiving the same amount of concentrate. When Harvey and Burns (1989) evaluated performance of EW calves grazing pearl millet [*Pennisetum glaucum* (L.) R. Br.] with ground ear maize fed ad libitum, the ADG of the calves was 0.92 kg d<sup>-1</sup>.

In the current study, average daily gain increased only 25% with an increase of 100% in amount of supplement fed. Because the level of gain observed is well below the genetic potential for these calves, it is likely that energy and/or protein limited growth of the calves. According to the NRC (1996) simulations calves grazing Tifton 85 with 10 g kg<sup>-1</sup> BW supplementation would gain 0.9 kg of liveweight d<sup>-1</sup>. The lesser ADG observed in this study may be related to greater than expected negative associative effect of concentrate on forage intake. In addition, high temperature and humidity during the grazing season may have contributed to the relatively poor performance of the calves.

The ADG and LWG of calves that did not receive concentrate supplementation were 0.33 kg d<sup>-1</sup> and 950 kg ha<sup>-1</sup>, respectively. These values were inferior to the ADG and gain per ha of calves supplemented with 10 g kg<sup>-1</sup> BW in concentrate, 0.52 kg d<sup>-1</sup> and 1080 kg ha<sup>-1</sup>, respectively.

There was a year\*period interaction on calf ADG (Fig. 4-5). The greater ADG observed during May 2003 may have resulted from differences in gut fill during the transition of the calves from cool-season to warm-season pastures. In 2003, calves were moved from rye-ryegrass directly to Tifton 85, and a greater amount of fill associated

with consumption of Tifton 85 relative to rye-ryegrass could explain the greater observed gain in May. In 2004, the calves spent 2 wk grazing warm-season grasses before the initiation of the warm-season study, decreasing the variation in fill effect between the first two weight measurements. With the exception of May 2003, there was a tendency of increasing ADG through the experimental period in both years. This may be related to generally increasing CP of pastures throughout the experimental period.

Table 4-4. Average daily gain (ADG) and liveweight gain (LWG)  $\text{ha}^{-1}$  of early weaned calves grazing Tifton 85 pastures supplemented with different levels of concentrate. (BW=body weight)

Concentrate g $\text{kg}^{-1}$ BW	ADG $\text{kg d}^{-1}$	LWG <sup>†</sup> $\text{kg ha}^{-1}$
10	0.52	1080
15	0.65	1450
20	0.65	1550
Polynomial contrast	L <sup>‡</sup>	L
P value	0.04	<0.01
SEM	0.02	85

<sup>†</sup>LWG during a period of 86 d.

<sup>‡</sup>L = linear

Using a fixed stocking rate, Rouquette et al. (2003) reported that supplementation with 0.9 kg of a mixture of maize and soybean meal increased LWG of yearling heifers on Tifton 85 pastures from 521 (unsupplemented control) to 615  $\text{kg ha}^{-1}$ . In the current study, gain  $\text{ha}^{-1}$  increased 43% when supplementation level increased from 10 to 20 g  $\text{kg}^{-1}$  BW.

There was no difference in total and forage OMI (Table 4-5). Trends were observed, especially for forage OMI, but missing data due to bolus regurgitation weakened the statistical tests.

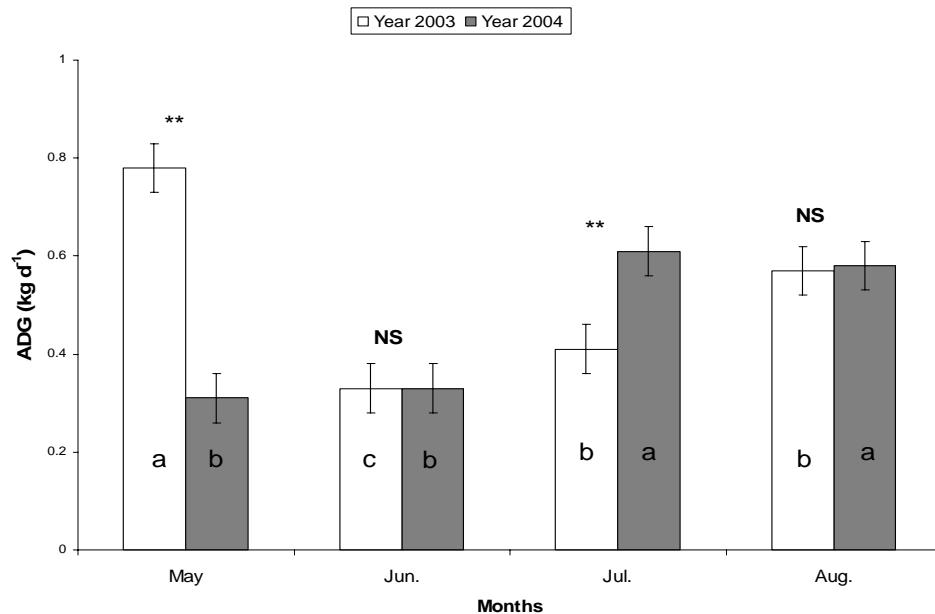


Fig. 4-5. Year\*period interaction effect on average daily gain of early weaned calves grazing Tifton 85 pastures and supplemented with different levels of concentrate. Year effect within period; \*\*,  $P \leq 0.01$ ; NS= not significant. Period effect within year; means are different if followed by different letters ( $P \leq 0.05$ ).

Table 4-5. Total organic matter intake (OMI) and forage OMI of Tifton 85 pastures grazed by early weaned calves supplemented with three levels of concentrate.

Concentrate	Total OMI <sup>†</sup>	Forage OMI
-----g kg <sup>-1</sup> BW-----	-----(% BW)-----	
10	3.2	2.3
15	2.8	1.6
20	2.5	1.2
Polynomial contrast	NS <sup>‡</sup>	NS
P value	0.45	0.21
SEM	0.4	0.4

<sup>†</sup> Total organic matter intake data adjusted according to Moore et al. (1999).

<sup>‡</sup>NS = not significant

Nelson et al. (1980) reported that intake of Coastal bermudagrass hay was 23.9 g kg<sup>-1</sup> BW for forage harvested at 4-wk regrowth. Hill et al. (1993) studied DM intake of

freshly harvested Tifton 85 forage at different maturities. Intake varied from 18 to 20 g kg<sup>-1</sup> BW for 3- to 7-wk regrowth. When supplemented with maize at 10 g kg<sup>-1</sup> BW, beef steers reduced the bermudagrass hay intake 0.46 kg for each kg of maize fed.

Burns et al. (1991) compared intake of different species of warm-season grasses in North Carolina. Bermudagrass (22.3 g kg<sup>-1</sup> BW) was the lowest compared with switchgrass (*Panicum virgatum* L.) and flacidgrass (*Pennisetum flaccidum* Griseb.) (30.9 g kg<sup>-1</sup> BW). The authors attributed the lower bermudagrass intake to low forage digestibility. Wheeler et al. (2002) verified increased DM intake in beef steers grazing stockpiled bermudagrass pastures when supplemented with concentrate of different CP concentrations. The intake was 21 and 23 g kg<sup>-1</sup> BW for steers supplemented with 16 and 40% CP supplement.

It is expected that calves grazing bermudagrass and consuming over 30 g kg<sup>-1</sup> of the diet as an energy supplement would have decreased forage OMI. The data collected in this study support this trend. However, the problems experienced with the methodology limit the conclusions that can be drawn.

Grazing time during daylight hours decreased linearly with increasing supplementation levels (Table 4-6). These date corroborate the results of Macoon (1999) who found that dairy cows supplemented with high levels of concentrate spent less time grazing (135 min) than cows that received low rates of concentrate (180 min). There was a significant year effect on grazing time with calves grazing 240 and 106 min for Years 2003 and 2004, respectively. The large difference in grazing time between years can be explained in part by the greater herbage mass present in 2003.

Table 4-6. Grazing time during daylight hours of early weaned calves grazing Tifton 85 pastures supplemented with three levels of concentrate. (BW=body weight)

Concentrate g kg <sup>-1</sup> BW	Grazing time min
10	193
15	181
20	147
Polynomial contrast <sup>†</sup>	L <sup>†</sup>
P value	<0.01
SEM	8

<sup>†</sup>L=linear

There was no effect of increasing supplementation rates on calf BUN (Table 4-7).

Based on the high CP concentration of the forage (180 g kg<sup>-1</sup>) and concentrate (160 g kg<sup>-1</sup>), it was expected that calves consuming more forage would have a higher BUN concentration; however, the forage rumen-degradable protein (550 g kg<sup>-1</sup>) was less than concentrate rumen degradable protein (700 g kg<sup>-1</sup>) (NRC, 1996). As a result, calves consumed similar total rumen degradable protein, resulting in similar BUN among the treatments. According to Hammond et al. (1993), cattle BUN concentrations from 9 to 12 mg dL<sup>-1</sup> are considered to be in a transition range below which daily response to protein supplementation has been positive. The calf BUN concentrations in this study suggest that protein supplementation is unlikely to improve performance of the calves. Further studies are necessary to clarify the relation of BUN concentrations and performance of early weaned calves grazing warm-season pastures.

Table 4-7. Blood urea nitrogen (BUN) concentrations of early weaned calves grazing Tifton 85 pastures supplemented with three levels of concentrate. (BW=body weight)

Concentration	BUN
-----g kg <sup>-1</sup> BW-----	-----mg dL <sup>-1</sup> -----
10	14.8
15	15.4
20	14.0
Polynomial contrast	NS <sup>†</sup>
P value	0.64
SEM	0.9

<sup>†</sup> NS = not significant

### Economic Analysis

Cost and income increased linearly with increasing supplement rate (Table 4-8).

The increase in income was more than compensated for by greater concentrate cost at the highest supplementation rate. There was a quadratic effect on economic return indicating that the 15 g kg<sup>-1</sup> BW treatment provided greater return than the average of the 10 and 20 g kg<sup>-1</sup> treatments.

Table 4-8. Economic analysis of three concentrate levels for early weaned calves grazing Tifton 85 pastures.

Concentrate	Concentrate cost	Income	Return
-----g kg <sup>-1</sup> BW-----	-----\$ ha <sup>-1</sup> -----		
10	1100	2380	1280
15	1670	3200	1530
20	2710	3400	700
Polynomial contrast	L <sup>†</sup>	L	Q
P value	<0.01	<0.01	0.04
SEM	74	187	284

<sup>†</sup> L = linear, Q = quadratic

### **Summary and Conclusions**

The different levels of supplement fed to early weaned calves grazing Tifton 85 pastures did not alter herbage mass, accumulation, and nutritive value of the forage. Herbage allowance was slightly lower for 20 g kg<sup>-1</sup> BW supplementation, the result of the greater number of put and take calves assigned to that treatment. Nevertheless, there was no evidence that the herbage allowance in that treatment negatively affected calf performance.

Average daily gain, SR, and LWG increased with greater rates of concentrate. Greater SR was associated with a tendency for calves consuming more concentrate to consume less forage. However, a problem with calves regurgitating the marker boluses limited the number of observations and made it impossible to draw firm conclusions about intake. Calves receiving lower concentrate rates had greater grazing time during daylight, supporting the observation of a trend toward lower forage intake with higher rates of supplement.

Blood urea N concentrations did not differ among treatments. This can be explained by similar rumen-degradable protein consumed by the calves among the different treatments.

Although greater supplementation levels resulted in greater ADG and gain per unit of land area, economic analysis of the data did not support use of the 20 g kg<sup>-1</sup> BW treatment. Economic return was greater for the 15 g kg<sup>-1</sup> BW concentrate treatment than the average of the 10 and 20 g kg<sup>-1</sup> treatments, thus the 15 g kg<sup>-1</sup> level is recommended for EW calves grazing Tifton 85 bermudagrass.

## CHAPTER 5

### BOTANICAL COMPOSITION, HERBAGE ACCUMULATION, NUTRITIVE VALUE, AND CRUDE PROTEIN FRACTIONATION OF RYE-RYEGRASS HERBAGE AT DIFFERENT REGROWTH INTERVALS AND N FERTILIZATION LEVELS

#### **Introduction**

Warm-season grasses dominate most of the pastures in the southeastern USA, but climatic conditions allow for use of cool-season annual grasses, either sod-seeded or in prepared seedbeds. Reasons for use of cool-season annual grasses include extending the grazing period, high nutritive value, compatibility and ease of establishment in warm-season perennial grass pastures, and tolerance to different defoliation regimens and stocking rates (Rouquette et al., 1997).

Annual ryegrass (*Lolium multiflorum* Lam.), a high-yielding, nutritious grass, is the most commonly grown cool-season pasture forage in the southern and southeastern USA from November to May (Evers et al., 1997). Small grains are mixed with annual ryegrass to improve early season forage production. Annual ryegrass-small grain mixtures provide the longest grazing season and the most forage production if planted early on a well-prepared seedbed. However, they also are relatively expensive and are most economically used by lactating dairy cows, stocker calves, replacement heifers, or for limit grazing by beef cows nursing fall calves (Evers et al., 1997). Small grains grow better from late December to mid-February, and ryegrass results in rapid forage growth during March to late May, often requiring frequent increases in stocking rate to efficiently use the herbage produced.

Many studies have shown the effect of N fertilization on herbage accumulation and nutritive value of cool-season forages. Allen et al. (1974) tested different levels of N in oat (*Avena sativa* L.)-ryegrass mixed swards. Forage yield was 4.3 Mg ha<sup>-1</sup> and 9.0 Mg ha<sup>-1</sup> with 0 and 280 kg N ha<sup>-1</sup>. Morris et al. (1994) reported ryegrass herbage accumulation of 10.5 Mg ha<sup>-1</sup> when 280 kg N ha<sup>-1</sup> was applied.

Ryegrass forage in vegetative stages of growth usually has in vitro digestible organic matter (IVDOM) > 700 g kg<sup>-1</sup>, approaching and sometimes exceeding 800 g kg<sup>-1</sup> in the first weeks of the grazing season (Ulyatt, 1981). In vitro digestibility of annual ryegrass grown at different N rates has been evaluated in Louisiana by Allen et al. (1974). The authors reported a 60 g kg<sup>-1</sup> increase in digestibility as N fertilization levels increased from 224 to 448 kg N ha<sup>-1</sup>.

The crude protein (CP) concentration of cool-season grasses is strongly influenced by the available soil N level. Application of N fertilizer to grasses usually increases CP concentration as well as crop growth. The majority of the increase in CP is non-protein N (NPN) in the form of nitrates and free amino acids (Van Soest, 1982). Crude protein concentrations in annual ryegrass tend to be high (Haby and Robinson, 1997), commonly averaging 150 to 200 g kg<sup>-1</sup> with no N applied and increasing to 280 g kg<sup>-1</sup> at N rates of 448 kg ha<sup>-1</sup>. Redfearn et al. (2002) analyzed nutritive value of different cultivars of ryegrass. The CP and in vitro digestible dry matter concentration (IVDDM) in January were 234, 229, and 232 g CP kg<sup>-1</sup> and 849, 849, and 846 g IVDDM kg<sup>-1</sup> for ‘Gulf’, ‘Jackson’, and ‘Marshall’, respectively. In general, CP concentrations of cool-season grasses range from 200 to 300 g kg<sup>-1</sup> when well fertilized and in vegetative growth stage.

High quality cool-season pastures and many tropical legumes would be expected to have high ruminal ammonia losses when their CP concentrations exceed 150 g kg<sup>-1</sup> because of the high concentration of rumen-degradable protein (Poppi and McLennan, 1995). According to Beever (1984), 800 to 900 g kg<sup>-1</sup> of ryegrass CP can be degraded in the rumen. Van Vuuren et al. (1991) stated that organic matter and CP in situ total degradability decreased with increasing ryegrass sward maturity and with decreasing rate of N application. Salaun et al. (1999) studied the relation between N fertilization and CP rumen degradability of perennial ryegrass (*Lolium perenne* L.). They concluded that reducing N fertilizer application decreased the theoretical degradability in the rumen due to decreases in NPN. The total N disappearance was 600 and 710 g kg<sup>-1</sup> for plots fertilized with 250 and 550 kg N ha<sup>-1</sup>.

In Florida beef cow-calf systems, early weaning of fall-born calves increases rebreeding of first-calf heifers and young cows (Arthington and Kalmbacher, 2003). More information is needed to develop pasture-based programs for feeding these calves during the cool season. Rye (*Secale cereale* L.) –ryegrass mixtures are important cool-season pastures in Florida, but to achieve the desired levels of calf weight gain it is thought that some supplement must be fed. In development of supplementation programs, seasonality of forage production, botanical composition, and nutritive value responses to management are key considerations. In addition, the patterns of forage dry matter (DM) and CP degradation in the rumen can provide useful information to guide the choice of supplement ingredient and chemical composition. Therefore, as part of a research program evaluating strategies for feeding early weaned calves, this study was conducted with the objectives of evaluating the effect of N fertilization levels and regrowth interval

on rye-ryegrass botanical composition, herbage accumulation, nutritive value, and in situ N fractionation and disappearance.

### **Material and Methods**

The study was located at the University of Florida Beef Research Unit, 18 km northeast of Gainesville, FL ( $30^{\circ}$  N). Data were collected during the 2003 and 2004 winter-spring seasons. The soil at the research site is Plummer sand (Grossarenic Paleaquults, loamy, siliceous, thermic). Drainage of these soils ranges are from poor to moderately rapid in A and moderate in B horizons. Prior to initiation of the study, mean soil pH (1:2 soil:deionized H<sub>2</sub>O ratio) was 6.0, and Mehlich-I (0.05 M HCl + 0.0125 M H<sub>2</sub>SO<sub>4</sub>) extractable P, K, Mg, and Ca in the Ap1 horizon (0- to 15-cm depth) were 4, 15, 109, and 661 mg kg<sup>-1</sup>, respectively. Temperature and rainfall during the study period are described in Table 1 (Appendix A).

In early October, the area was sprayed with 3.0 L ha<sup>-1</sup> of glyphosate (Monsanto Co., St. Louis, MO; isopropylamine salt [10 g kg<sup>-1</sup>] of N-phosphonomethyl glycine) to kill bahiagrass. Three weeks later, the pastures were overseeded with a mixture of rye-ryegrass using a John Deere 1590 no-till drill. The seeding rates were 20 kg ha<sup>-1</sup> of ‘Jumbo’ ryegrass and 80 kg ha<sup>-1</sup> of a mixed blend rye (‘Grazemaster’). All pastures received an initial application of 40 kg N ha<sup>-1</sup>, 17 kg P ha<sup>-1</sup>, and 66 kg K ha<sup>-1</sup>, 3-wk after planting.

Treatments were the factorial combinations of two regrowth intervals (3 and 6 wk) and three N fertilization levels (0, 40, and 80 kg N ha<sup>-1</sup> per season) evaluated in two seasons, winter (January-February) and spring (March-April). There were six plots per block and treatments were arranged in three randomized complete blocks. The criteria used for blocking was primarily soil drainage. All plots were staged at the beginning of

the winter season (10 Jan. 2003 and 16 Jan. 2004), and the same plots were harvested during both winter and spring seasons. The second 3-wk harvest and the first 6-wk harvest of the winter season also served as the staging cut for the spring season. Plot size was 2 x 4 m with 1-m distance between plots. In this study, winter was the 6-wk period starting on 10 Jan. 2003 and 16 Jan. 2004, and spring was the 6-wk period starting on 21 Feb. 2003 and 27 Feb. 2004. The 6-wk cutting-interval plots received the entire N application for that season at the beginning of the 6-wk growth period, while the 3-wk plots received half of seasonal rate at the beginning of each of the two, 3-wk growth periods per season.

Herbage was harvested to a 5-cm stubble from two representative 0.25-m<sup>2</sup> quadrats per plot and was dried at 60°C for 48 h to measure herbage accumulation. Herbage accumulation data are reported by season (winter and spring), and data from a given season is the total of one harvest of the 6-wk treatment and two harvests of the 3-wk treatment. One additional 0.25-m<sup>2</sup> quadrat per plot was clipped, hand separated into rye and ryegrass, and used to calculate botanical composition of the swards.

### **Laboratory Analyses**

For laboratory analyses, herbage from the two quadrats used to determine herbage accumulation (i.e., not separated by species) was ground in an Udy cyclone mill (Udy Corporation, Fort Collins, CO.) to pass a 4-mm screen, and stored for chemical analyses. Samples were analyzed for IVDOM using the two-stage technique described by Tilley and Terry (1974) modified by Moore and Mott (1974). Nitrogen concentration was determined using a micro-Kjeldahl method, a modification of the aluminum block digestion technique described by (Gallaher et al., 1975).

### In situ Disappearance Procedure

Rye-ryegrass samples from a given experimental unit were composited across seasons. Four grams of dried and ground sample were weighed and placed into N-free polyester bags (pore size, 50-60 µm). Bags were 20 x 10 cm in , and heat sealed using an impulse sealer (model MP-8; Midwest Pacific, Co., Baltimore MD). The ratio of weight to surface area was 20 mg cm<sup>-2</sup>. Duplicate samples were incubated for 0, 3, 6, 9, 12, 24, 48, and 72 h. The bags were soaked in water, attached to a rope, and placed into a ruminally-fistulated Holstein cow. The cow was housed in a free-air circulating barn in an individual stall. The cow was fed a diet of bermudagrass [*Cynodon dactylon* (L.) Pers.] hay ad libitum supplemented with 0.4 kg of soybean (*Glycine max* L.) meal d<sup>-1</sup>.

For a given incubation time, 72 bags representing all experimental units (three N levels, two regrowth periods, 2 yr, and three replications; all in duplicate) were incubated and withdrawn at the same time. This procedure guaranteed identical ruminal conditions among treatments at each incubation time. Samples were composited across seasons (within plot) to ensure sufficient forage for analyses. The 0-h bags were not incubated in the rumen but were subjected to the same rinsing procedure used for the ruminally incubated bags. After withdrawal of bags from the rumen, bags were placed in a plastic bucket with water and rinsed repeatedly until the rinse water was colorless. Bags were frozen (-20°C), and at the end of the experiment all bags were washed at the same time in a clothes washing machine set at low water levels for one cycle. Afterwards, bags were dried at 60°C in a forced-air oven for 48 h and weighed. No corrections were made for microbial N contamination. According to Vanzant et al. (1998), techniques to predict microbial contamination have proven unsatisfactory for universal application. The N

concentration in the samples post-incubation was determined using the micro-Kjeldahl procedure described earlier.

### **Dry Matter and Crude Protein Degradation Kinetics**

Crude protein fractions were estimated using an in situ ruminal degradation method where N is partitioned into fractions A, B, and C (Krishnamoorthy et al., 1983). Fraction A represents the soluble portion of the N and was assumed to be degraded rapidly and completely. It was measured as the N that washed out of the bag when rinsed with water. Fraction C was considered to be ruminally unavailable N and was the portion of N remaining in the bags following incubation for 72 h. Fraction B was calculated by difference ( $B = A - C$ ) and represents the insoluble, potentially degradable N.

Kinetic parameters of DM disappearance were estimated using the non-linear model proposed by (McDonald, 1981).

$$P = A + B(1 - e^{-c(t-L)})$$

Where P = DM degraded at time t ( $\text{g kg}^{-1}$ ), A = wash loss ( $\text{g kg}^{-1}$ ), B = potentially degradable fraction ( $\text{g kg}^{-1}$ ), c = the rate at which b is degraded ( $\text{g kg}^{-1} \text{ h}^{-1}$ ), t = time (h) incubated in the rumen, and L = lag time (h). The constants A, B, c, and L were estimated using the nonlinear regression procedures (SAS Institute Inc., 1996).

For CP disappearance kinetics, the non-linear model proposed by Orskov and McDonald (1979) was used. This model used the same principles as the model described above, however, it does not include lag time. High solubility of the N present in cool-season grasses results in no lag time after incubation in the rumen.

The estimation of potential DM and CP degradability was calculated by fixing the particle turnover at  $0.06 \text{ h}^{-1}$  (Cerneau and Michalet-Doureu, 1991; cited by Michalet-

Doureu and Ould-Bah, 1992). The model used was proposed by Orskov and McDonald (1979) [PD= a + (b x c)/(c+0.06)].

### Statistical Analyses

Data were analyzed using mixed model methodology through MIXED procedure (SAS Institute Inc., 1996). Nitrogen fertilization, regrowth interval, year, and season were considered fixed effects and block and its interactions were considered random effects. The means reported in this text are least squares means. For botanical composition, herbage accumulation, CP, and IVDOM, the model used was:

$$Y_{ijkl} = \mu + A_i + N_j + R_k + S_l + B_m + (AN)_{ij} + (AR)_{ik} + (AS)_{il} + (NR)_{jk} + (NS)_{jl} + (RS)_{kl} \\ + (ANR)_{ijk} + (ANS)_{ijl} + (NRS)_{jkl} + (ANRS)_{ijkl} + e_{ijkl}$$

Where  $Y_{ijkl}$  is the dependent variable

$\mu$  is the overall mean

$N_j$  is the N effect (main plot)

$R_k$  is the regrowth interval effect (main plot)

$A_i$  is the year effect (sub-plot)

$S_l$  is the season effect (sub-sub-plot)

$B_m$  is the block effect

$(NR)_{jk}$  is the N\*regrowth intervals interaction

$(AN)_{ij}$  is the year\*N interaction

$(AR)_{ik}$  is the year\*regrowth interval interaction

$(AS)_{il}$  is the year\*season interaction

$(NS)_{jl}$  is the N\*season interaction

$(RS)_{kl}$  is the regrowth interval\*season interaction

$(ANR)_{ijk}$  is the year\*N\*regrowth interval interaction

$(ANS)_{ijl}$  is the year\*N\*season

$(ARS)_{ikl}$  is the year\*regrowth interval\*season interaction

$(NRS)_{jkl}$  is the N\*regrowth interval\*season interaction

$(ANRS)_{ijkl}$  is the year\*N\*regrowth interval\*season interaction

$e_{ijklm}$  is the error

Main plot (N and Regrowth interval) error was block\*N\*regrowth interval; sub-plot (year) error was block\*year; sub-sub-plot (season) error was the residual.

For the DM and N in situ fractionation response variables the model used was:

$$Y_{ijkl} = \mu + A_i + N_j + R_k + B_m + (AN)_{ij} + (AR)_{ik} + (NR)_{jk} + (ANR)_{ijk} + e_{ijk}$$

Where  $Y_{ijkl}$  is the dependent variable

$\mu$  is the overall mean

$N_j$  is the N effect (main plot)

$R_k$  is the regrowth interval effect (main plot)

$A_i$  is the year effect (sub-plot)

$B_m$  is the block effect

$(AN)_{ij}$  is the year\*N interaction

$(AR)_{ik}$  is the year\*regrowth interval interaction

$(NR)_{jk}$  is the N\*regrowth interval interaction

$(ANR)_{ijk}$  is the year\*nitrogen\*regrowth interval interaction

$e_{ijklm}$  is the error

Main plot (N, regrowth interval) error was block\*N\*regrowth interval; sub-plot (year) error was the residual.

## Results and Discussion

### **Botanical Composition, Herbage Accumulation, and Nutritive Value**

Botanical composition was not affected by N fertilization level or regrowth interval; however, there was a season\*year interaction (Table 5-1). In 2003, rye was predominant in the canopy during the winter and ryegrass was predominant during the spring. However, the low rainfall from March through May 2004 (92 mm vs. the 30-yr average of 274 mm) reduced ryegrass contribution during spring 2004, and there was no seasonal difference in ryegrass percentage. Fontaneli et al. (2000) observed ~ 80% rye and 15% ryegrass in the canopy in early winter (December – February) 1996. In early spring (March – May), there was a greater proportion of ryegrass (60%) than rye (30%). According to Rouquette et al. (1997), small grains grow better from late December to mid-February and ryegrass growth is rapid during March to late May.

There were effects of N level, season\*regrowth interval interaction, and year \* season interaction on herbage accumulation. Herbage accumulation increased linearly from 0.9 to 1.8 Mg ha<sup>-1</sup> at the 6-wk regrowth interval as N increased from 0 to 80 kg N ha<sup>-1</sup> (data not shown). Allen et al. (1974) tested different levels of N fertilization on oat-ryegrass mixed swards. Forage yield was 4.3 Mg ha<sup>-1</sup> and 9.0 Mg ha<sup>-1</sup> with 0 and 280 kg N ha<sup>-1</sup> yr<sup>-1</sup>. In studies where the maximum N rate was below 450 kg ha<sup>-1</sup>, the greatest yields have commonly occurred at the highest N rate applied (Morris et al., 1994).

There was a season\*regrowth interval interaction for herbage accumulation (table 5-2). Interaction occurred because during the winter period there was no effect of regrowth interval on accumulation, but in spring accumulation was greater for the 6-wk interval. At both intervals, spring herbage accumulation was greater than winter. Craigmiles and Weihsing (1971) harvested annual ryegrass every 1, 2, 3, or 4 wk

beginning in January. Highest yields were obtained by harvesting every 4 wk, with average forage yields of 1 Mg ha<sup>-1</sup> per 4-wk period. Altom et al. (1996) compared the herbage accumulation of rye-wheat-ryegrass at different N rates during fall-winter and spring. Herbage accumulation was 1 and 1.2 Mg ha<sup>-1</sup> (0 kg N ha<sup>-1</sup>) and 1.1 and 3.2 Mg ha<sup>-1</sup> (110 kg N ha<sup>-1</sup>) for fall-winter and spring accumulation, respectively. In the current study, lesser herbage accumulation in January and February likely was caused by the lower temperatures (Table 1, Appendix A). In contrast, during March-April, warmer temperatures resulted in greater herbage accumulation.

There also was a year\*season interaction for herbage accumulation (Table 5-1). Herbage accumulation was greater during the spring than winter both years; however, interaction occurred because the magnitude of the increase from winter to spring was greater in 2004 than in 2003. Extremely high rainfall in 2003 (209 mm above average for February and March) likely reduced the efficiency of N fertilizer utilization and resulted in lesser herbage accumulation that year. Although herbage accumulation was greater in 2004, the season effect was similar to that in 2003. In general, herbage accumulated during winter was ~ 50% of that during the spring. Cuomo et al. (1999) studied herbage accumulation of ryegrass established in different warm-season grass residues. There was a significant effect of season for all treatments. Average forage accumulation across treatments and years ranged from 0.2 Mg ha<sup>-1</sup> on January to 3.0 Mg ha<sup>-1</sup> on May. When annual ryegrass is planted using no-till systems, forage production has been inconsistent, particularly early in the growing season (Cuomo et al., 1999). However, greater consistency can be gained in no-till annual ryegrass production when warm-season annual

grass swards are treated with glyphosate 30 d before planting or where the residue was burned before planting (Cuomo et al. 1999).

There were effects of N\*season interaction, regrowth interval\*season interaction, and year\*season interaction on herbage CP and IVDOM (Table 5-3). There was a linear increase in CP concentrations in both seasons as N fertilization levels increased.

Nitrogen\*season interaction occurred because the range in the response to N was greater in the winter than spring. In addition, except for 0 N level, CP concentrations were always greater in winter than in spring. This can be attributed to the dilution effect of greater herbage mass produced in the spring that resulted in lesser CP concentrations. There was a linear increase in IVDOM during the winter as N level increased, however, there was only a trend ( $P = 0.11$ ) toward fertilization level effect on IVDOM during the spring. Appearance of ryegrass reproductive tillers likely diminished the effects of N fertilization level on IVDOM concentration.

There was a significant regrowth interval\*season interaction effect on CP and IVDOM (Table 5-2). During the winter, there was a small decrease in CP as regrowth interval increased, however, during the spring, because of the appearance of reproductive tillers, the rate of decline with increasing regrowth interval was more rapid. Crude protein concentrations of the herbage harvested at 6 wk in the winter and at 3 wk in the spring were similar. There was no difference in IVDOM concentrations for 3-wk and 6-wk regrowth intervals during the winter, but there was a significant decrease in IVDOM with increasing regrowth interval observed during the spring. There was a trend ( $P = 0.06$ ) for herbage harvested at the 3-wk regrowth interval to have lesser IVDOM ( $30 \text{ g kg}^{-1}$ ) in the spring than in the winter, but for the 6-wk regrowth interval, IVDOM concentration was

much less ( $150 \text{ g kg}^{-1}$ ) in the spring than in the winter. Data from Buxton and Russell (1988) for forages sampled following the beginning of reproductive development indicate a decline in IVDOM from 761 to  $552 \text{ g kg}^{-1}$  in orchardgrass (*Dactylis glomerata* L.) leaves from May to July. Buxton and Mertens (1989) reported that herbage IVDOM of four cool-season grass species decreased linearly with time during the spring. Plants with moderate number of reproductive tillers had an average decline in degradability of  $3.9 \text{ g kg}^{-1} \text{ d}^{-1}$ .

Year\*season interaction effects were observed in CP and IVDOM concentrations (Table 5-1). The extremely high rainfall during the winter of 2003 resulted in herbage with lesser CP concentrations than the herbage harvested during the winter of 2004. The CP concentration was greater during the spring of 2003 than the spring of 2004. In addition, CP concentrations were always greater in the winter than in the spring. Greater herbage accumulation was always associated with lesser CP concentrations because of the dilution effect mentioned before. The same pattern of response was observed for IVDOM concentrations as already described for CP.

### **Protein Fractionation of the Forage**

The CP fractions in rye-ryegrass herbage are presented as a proportion of the total CP. There was a significant effect of N fertilization level on concentrations of the CP fractions in rye-ryegrass herbage (Fig. 5-1). Fraction A increased linearly and Fraction B decreased linearly as level of N fertilization increased from 0 to  $80 \text{ kg N ha}^{-1}$ . In addition, there was a linear decrease in Fraction C from  $73 \text{ g kg}^{-1}$  to  $47 \text{ g kg}^{-1}$  as N fertilization level increased from 0 to  $80 \text{ kg ha}^{-1}$ .

Table 5-1. Year\*season interaction forage effects on botanical composition, crude protein (CP), and in vitro digestible organic matter (IVODM) of rye-ryegrass mixtures.

Year	Ryegrass <sup>†</sup>			SE	<i>P</i> <sup>‡</sup>	Herbage accumulation			SE	<i>P</i> <sup>‡</sup>	CP			SE	<i>P</i> <sup>‡</sup>	IVODM			SE	<i>P</i> <sup>‡</sup>								
	Winter	Spring				Winter	Spring				Winter	Spring				Winter	Spring											
-----%-----																												
----Mg ha <sup>-1</sup> ----																												
2003	47	95	3.5	<0.01	0.6	1.2	0.1	<0.01	200	170	6	<0.01	740	700	9	<0.01												
2004	30	35	3.5	0.22	1.2	2.2	0.1	<0.01	220	150	6	<0.01	770	640	9	<0.01												
<i>P</i> value <sup>§</sup>	<0.01	<0.01			<0.01	<0.01			<0.01	<0.01			<0.01	<0.01														
SE	4	4			0.1	0.1			6	6			9	9														

<sup>†</sup> As a proportional of total herbage accumulation on a dry matter basis

<sup>‡</sup>*P* value for effect of season within year

<sup>§</sup>*P* value for effect of year within season

Table 5-2. Season\*regrowth interval interaction effects for herbage accumulation and crude protein (CP) and in vitro digestible organic matter (IVDOM) concentrations of rye-ryegrass forage mixtures during 2003 and 2004.

Regrowth interval	Herbage accumulation		SE	$P^{\dagger}$	CP		SE	$P^{\dagger}$	IVDOM		SE	$P^{\dagger}$
	Winter	Spring			Winter	Spring			Winter	Spring		
----wk----												
	----Mg ha <sup>-1</sup> ----				-----g kg <sup>-1</sup> -----							
3	0.9	1.6	0.1	<0.01	220	200	7	0.02	760	730	12	0.06
6	1.0	2.2	0.1	<0.01	200	130	7	<0.01	750	600	12	<0.01
$P^{\ddagger}$	0.70	<0.01			<0.01	<0.01			0.73	<0.01		
SE	0.1	0.1			7	7			12	12		

<sup>†</sup> $P$  value for effect of season within cutting interval

<sup>‡</sup> $P$  value for effect of cutting interval within season

Table 5-3. N\*season interaction effects on crude protein (CP) and in vitro digestible organic matter (IVDOM) concentrations of rye-ryegrass forage.

Season	CP	SE	OPC <sup>†</sup>	IVDOM			SE	OPC <sup>†</sup>
N fertilization (kg ha <sup>-1</sup> )						N fertilization (kg ha <sup>-1</sup> )		
	0	40	80			0	40	80
	-----g kg <sup>-1</sup> -----			-----g kg <sup>-1</sup> -----				
Winter	150	210	260	7	L <sup>‡</sup>	720	770	770
Spring	130	160	200	7	L <sup>‡</sup>	660	660	690
P <sup>¶</sup>	0.06	<0.01	<0.01			<0.01	<0.01	<0.01
SE	9	9	9			16	16	16

<sup>†</sup>OPC = orthogonal polynomial contrast for effect of N fertilization levels within season

<sup>‡</sup>L = linear ( $P < 0.01$ )

<sup>§</sup>P for linear contrast for effect of N fertilization on IVDOM in spring

<sup>¶</sup>P for effect of season within N fertilization levels.

The concentrations of Fraction A in rye-ryegrass swards in this study are in the range reported by Hoffman et al. (1993b) for five species of cool-season grasses (from 370 to 600 g kg<sup>-1</sup>). Similar values of Fractions A, B, and C (430, 490, and 80 g kg<sup>-1</sup>, respectively) were observed by Michalet-Dourenu and Ould-Bah (1992) with perennial ryegrass. Salaun et al. (1999) studied the relationship between N fertilization and CP rumen degradability of perennial ryegrass. They concluded that reducing N fertilizer application decreased the theoretical degradability in the rumen due to the decrease in NPN. The total N disappearance was 600 and 710 g kg<sup>-1</sup> for plots fertilized with 250 and 550 kg N ha<sup>-1</sup>. Van Vuuren et al. (1991) observed increased levels of instantly degradable protein of perennial ryegrass as N fertilization levels increased from 0 to 700 kg ha<sup>-1</sup>.

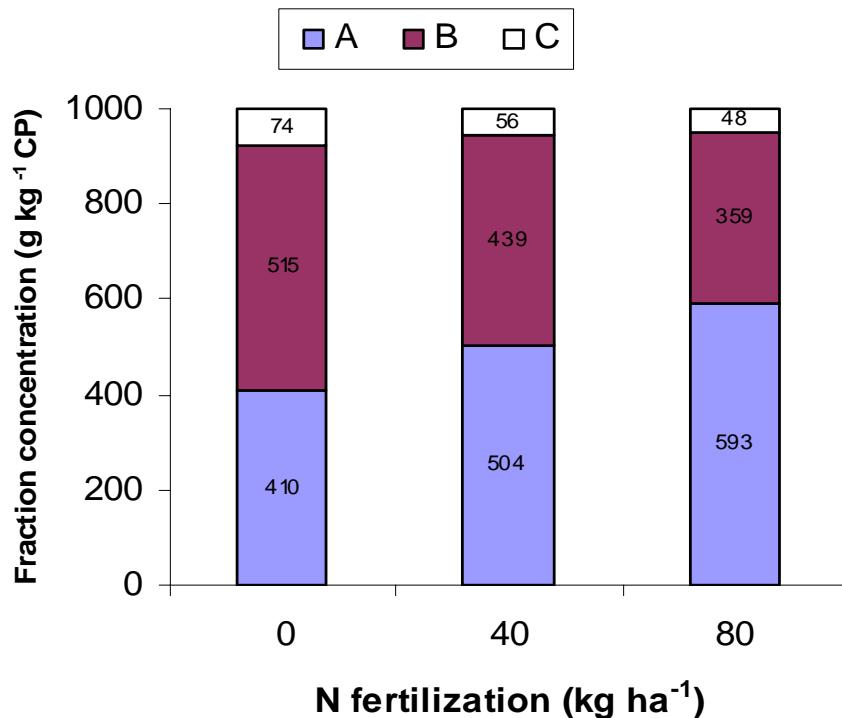


Fig. 5-1. Nitrogen fertilization effects on crude protein (CP) fraction concentrations in total CP of rye-ryegrass forage. There was a linear increase in Fraction A ( $P<0.01$ ,  $SE = 28$ ), and a linear decrease in Fraction B ( $P<0.01$ ,  $SE = 23$ ) and Fraction C ( $P<0.05$ ,  $SE = 12$ ).

There was significant regrowth interval effect on Fraction C concentration. Forage harvested at 3 wk ( $48 \text{ g kg}^{-1}$ ) had less Fraction C concentration than that harvested at 6 wk ( $71 \text{ g kg}^{-1}$ ).

According to Van Vuuren and Meijss (1987), CP of highly-fertilized young grass is characterized by a high rate of rumen degradation that will result in substantially greater ruminal ammonia concentrations and potentially greater losses of N via urine. The greater Fraction A associated with greater N fertilization levels in this study suggest that this may occur.

### Degradation Parameters of DM and CP

There was no effect of N fertilization level or regrowth interval on in situ DM degradation rates, lag time, and potential DM degradability (Table 5-4). Cool-season grasses generally have less DM disappearance lag time than warm-season grasses. For highly-digestible warm-season forages like elephantgrass (*Pennisetum purpureum* Schum.), Vieira et al. (1997) found lag times values of 4 h. With cool-season grasses, Waghorn and Burke (2001) reported values ranging from 0 to 4.5 h. The DM disappearance lag time in this study was 3 h.

Although there was a lag for DM disappearance, there was none for CP disappearance (Table 5-4). A difference in the most soluble fraction of the CP was observed among fertilization levels from 0 to 20 h of incubation, but CP disappearance was similar among treatments thereafter (Fig. 5-2). Newman et al. (2002a) observed a linear increase in lag time from 16 to 21 h as canopy height of continuously stocked limpograss increased. It is expected that warm-season grasses have longer lag time and slower N disappearance because of the lower soluble protein concentration than in cool-season grasses, which is thought to be mainly due to differences in Rubisco concentration (Akin and Burdick, 1975). Furthermore, much of the protein in warm-season grasses may be protected structurally because of its association with bundle-sheath cells (Mullahey et al., 1992).

There was a linear increase in potential CP degradability of the forage as N fertilization level increased, however, no effect of N levels were verified on CP lag time and rate of disappearance (Table 5-5). Potentially degradable CP was greater in 2004 ( $780 \text{ g kg}^{-1}$ ) than in 2003 ( $690 \text{ g kg}^{-1}$ ). The average CP rate of disappearance in this study is similar to rates described by Krishnamoorthy et al. (1983) for cool-season grasses and

legumes,  $0.05\text{ h}^{-1}$ . Other authors have found greater rates of disappearance for legumes. Hoffman et al. (1993b) reported protein disappearance rates of  $0.40\text{ h}^{-1}$  for birdsfoot trefoil (*Lotus corniculatus* L.) in the late-bud stage of growth, and Brown and Pitman (1991) found an average of  $0.43\text{ h}^{-1}$  for different species of tropical legumes. There was no significant effect of the N fertilization levels in this study on DM and CP rate of disappearance. Van Vuuren et al. (1991) found significant increases in OM ( $0.03\text{-}0.06\text{ h}^{-1}$ ) and CP ( $0.05\text{-}0.09\text{ h}^{-1}$ ) disappearance rates of perennial ryegrass as N fertilization level increased from 0 to  $700\text{ kg ha}^{-1}$ . Michalet-Douren and Ould-Bah (1992) observed rate of CP degradation and potential N degradability of perennial ryegrass herbage of  $0.1\text{ h}^{-1}$  and  $740\text{ g kg}^{-1}$ , respectively.

Table 5-4. Effect of N fertilization levels on DM and CP degradation parameters of rye-ryegrass forage.

	N fertilization levels ( $\text{kg ha}^{-1}$ )			SE	OPC <sup>†</sup> <i>P</i>
	0	40	80		
<b>DM</b>					
Lag time (h)	2.7	3.1	3.4	1.2	0.54
Rate of disappearance ( $\text{h}^{-1}$ )	0.08	0.09	0.16	0.06	0.21
Potential degradability ( $\text{g kg}^{-1}$ )	670	670	690	23	0.50
<b>CP</b>					
Lag time (h)	0	0	0	-	-
Rate of disappearance ( $\text{h}^{-1}$ )	0.08	0.06	0.06	0.01	0.14
Potential degradability ( $\text{g kg}^{-1}$ )	700	720	770	9	L <sup>‡</sup>

<sup>†</sup> OPC = orthogonal polynomial contrast

<sup>‡</sup>L=linear ( $P<0.01$ )

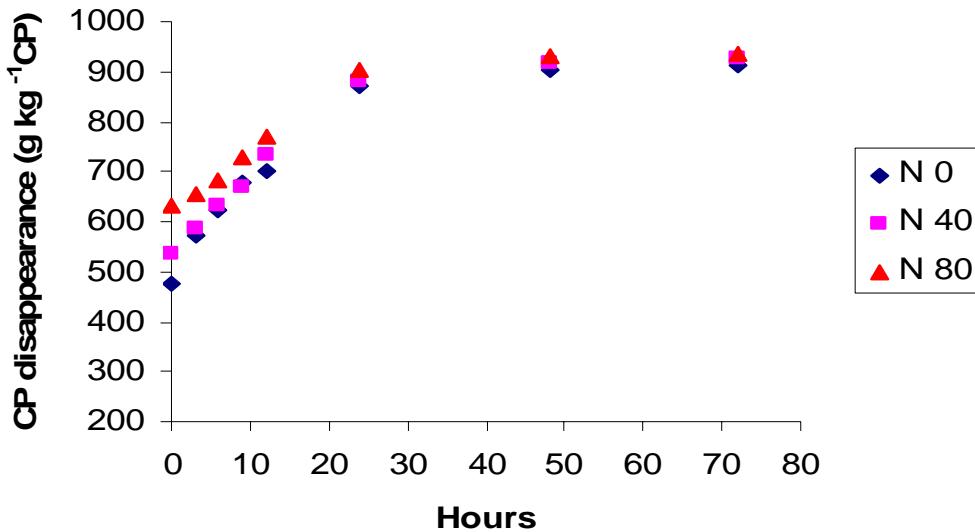


Fig. 5-2. N fertilization rate on crude protein (CP) disappearance of rye-ryegrass forage.

### Summary and Conclusions

Botanical composition of rye-ryegrass swards was affected by season with the proportion of rye being greater during the winter and proportion of ryegrass greater during the spring of a high rainfall year. During a drier year there was no difference in seasonal botanical composition due to reduced contribution from ryegrass in spring.

Nitrogen fertilization and regrowth interval did not affect botanical composition.

Herbage accumulation increased linearly with increased levels of N fertilization. More herbage accumulated with the 6-wk than the 3-wk regrowth interval in spring, but during winter, regrowth interval did not affect total accumulation. Accumulation was greater in spring than winter regardless of regrowth interval.

The effect of regrowth interval on herbage CP and IVDOM concentrations varied with season. There was no difference in IVDOM during the winter for the two regrowth intervals, however, lesser IVDOM concentrations were observed for the 6-wk than the 3-wk regrowth interval during the spring. Herbage CP concentrations were greater for the

3-wk regrowth interval during the winter and spring, but the difference was much greater in spring. Thus, regrowth interval is of much greater importance in determining forage nutritive value and herbage accumulation during spring than winter and during the spring season, greater N fertilization levels and shorter regrowth periods than in winter may be necessary to maintain the nutritive value of the forage.

There was a significant effect of N fertilization level on the CP fractions of rye-ryegrass. Increased N fertilization increased the concentration of Fraction A and decreased Fraction B and C. More Fraction A at greater fertilization levels has the potential to result in less efficient use of N by ruminants that can lead to greater N losses through the urine. No lag time was observed for in situ CP disappearance indicating that the CP present in rye-ryegrass herbage is highly soluble. Greater N fertilization increased the potential CP disappearance linearly.

When considering utilization of rye-ryegrass herbage for early weaned calves, the greater total CP and Fraction A concentrations in rye-ryegrass with increased levels of N fertilization implies that there may be an excess of ruminal degradable protein under these circumstances. Reduced N fertilization levels lower herbage accumulation and may not be a practical strategy to address this problem especially during a time of the year when quantity of forage is often the primary factor limiting animal performance.

Utilization of high energy, low protein supplements may be a useful management practice to improve better N and energy synchronization in the rumen and increase the efficiency of rumen degradable protein utilization by early weaned calves grazing cool-season grass pastures.

## CHAPTER 6

### HERBAGE ACCUMULATION, NUTRITIVE VALUE, AND CRUDE PROTEIN FRACTIONS OF TIFTON 85 SWARDS AT DIFFERENT CUTTING INTERVALS AND N FERTILIZATION LEVELS

#### **Introduction**

Bermudagrass is an important forage for beef and dairy cattle in the southern USA (Hill et al., 1998). ‘Tifton 85’ bermudagrass (*Cynodon spp.*) has been widely grown in the USA, central and South America, and southern Africa (Mandebvu et al., 1999). When compared with ‘Coastal’ and ‘Tifton 78’ bermudagrass, Tifton 85 is higher yielding and more digestible (Hill et al., 1993).

Warm-season grasses have larger proportions of cell-wall material compared with C3 grasses. This fraction is potentially digestible, but because of its chemical composition and anatomical structure, the rate of degradation and fermentation in warm-season grasses is relatively slow (Coleman et al., 2004). On the other hand, warm-season grasses have more efficient carbon fixation, resulting in greater total forage production when compared with cool-season grasses.

Bermudagrass herbage yield and nutritive value are dependent upon management practices, including N fertilization and regrowth interval. According to Wilkinson and Langdale (1974), Coastal and other bermudagrass cultivars produced maximum yields of about  $27 \text{ Mg ha}^{-1} \text{ yr}^{-1}$  at N rates of  $1200 \text{ kg ha}^{-1}$ , with near linear yield response to N up to about  $600$  to  $700 \text{ kg N ha}^{-1}$ . Prine and Burton (1956) evaluated the effects of different N rates and harvest frequencies on Coastal bermudagrass forage production and nutritive value. There was a curvilinear increase in herbage accumulation as N rate increased from

0 to 1008 kg N ha<sup>-1</sup> yr<sup>-1</sup> with maximum dry matter (DM) accumulation of 18.4 Mg ha<sup>-1</sup> yr<sup>-1</sup> with a 6- to 8-wk harvest interval. The forage crude protein (CP) concentration ranged from 97 to 190 g kg<sup>-1</sup> across the range of N fertilization rates. Burton et al. (1963) studied different defoliation intervals of Coastal fertilized with 660 kg N ha<sup>-1</sup> yr<sup>-1</sup>. The maximum herbage accumulation was 22 Mg ha<sup>-1</sup> using a 6-wk defoliation interval.

Warm-season grass CP tends to be more slowly degraded in the rumen than that of cool-season grasses (Minson, 1990), and CP concentration often does not meet the nutrient requirement of growing ruminants (Moore, 1992). The C4 grasses have a lower soluble protein concentration (260 to 300 g kg<sup>-1</sup>) than C3 grasses (330 to 480 g kg<sup>-1</sup>). This is thought to be mainly due to lower Rubisco concentration and to the relative abundance of Rubisco in the slowly or incompletely-digested bundle sheath cells of C4 plants vs. the prevalence of Rubisco in the rapidly degraded mesophyll of C3s (Akin and Burdick, 1975). Redfearn et al. (1995) studied the rates of ruminal protein disappearance for switchgrass (*Panicum virgatum* L.), big bluestem (*Andropogon gerardii* Vitman), and smooth bromegrass (*Bromus inermis* Leyss.) and suggested that generalizations regarding ruminal protein degradability should not be made among forage species. The total protein disappearance was 847, 795, and 974 mg g<sup>-1</sup> for switchgrass, big bluestem, and smooth bromegrass, respectively. Newman et al. (2002a) fractionated the N content of limpograss (*Hermathria altissima* Stapf. And Hubb.). They concluded that low total CP in the DM, low concentrations of CP Fractions A and B in the rumen, and the long lag phase for degradation of the B fraction, may contribute to reported protein deficiencies of cattle grazing limpograss. Johnson et al. (2001b) reported that with no N fertilization, Fraction A concentration was 212 (bahiagrass[*Paspalum notatum* Flügge]), 310 (bermudagrass),

and 279 g kg<sup>-1</sup> (stargrass [*Cynodon lnemfuensis* Vanderyst]) of the total N, but upon application of 160 kg N ha<sup>-1</sup> per cutting, Fraction A represented 285 (bahiagrass), 400 (bermudagrass), and 421 g kg<sup>-1</sup> (stargrass) of the total N. Assis et al. (1999) studied the effects of N fertilization levels on CP fractions of Tifton 85. Fraction A ranged from 270 to 300 g kg<sup>-1</sup> with no significant effect of fertilization levels from 0 to 400 kg N ha<sup>-1</sup>.

In Florida cow-calf systems, early weaning has been an effective management practice to increase the rebreeding rates of first-calf heifers. Tifton 85 bermudagrass is an important warm-season grass in southeast USA that could be used in pasture-based systems for early weaned calves. However, warm-season grasses usually have low nutritive value and are incompatible with the high nutritional requirements of early weaned calves. In order to maximize the performance of these calves on pastures, an effective supplementation program must be developed to overcome the limitations of the forage. For development of a supplementation program it is important to know seasonal patterns of herbage accumulation and nutritive value. In addition, measurements of DM and CP degradation in the rumen can provide useful information to guide the choice of supplement composition. Therefore, as part of a research program evaluating strategies for feeding early weaned calves, this study was conducted to evaluate the effect of N fertilization level and regrowth interval on herbage accumulation, nutritive value, and CP in situ fractions of Tifton 85 bermudagrass swards.

## **Material and Methods**

The plot study was conducted at the University of Florida Beef Research Unit, 18 km northeast of Gainesville, FL (30° N). Data were collected during 2003 and 2004. The soils at the research site are Adamsville fine sand (Aquic Quartzipamments, hyperthermic, uncoated) and Sparr fine sand (Grossarenic Paleudult, hyperthermic, loamy

siliceous). These soils are moderately well-drained with rapid permeability. Prior to initiation of summer grazing at the site, mean soil pH (1:2 soil:deionized H<sub>2</sub>O ratio) was 5.5, and Mehlich-I (0.05 M HCl + 0.0125 M H<sub>2</sub>SO<sub>4</sub>) extractable P, K, Mg, and Ca concentrations in the Ap1 horizon (0- to 15-cm depth) were 44, 17, 40, and 328 mg kg<sup>-1</sup>, respectively. Average annual temperature and rainfall are described in Table 1 (Appendix A).

Treatments were the factorial combinations of two regrowth intervals (2 and 4 wk) and three N fertilization levels (0, 40, and 80 kg ha<sup>-1</sup> in each 4-wk period) evaluated in two periods of 4 wks in each of 2 yr. Treatments were replicated three times in a completely randomized design. Plot size was 2 x 4 m with a 1 m border between plots.

In early April of 2003 and 2004, plots received an initial application of 40 kg N ha<sup>-1</sup>, 17 kg P ha<sup>-1</sup>, and 66 kg K ha<sup>-1</sup> to stimulate growth and provide maintenance P and K. Plots were staged to a 15-cm stubble on 20 June 2003 and 21 May 2004 to begin the first 4-wk period. The first experimental period was from 20 June to 18 July 2003 and 21 May to 18 June 2004. The second 4-wk period followed immediately after the harvests on 18 July 2003 and 18 June 2004 and ended on 15 Aug. 2003 and 16 July 2004. The 2-wk treatment plots were harvested twice in each 4-wk period and the 4-wk treatment plots once. Forage samples were harvested at a 15-cm stubble height using a sickle bar mower. The central 1-m<sup>2</sup> area of the plot was harvested, the wet weight recorded, and a subsample dried at 60°C for 48 h. After drying, the subsample was weighed and ground in an Udy mill (Udy Corporation, Fort Collins, CO.) to pass a 4-mm screen. Herbage accumulation, laboratory analyses, and in situ determinations were the same as described in Chapter 5.

### Dry Matter and Crude Protein Degradation Kinetics

The DM and CP degradation kinetics measurements were similar to those reported in Chapter 5. The exception was that DM and CP disappearance were estimated using the non-linear model proposed by (McDonald, 1981). Unlike the cool-season C3 grasses, warm-season C4 grasses usually present a lag time for in situ CP disappearance.

$$P = A + B(1 - e^{-c(t-L)})$$

In this model, P = DM degraded at time t ( $\text{g kg}^{-1}$ ), A = wash loss ( $\text{g kg}^{-1}$ ), B = potentially degradable fraction ( $\text{g kg}^{-1}$ ), c = the rate at which b is degraded ( $\text{g kg}^{-1} \text{ h}^{-1}$ ), t = time (h) incubated in the rumen, and L = lag time (h). The constants A, B, c, and L were estimated using the nonlinear regression procedures of SAS, version 8 (SAS Institute Inc., 1996).

Potential DM and CP disappearance were calculated by fixing the particle turnover at  $0.04 \text{ h}^{-1}$ . The model used to estimate the potential CP disappearance was proposed by Orskov and McDonald (1979) [ $\text{PD} = a + (b \times c)/(c+0.04)$ ].

### Statistical Analyses

Data were analyzed using mixed models methodology through PROC MIXED (SAS Institute Inc., 1996). Nitrogen fertilization, regrowth interval, year, and period were considered fixed affects, and replicates and their interactions were considered random effects. The nature of the response to N was determined using orthogonal polynomial contrasts. The means reported are least squares means. For herbage accumulation, CP, and IVOMD, the model used was:

$$Y_{ijkl} = \mu + A_i + N_j + R_k + P_l + (AN)_{ij} + (AR)_{ik} + (AP)_{il} + (NR)_{jk} + (NP)_{jl} + (RP)_{kl} + (ANR)_{ijk} + (ANP)_{ijl} + (NRP)_{jkl} + (ANRP)_{ijkl} + e_{ijkl}$$

Where  $Y_{ijkl}$  is the dependent variable

$\mu$  is the overall mean

$N_j$  is the N effect (main plot)

$R_k$  is the regrowth interval effect (main plot)

$A_i$  is the year effect (sub-plot)

$P_l$  is the period effect (sub-sub-plot)

$(AN)_{ij}$  is the year\* N interaction

$(AR)_{ik}$  is the year\*regrowth interval interaction

$(AP)_{il}$  is the year\*period interaction

$(NP)_{ijl}$  is the N\*period interaction

$(RP)_{kl}$  is the regrowth interval\*period interaction

$(ANR)_{ijk}$  is the year\*N\*regrowth interval interaction

$(ANP)_{ijl}$  is the year\*N\*period interaction

$(ARP)_{ikl}$  is the year\*regrowth interval\*period interaction

$(NRP)_{jkl}$  is the N\*regrowth interval\*period interaction

$(ANRP)_{ijkl}$  is the year\*N\*regrowth interval\*period interaction

$e_{ijkl}$  is the error

Main plot (N, regrowth interval, and N\*regrowth interval) error was

replicate\*N\*regrowth interval; sub-plot (year) error was replicate\*year; sub-sub-plot

(season) error was the residual.

For the DM and N in situ fractionation response variables, season was not included in the model because samples from a given experimental unit were composited across seasons. The model used was:

$$Y_{ijkl} = \mu + A_i + N_j + R_k + (AN)_{ij} + (NR)_{jk} + (AR)_{ik} + (ANR)_{ijk} + e_{ijkl}$$

Where  $Y_{ijkl}$  is the dependent variable

$\mu$  is the overall mean

$N_j$  is the N effect (main plot)

$R_k$  is the regrowth interval effect (main plot)

$A_i$  is the year effect (sub-plot)

$(AN)_{ij}$  is the year\*N interaction

$(AR)_{ik}$  is the year\*regrowth interval interaction

$(NR)_{jk}$  is the N\*regrowth interval interaction

$(ANR)_{ijk}$  is the year\*N\*regrowth interval interaction

$e_{ijk}$  is the error

Main plot (N, regrowth interval, and N\*regrowth interval) error was

replicate\*N\*regrowth interval; sub-plot (year) error was the residue.

## Results and Discussion

### Herbage Accumulation and Nutritive Value

There were N-rate main effect on herbage accumulation. That resulted from a linear increase (1.6-2.6 Mg ha<sup>-1</sup> per 4-wk period) in herbage accumulation as levels of N fertilization increased from 0 to 80 kg ha<sup>-1</sup> (Table 6-1). Prine and Burton (1956) reported a curvilinear increase in herbage accumulation as N rate increased from 0 to 1008 kg N ha<sup>-1</sup>. The highest efficiency in production (kg DM kg<sup>-1</sup> N ha<sup>-1</sup>) occurred at 336 kg N ha<sup>-1</sup>, which approximately corresponds to the highest N rate in the current study if one extends the current 8-wk trial to four cuttings at 4-wk intervals over an entire growing season. Wilkinson and Langdale (1974) reported linear yield responses of several bermudagrass cultivars to N rates of 600 to 700 kg ha<sup>-1</sup>.

The year\*regrowth interval interaction occurred because there was no difference in herbage accumulation between 2-wk ( $1.3 \text{ Mg ha}^{-1}$ ) and 4-wk ( $1.4 \text{ Mg ha}^{-1}$ ) intervals in 2003, but there was a difference in 2004 (2.3 vs.  $3.5 \text{ Mg ha}^{-1}$  for 2- and 4-wk intervals, respectively (data not shown). The reason for lack of a regrowth interval effect in 2003 is not clear, and results of most previous studies are more like 2004 results in the current study. Prine and Burton (1956) observed greater herbage accumulation when Coastal bermudagrass was harvested from 6- to 8-wk of regrowth compared to shorter intervals. Mandebvu et al. (1999) reported bermudagrass herbage accumulation of  $5.8 \text{ Mg ha}^{-1}$  at a 7-wk cutting intervals compared with  $2.2 \text{ Mg ha}^{-1}$  at 3 wk. Burton et al. (1963) studied different defoliation intervals of Coastal fertilized with  $660 \text{ kg N ha}^{-1}$ . Maximum herbage accumulation occurred when using a 6-wk defoliation regimen.

There was a year\*period interaction for herbage accumulation (data not shown). There was no difference in herbage accumulation between the periods in 2003 (1.4 vs.  $1.2 \text{ Mg ha}^{-1}$ ), however, in May to June 2004 Tifton 85 accumulated more DM than during June to July (3.7 vs.  $2.0 \text{ Mg ha}^{-1}$ , respectively). The pattern of Tifton 85 herbage accumulation has not been consistent across periods of the growing season in the literature, and this is likely due to changes in year-to-year and location-to-location weather conditions. Mandebvu et al. (1999) did not find differences in herbage accumulation of Tifton 85 from July to September. The authors suggested that weather conditions are important factors affecting variation in herbage accumulation through the season. There was no indication that weather conditions affected herbage accumulation during the two periods per year in the current study. It is likely that the greater herbage

accumulation during May to June 2004 was due in part to this period's proximity in time to the initial fertilization made in April.

Table 6-1. N fertilization effects on herbage accumulation and in vitro digestible organic matter (IVDOM) of Tifton 85 forage during 42-d periods.

Variable	N fertilization ( $\text{kg ha}^{-1} \text{ period}^{-1}$ )			SE	OPC <sup>†</sup>
	0	40	80		
-----Mg $\text{ha}^{-1}$ -----					
Herbage accumulation	1.6	2.2	2.6	0.1	L <sup>‡</sup>
IVDOM	480	500	530	12	L <sup>‡</sup>

<sup>†</sup>OPC = orthogonal polynomial contrast

<sup>‡</sup>L = linear ( $P < 0.01$ )

There was a linear increase in IVDOM with increasing N fertilization level (Table 6-1). In addition, there was a N fertilization\* regrowth interval interaction in CP concentration of Tifton 85 (Table 6-2). At both regrowth intervals, there was a linear increase in CP concentration with increasing N fertilization, but interaction occurred because the rate of increase was greater for the 2-wk than the 4-wk interval. The CP concentrations were greater at 2- than 4-wk regrowth intervals at all N fertilization levels tested. Johnson et al. (2001b) reported a linear increase in bermudagrass CP concentration with increasing levels of N fertilization. Herbage CP concentrations were 98, 146, and 180 g  $\text{kg}^{-1}$  for fertilization levels of 0, 78, and 156  $\text{kg N ha}^{-1}$ . Similar results were found by Lima et al. (1999b) with limpograss. Increasing the N fertilization levels from 50 to 150  $\text{kg ha}^{-1}$  increased CP concentrations from 97 to 115 g  $\text{kg}^{-1}$ . Stallcup et al. (1986) reported that CP concentrations in bermudagrass pastures fertilized with 0 and 50  $\text{kg N ha}^{-1}$  increased from 114 to 143 g  $\text{kg}^{-1}$ .

Table 6-2. Regrowth interval\*N fertilization level interaction effects on CP concentrations of Tifton 85 forage.

Regrowth interval (wk)	N fertilization (kg ha <sup>-1</sup> period <sup>-1</sup> )			SE	OPC <sup>†</sup>
	0	40	80		
-----g kg <sup>-1</sup> -----					
2	140	155	190	6	L <sup>‡</sup>
4	115	120	135	6	L <sup>‡</sup>
P <sup>§</sup>	<0.01	<0.01	<0.01		
SE	6	6	6		

<sup>†</sup> OPC = orthogonal polynomial contrast

<sup>‡</sup> L = linear ( $P < 0.01$ )

<sup>§</sup> P regrowth interval within N fertilization level

Mandebvu et al. (1999) tested the effects of regrowth interval on in vitro digestible dry matter (IVDMD) and CP concentrations of Tifton 85 swards and found a linear decrease in IVDMD of Tifton 85 from a 3-wk (620 g kg<sup>-1</sup>) to a 7-wk (510 g kg<sup>-1</sup>) regrowth period. In addition, a linear decrease in CP concentration was observed from 210 to 136 g kg<sup>-1</sup> for 3- and 7-wk regrowth herbage.

### Protein Fractionation of the Forage

Nitrogen fertilization levels did not affect Fraction A in Tifton 85 herbage. However, there was a linear increase in fraction B and a linear decrease in fraction C as level of N fertilization increased (Fig. 6-1 A). Johnson et al. (2001b) observed a linear increase in Fraction A (310-400 g kg<sup>-1</sup>) as N fertilization of bermudagrass increased from 0 to 157 kg N ha<sup>-1</sup>. According to Follett and Wilkinson (1995), increased level of N

fertilization increases nitrate accumulation in the plant, and nitrate is a component of Fraction A. In contrast, Assis et al. (1999) tested two N fertilization levels (0 and 400 kg ha<sup>-1</sup>) on ‘Tifton 44’ and Tifton 85 and did not find differences in Fraction A concentration. Fraction A was 304 and 302 g kg<sup>-1</sup> for Tifton 44, and 270 and 300 g kg<sup>-1</sup> for Tifton 85 at N rates of 0 and 400 kg ha<sup>-1</sup>, respectively. In this study, there was a linear decrease in Fraction C of Tifton 85 as fertilization increased from 0 to 80 kg N ha<sup>-1</sup>. Similar results were found by Johnson et al. (2001b) who reported a linear decrease (80 to 60 g kg<sup>-1</sup>) in bermudagrass Fraction C as N fertilization level increased from 0 to 157 kg ha<sup>-1</sup>.

Regrowth interval did not affect concentrations of Fractions A and B, but a smaller Fraction C was observed in Tifton 85 at the 2- (207 g kg<sup>-1</sup>) than at the 4-wk (282 g kg<sup>-1</sup>) interval (Fig. 6-1 B). Lima et al. (1999a) reported a greater proportion of the CP linked to the acid detergent fiber (ADF) and unavailable for ruminal digestion for Tifton 85 at 8- than 4-wk regrowth. The values for Fraction C at 4-wk regrowth found in this study were similar to those reported by Malafaia et al. (1997) for palisadegrass (*Brachiaria brizantha* Stapf.) at 4 wk of regrowth (280 g kg<sup>-1</sup>) but greater than the values found for Tifton 85 (170 g kg<sup>-1</sup>).

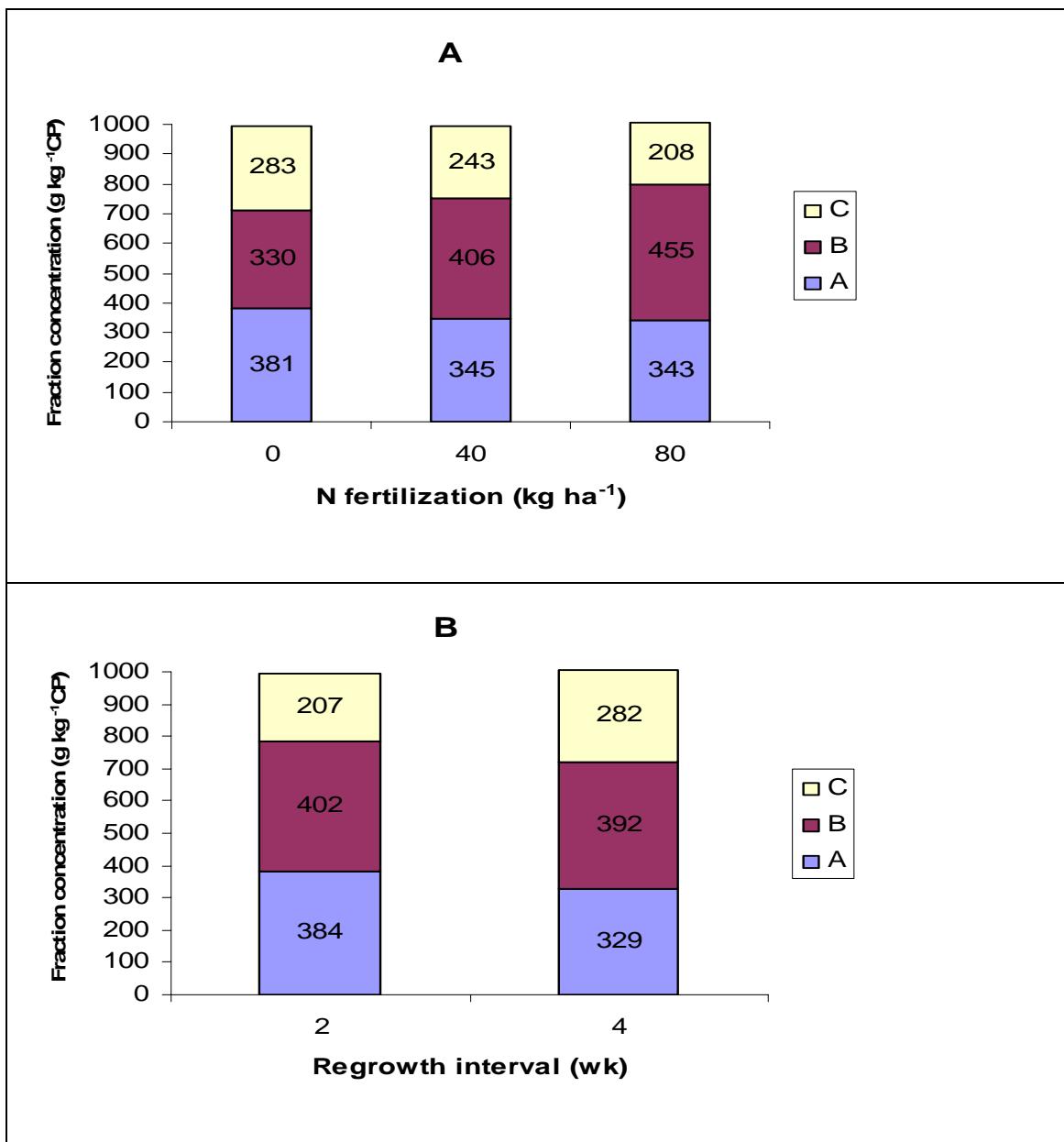


Fig. 6-1. N fertilization (Fig. A) and regrowth interval (Fig. B) effects on crude protein (CP) fraction concentrations in total CP of Tifton 85 forage. There was no effect of N fertilization on Fraction A ( $P>0.10$  SEM=23), a linear increase ( $P<0.05$ , SEM=30) in Fraction B, and a linear decrease ( $P<0.01$ , SEM=11) in Fraction C. There was no effect of regrowth interval on Fractions A and B. Fraction C was different ( $P<0.05$ ) between intervals.

#### Disappearance Parameters of DM and CP

There was no effect of N fertilization on rate of DM disappearance and lag time, however, a linear increase in potentially degradable DM was observed with increasing N

fertilization levels (Table 6-3). There was a significant effect of regrowth interval on rates of DM disappearance and potentially degradable DM (Table 6-4). In contrast to these results, Mandebvu et al. (1999) did not find differences in rate of DM disappearance ( $0.03\text{ h}^{-1}$ ) or potential degradability ( $650\text{ g kg}^{-1}$ ) of Tifton 85 at regrowth intervals from 3 to 7 wk. Newman et al. (2002a) did not find differences in lag time (9 h) or rate of disappearance (0.06) for limpograss herbage from continuously stocked swards grazed at different canopy heights, however, a linear decrease in potentially degradable DM was observed as canopy height increased from 20 to 60 cm. Assis et al. (1999) tested the effect of N fertilization levels of 0 and  $400\text{ kg ha}^{-1}$  on DM digestibility parameters of Tifton 85. They found no significant effect of N fertilization level on lag time (3.5 h) or potentially degradable DM ( $400\text{ g kg}^{-1}$ ). The DM disappearance lag time found in this study (5.9 h) was greater than those reported by Vieira et al. (1997) for elephantgrass (*Pennisetum purpureum* Schum.) (3 h) and shorter than the values reported by Brown and Pitman (1991) for bahiagrass (14.1 h).

The rate of CP disappearance and lag time were not affected by the N fertilization level with average values of  $0.06\text{ h}^{-1}$  and 4.2 h, respectively (Table 6-3). The CP lag time observed in this study was similar to the lag times reported by Assis et al. (1999) (3.5 – 6.0 h) for Tifton 85 and shorter than the average lag time found by Newman et al. (2002a) for limpograss (18 h). Assis et al. (1999) did not find significant effects of N fertilization on rate of degradation, corroborating the data presented in this study.

Table 6-3. Effect of N fertilization rates on dry matter (DM) and crude protein (CP) degradation of Tifton 85 forage.

	N fertilization (kg ha <sup>-1</sup> )			SE	OPC <sup>†</sup> P value
	0	40	80		
<b>DM</b>					
Lag time (h)	5.7	5.6	6.3	1.0	0.55
Rate of disappearance (h <sup>-1</sup> )	0.04	0.04	0.08	0.01	0.77
Potential degradability (g kg <sup>-1</sup> )	476	512	512	13	L <sup>‡</sup>
<b>CP</b>					
Lag time (h)	4.4	4.0	4.2	2.2	0.94
Rate of disappearance (h <sup>-1</sup> )	0.02	0.05	0.11	0.07	0.27
Potential degradability (g kg <sup>-1</sup> )	567	597	611	17	L <sup>‡</sup>

<sup>†</sup>OPC = orthogonal polynomial contrast

<sup>‡</sup>L=linear, ( $P<0.05$ )

The potential degradability of the CP increased linearly with increasing N fertilization levels (Table 6-3). Assis et al. (1999) also found greater potential CP degradability of Tifton 85 fertilized with 400 kg N ha<sup>-1</sup> (490 g kg<sup>-1</sup>) than non-fertilized (470 g kg<sup>-1</sup>). Newman et al. (2002a) observed a linear decrease in potential CP degradability when canopy heights of continuously-stocked limpograss pastures increased from 20 to 60 cm.

Although there was no regrowth interval effect on DM disappearance lag time, rate of DM disappearance and potentially degradable DM were less at the 4-wk than the 2-wk regrowth interval (Table 6-4).

Table 6-4. Effect of regrowth interval on dry matter (DM) and crude protein (CP) degradation of Tifton 85 forages.

	Regrowth interval		SE	P
DM	2 wk	4 wk		
Lag time (h)	6.5	5.0	0.6	0.06
Rate of disappearance ( $\text{h}^{-1}$ )	0.05	0.03	0.01	< 0.01
Potential degradability ( $\text{g kg}^{-1}$ )	530	470	8	< 0.01
CP				
Lag time (h)	1.1	7.3	1.3	< 0.01
Rate of disappearance ( $\text{h}^{-1}$ )	0.05	0.07	0.04	0.70
Potential degradability ( $\text{g kg}^{-1}$ )	590	581	12	0.14

There was no effect of regrowth interval on rate of CP disappearance and potentially degradable CP (Table 6-4). However, lag time was shorter for Tifton 85 at a 2- (1.1 h) than a 4-wk (7.3 h) regrowth. The lag time observed in this study for 2-wk-old Tifton 85 is comparable to the lag time in cool-season grasses (0 to 4.5 h) reported by Waghorn and Burke (2001), possibly because of the greater concentration of soluble protein in younger plants (Minson, 1990).

There was an increase in CP disappearance from 0 to 72 h of incubation at all N fertilization levels and regrowth intervals (Fig. 6-2A). The CP disappearance of Tifton 85 herbage from the three N fertilization levels was similar during the first 3 h of incubation. A difference between the 0 N treatment and the others was observed after 6 h when the 0 N treatment started to show a greater proportion of undegradable CP. This continued

through 72 h. A similar pattern of CP disappearance was observed for the two regrowth intervals (Fig. 6-2B). After 6 h of incubation, the forage harvested at a 4-wk regrowth was less degraded and that difference was maintained through 72 h.

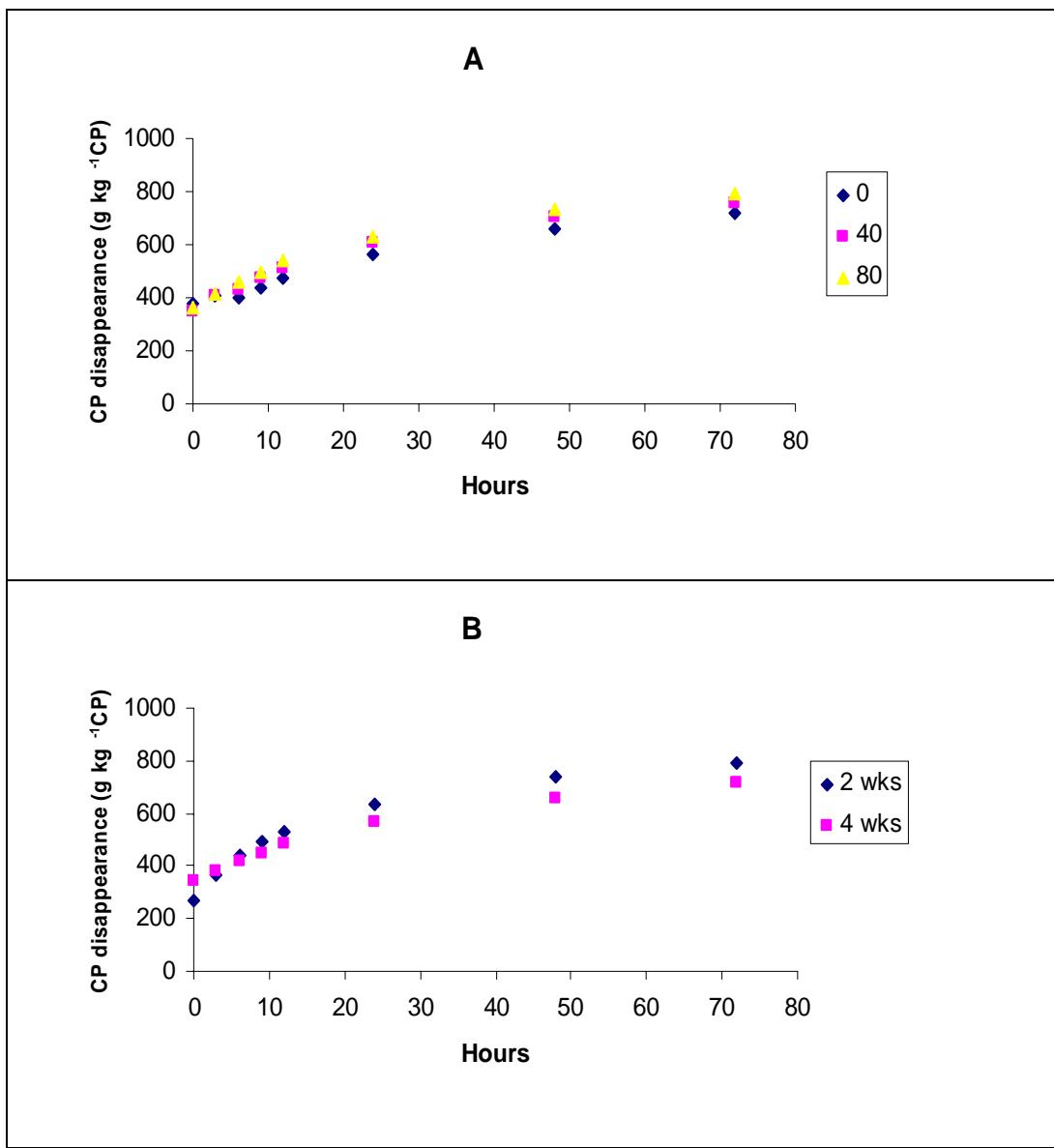


Fig. 6-2. Tifton 85 crude protein (CP) disappearance at three N fertilization levels (A) and two regrowth intervals (B).

According to Minson (1990), the CP in warm-season grasses is more slowly degraded in the rumen than that of cool-season grasses. The C4 plants have a lower soluble protein concentration, which is thought to be mainly due to lower Rubisco

concentration than for C3s. Most of the Rubisco in C4 plants is located in the parenchyma bundle sheath, which is slowly or incompletely digested in the rumen (Akin and Burdick, 1975) and further contributes to the less rapid release of CP by C4 grass species.

### **Summary and Conclusions**

Herbage accumulation of Tifton 85 bermudagrass increased linearly as the N fertilization level increased and was greater for 4- than the 2-wk regrowth period in 1 of the 2 yr. Increasing N fertilization rates from 0 to 80 kg ha<sup>-1</sup> resulted in a linear increase in CP and IVDOM concentrations, and herbage harvested at 4 wk contained less CP and IVDOM when compared with 2-wk regrowth.

Crude protein Fraction A was not affected by N fertilization levels or maturity, however, there was a linear increase in Fraction B and linear decrease in Fraction C as N fertilization increased. Forage harvested at 4 wk had a greater proportion of Fraction C than forage harvested at 2 wk. In general, the proportion of the more degradable fractions (A and B) was greater for less mature and more heavily fertilized herbage.

Level of N fertilization did not affect in situ lag time in DM disappearance, rate of disappearance, or potential disappearance. However, DM rate and potential disappearance were less with a longer regrowth period. Potential CP disappearance increased linearly as N fertilization level increased. The in situ lag time for CP was shorter for forage harvested at 2 than at 4 wk of regrowth. The in situ CP lag time for Tifton 85 harvested at 2 wk was comparable to lag times reported in the literature for cool-season grasses. In situ CP disappearance increased from 270 to 380 g kg<sup>-1</sup> at 0 h to 720 to 790 g kg<sup>-1</sup> at 72 h of incubation for the N fertilization levels and regrowth intervals tested in this study.

In order to supply better nutritive value forage to ruminants, N fertilization and shorter regrowth intervals must be considered. In Tifton 85 bermudagrass longer regrowth intervals and/or no N fertilization decreased rumen degradable CP concentration in the forage. It is likely that if the grass was fed to ruminants there would be a deficiency of rumen-degradable protein. Diets that are low in rumen-degradable protein will have a greater negative impact on performance of ruminants with high CP requirements, e.g., early weaned calves and dairy cows. Use of N fertilization and a shorter regrowth interval are easily implemented management practices to improve nutritive value and potential rumen-degradable protein in Tifton 85 swards. Their use in production systems will depend upon the economics of fertilization and the potential yield reductions and lower stocking rates associated with shorter regrowth intervals. From a supplementation perspective, the issues are clearly different for Tifton 85 than for the rye (*Secale cereale* L.)-ryegrass (*Lolium multiflorum* Lam.) mixture. For rye-ryegrass, rapid release of N in the rumen suggests the need for high energy supplements with slowly ruminally degraded CP sources, while for Tifton 85, especially if more mature or less well fertilized, the supplement must assure that N levels in the rumen are sufficiently high to allow utilization of available energy.

## CHAPTER 7 SUMMARY AND CONCLUSIONS

The profitability of the Florida cow-calf enterprise is largely dependent on the reproductive performance of the cow herd. Low body condition is responsible for lower conception rates and overall cow herd productivity. Early weaning of the calves of young cows and first-calf heifers is a management strategy that has potential to increase their reproductive rates by allowing more rapid restoration of body condition after parturition. Although the benefits of early weaning, i.e., improving reproduction and reducing nutrient requirements of the cow, have been recognized for many years, one factor limiting practical application of early weaning has been management of the early weaned (EW) calves. Producers that early wean their calves could possibly send these animals directly to the feedlot; however, this has not been the most profitable. The necessity of keeping the calves during the winter to get a higher price has resulted in recent studies evaluating feed management of EW calves.

Mild winters in the southern USA offer an opportunity to raise calves on forage-based grazing systems using high nutritive value cool season annual forages in winter and warm-season perennial grasses during summer, however, some concentrate supplementation may be needed because the calves have a limited rumen capacity and high nutrients requirements. The major expense in raising these calves is feed cost, therefore low-cost alternatives to high concentrate diets, e.g. pasture-based systems, are needed. Two grazing studies (Chapters 3 and 4) were conducted to test the effects of supplementation level on herbage characteristics, forage intake, and performance of early

weaned calves grazing rye (*Secale cereale* L.)-ryegrass (*Lolium multiflorum* Lam.) and Tifton 85 bermudagrass (*Cynodon spp.*) pastures during the winter-spring and summer seasons, respectively. In addition, two plot studies were conducted to assess the effects of N fertilization levels and regrowth interval on herbage accumulation, nutritive value, and in situ crude protein (CP) fractions of rye-ryegrass and Tifton 85 (Chapters 5 and 6). The overall goal of the research effort was to assess a range of strategies for raising early weaned calves and to explain the biological basis for the success or failure of these approaches. All studies were conducted at the University of Florida Beef Research Unit, 18 km northeast of Gainesville, FL.

### Rye-ryegrass Grazing Study

Treatments were three levels of a commercial pelleted concentrate (147 g CP kg<sup>-1</sup> and total digestible nutrient concentration of 700 g kg<sup>-1</sup>), 10, 15, and 20 g kg<sup>-1</sup> of calf BW, offered daily. Each treatment was replicated three times in a completely randomized design, so there were a total of nine experimental units in the study. Data were collected during the 2003 and 2004 winter-spring seasons. Starting dates were 28 Jan. 2003 and 15 Jan. 2004, and grazing ended on 14 May 2003 and 29 Apr. 2004. Calves were weaned on 2 Jan. 2003 and 5 Jan. 2004 at approximately 90 d of age and 100 kg of body weight (BW). Pasture size was 0.2 ha, and each pasture was subdivided into four paddocks. Pastures were rotationally stocked with a 7-d grazing and 21-d resting period. Two early weaned calves (1 steer and 1 heifer) were assigned as testers to each experimental unit such that BW was equal across all experimental units. "Put and take" early weaned calves of comparable age and weight to the testers were used to maintain similar herbage allowance across experimental units.

Rye-ryegrass pastures grazed by EW calves receiving different levels of supplement had similar herbage mass, accumulation, allowance, and nutritive value. Seasonal variation in forage responses were the result of the wheather conditions during the trial, especially the very high rainfall that occurred during the 2002/03 season. It resulted in lower herbage mass and CP during that year.

Total organic matter intake (OMI) did not vary among the different supplementation levels, but forage OMI decreased linearly as supplement level increased. Average daily gain, SR, and LWG increased linearly with increasing levels of supplement, but grazing time decreased as greater amounts of supplement was fed. Greater ADG at the same level of intake suggests that there may have been better synchronization of energy and N in the rumen of the higher supplement treatment animals, and possibly an effect associated with the greater amounts of ruminal undegradable protein provided by the concentrate. Stocking rate increased because of the substitution of concentrate for forage in the 15 and 20 g kg<sup>-1</sup> BW treatments. The blood urea nitrogen (BUN) concentrations of all treatments were in the range considered adequate for growing cattle. Economic analysis showed that there was no economic benefit of increasing the supplementation levels above 10 g kg<sup>-1</sup> BW. Given the pasture conditions, and the concentrate and calf pricing in this study, the 10 g kg<sup>-1</sup> BW supplement level is recommended for EW calves grazing cool-season grass pastures.

### **Tifton 85 Bermudagrass Grazing Study**

Treatments were three levels, 10, 15, and 20 g kg<sup>-1</sup> of calf BW offered daily, of the same commercial pelleted concentrate used in the winter study. Each treatment was replicated three times in a completely randomized design so there were a total of nine

experimental units in the study. Dates for the trial during the 2 yr were 14 May through 13 Aug. 2003 (86 d) and 18 May through 10 Aug. 2004 (86 d).

Calves had grazed rye-annual ryegrass pastures from January to April. In the summer study, they received the same supplement treatment as they did during the winter-spring period. At the start of the summer trial, they were approximately 200-d old with an average liveweight of 190 kg. Pasture size was 0.15 ha subdivided in three paddocks for rotational stocking. The grazing period was 7 d and the rest period was 14 d. Two early weaned calves (1 steer and 1 heifer) were assigned as testers to each pasture and “put and take” early weaned calves were used to maintain herbage allowance at approximately 1 kg forage DM kg<sup>-1</sup> of calf BW.

The different levels of supplement fed to early weaned calves grazing Tifton 85 pastures did not affect herbage mass, accumulation, or nutritive value of the pasture. Herbage allowance was slightly lower for the 20 g kg<sup>-1</sup> BW supplementation, the result of the greater number of put and take calves assigned to that treatment. Nevertheless, there was no evidence that the herbage allowance in that treatment negatively affected calf performance.

Average daily gain, SR, and LWG increased with greater levels of supplementation. Greater SR was associated with a tendency for calves consuming more concentrate to consume less forage; however, a problem with calves regurgitating the marker boluses limited the number of observations and made it impossible to draw firm conclusions about intake. Calves receiving lower concentrate rates had greater grazing time during daylight, supporting the observation of a trend toward lower forage intake with higher rates of supplement.

Although greater supplementation levels resulted in greater average daily gain and gain per unit of land area, economic analysis of the data did not support use of the 20 g kg<sup>-1</sup> BW treatment. Economic return per hectare was greater for the 15 g kg<sup>-1</sup> BW concentrate treatment than the average of 10 and 20 g kg<sup>-1</sup> treatments.

### Rye-Ryegrass Plot Study

Treatments were the factorial combinations of two regrowth intervals (3 and 6 wk) and three N fertilization levels (0, 40, and 80 kg N ha<sup>-1</sup> per season) evaluated in two seasons, winter (January-February) and spring (March-April). Plot size was 2 x 4 m with a 1-m alley between plots. Treatments were replicated three times in a randomized complete block design. The 6-wk cutting interval plots received the entire N application for that season (winter or spring) at the beginning of the 6-wk growth period, while the 3-wk plots received half the seasonal rate at the beginning of each of the two 3-wk growth periods per season. Data were collected during January through April 2003 and 2004. Herbage accumulation, botanical composition, and nutritive value were measured. In addition, an in situ technique was used to determine CP fractions and disappearance kinetics of DM and CP.

Botanical composition of rye-ryegrass swards was affected by season of the year with the proportion of rye being greater during the winter and proportion of ryegrass greater during spring of the wetter year. Nitrogen fertilization and regrowth interval did not affect botanical composition.

Herbage accumulation increased linearly with increased levels of N fertilization. More herbage accumulated with the 6-wk than the 3-wk regrowth interval in spring, but during winter, regrowth interval did not affect total accumulation. Accumulation was greater in spring than winter regardless of regrowth interval.

The effect of regrowth interval on herbage CP and in vitro digestible organic matter (IVDOM) concentrations varied with season. There was no difference in IVDOM during the winter for the two regrowth intervals, however, lesser IVDOM concentrations were observed for the 6-wk than the 3-wk regrowth interval during the spring. Herbage CP concentrations were greater for the 3-wk than the 6-wk regrowth interval during both winter and spring, but the difference between intervals was much greater in spring. Thus, regrowth interval is of much greater importance in determining forage nutritive value and herbage accumulation during more rapid forage growth in spring than winter, and during spring, greater N fertilization levels and shorter regrowth periods than in winter may be necessary to maintain the nutritive value of the forage.

There was a significant effect of N fertilization level on the CP fractions of rye-ryegrass. Greater N fertilization increased the concentration of Fraction A and decreased Fractions B and C. More Fraction A at greater fertilization levels has the potential to result in less efficient use of N by ruminants that can lead to greater N losses through the urine. No lag time was observed for in situ CP disappearance indicating that the CP present in rye-ryegrass herbage is highly soluble. Greater N fertilization increased the potential CP disappearance linearly.

When considering utilization of rye-ryegrass herbage for early weaned calves, the greater total CP and Fraction A concentrations in rye-ryegrass with increased levels of N fertilization implies that there may be an excess of ruminal degradable protein under these circumstances. Utilization of high energy, low protein supplements may be a useful management practice to improve synchronization of N and energy availability in the

rumen and increase the efficiency of rumen degradable protein utilization by EW calves grazing cool-season grass pastures.

### Tifton 85 Bermudagrass Plot Study

Treatments were the factorial combinations of two regrowth intervals (2 and 4 wk) and three N fertilization levels (0, 40, and 80 kg ha<sup>-1</sup> per 4-wk period) evaluated in two periods in each of 2 yr. Treatments were replicated three times in a completely randomized design. Plot size was 2 x 4 m with a 1-m alley between plots.

Herbage was harvested to a 15-cm stubble. Herbage accumulation data were reported by period, and data from a given period are based on one harvest of the 4-wk treatment and two harvests of the 2-wk treatment. For laboratory analyses, samples used to determine herbage accumulation were analyzed for IVDOM and N concentration. Crude protein fractions and DM and CP disappearance kinetics were determined using an in situ technique.

Herbage accumulation of Tifton 85 bermudagrass increased linearly as the N fertilization level increased and was greater for the 4- than the 2-wk regrowth interval in 1 of the 2 yr. Increasing N fertilization from 0 to 80 kg ha<sup>-1</sup> resulted in a linear increase in CP and IVDOM concentrations, and herbage harvested at 4 wk presented lesser CP and IVDOM when compared with 2-wk regrowth.

Crude protein Fraction A was not affected by N fertilization level or maturity, however, there was a linear increase in Fraction B and linear decrease in Fraction C observed as N fertilization level increased. Forage harvested at 4 wk had a greater proportion of Fraction C than forage harvested at 2 wk. In general, the proportion of the more degradable fractions (A and B) was greater for less mature and more heavily fertilized herbage.

Level of N fertilization did not affect in situ lag time in DM disappearance, rate of disappearance, or potential disappearance; however, DM rate and potential disappearance were less with a longer regrowth period. Potential CP disappearance increased linearly as N fertilization level increased. The in situ lag time for CP was shorter for forage harvested at 2 than at 4 wk of regrowth. The in situ CP lag time for Tifton 85 harvested at 2 wk was comparable to lag times reported in the literature for cool-season grasses. In situ CP disappearance increased from 270 to 380 g kg<sup>-1</sup> at 0 h to 720 to 790 g kg<sup>-1</sup> at 72 h incubation for the N fertilization levels and regrowth intervals tested in this study.

As it matured, IVDOM and CP of the warm-season grass decreased. In order to supply better nutritive value forage to ruminants, greater N fertilization and shorter regrowth intervals may be considered. Longer regrowth intervals and/or low N fertilization decreases ruminal degradable CP concentration in the forage, and when fed to ruminants, is more likely to result in a deficient supply of rumen degradable protein. Diets that are low in rumen degradable protein will have a greater negative impact when fed to ruminants with high CP requirements, e.g., EW calves and dairy cows. Use of N fertilization and a shorter regrowth interval are easily implemented management practices to improve nutritive value and potential rumen degradable protein in Tifton 85 swards. Their use in production systems will depend upon the economics of fertilization and the potential yield reductions and lower stocking rates associated with shorter regrowth intervals.

### **Implications of the Research**

The results of this series of studies are useful in guiding development of pasture-based feeding systems for EW calves. During winter the high nutritive value of cool-season grasses reduces the need for concentrate supplement. At supplement levels above

10 g kg<sup>-1</sup> BW, the calves grazing cool-season pasture reduced forage intake by 1.0 kg per kg of supplement fed. This high substitution rate diminished the potential for favorable economic impact and resulted in the 10 g kg<sup>-1</sup> BW supplement level being the most practical treatment tested. The extremely high CP concentration and CP degradability of the cool-season grasses leads to the suggestion that the supplement fed need not be high in rumen degradable CP, but that it be relatively high in TDN and perhaps contain some rumen undegradable CP.

Additional research with cool-season pasture systems is needed in several areas. First, it is recommended that lower levels of supplement be evaluated, perhaps 0, 5, and 10 g kg<sup>-1</sup> BW. Also, supplement composition should be further evaluated, specifically different energy sources and different proportions of rumen degradable and undegradable CP.

It was anticipated that higher levels of supplement would be more critical to performance of calves during summer because of the lower nutritive value of the warm-season grass. There was greater economic benefit associated with the 15 g kg<sup>-1</sup> BW supplement treatment compared to the average of the 10 g kg<sup>-1</sup> and 20 g kg<sup>-1</sup> BW levels. Based on the results of the in situ study, N concentration of total CP and rumen degradable CP in the supplement are more important for calves grazing Tifton 85 than rye-ryegrass because of the proportion of CP that is immediately available and that which is potentially degradable are less for Tifton 85.

Future research with warm-season pasture system with EW calves may focus supplement energy sources as well as sources of rumen degradable protein to increase efficiency of energy utilization. In addition, high nutritive value warm-season forages,

e.g., pearl millet [*Pennisetum glaucum* (L.) R. Brown] and rhizoma peanut (*Arachis glabrata* Benth.), may be evaluated as alternatives to Tifton 85, especially for North Florida. In situation where high rates of concentrate are fed, the use of ionophores and implants may be tested to determine if they increase the efficiency of concentrate utilization.

In summary, these studies have shown that relatively high levels of performance can be achieved by EW calves, on practical, pasture-based feeding systems. Supplementation programs need to be tailored to complement the forage component of the diet, and these studies have provided information that will be usefull in deciding the amount and composition of supplement to be fed to calves grazing cool- and warm-season grasses.

**APPENDIX A**  
**DATA TABLES A**

Table A-1. Weather data for Years 2002, 2003, and 2004 in Gainesville FL.

Month	Rainfall				Average Ambient Air Temperature			
	2002	2003	2004	30-yr Average	2002	2003	2004	30-yr Average
-----mm-----				-----°C-----				
Jan.	99	46	30	83	12.7	8.2	11.0	13.4
Feb.	25	158	149	99	12.4	13.4	12.3	14.3
Mar.	50	243	51	93	17.4	18.7	16.5	17.7
Apr.	62	23	26	75	21.9	19.2	17.9	20.6
May	33	43	15	106	23.1	24.0	23.9	24.1
June	135	265	194	168	24.8	25.2	25.7	26.7
July	249	144	131	180	25.7	25.9	26.0	27.4
Aug.	165	123	281	203	25.0	25.6	25.8	27.4
Sep.	133	126	442	142	25.0	23.9	24.6	26.3
Oct.	63	84	81	59	22.1	20.7	21.4	22.0
Nov.	95	60	57	52	14.0	17.4	17.0	17.7
Dec.	128	26	43	81	10.8	10.1	14.8	14.5
Total	1237	1341	1487	1341				

Table A-2. Herbage mass double sampling equations and r<sup>2</sup> for the rye-ryegrass pastures

year	Month	Equation	r <sup>2</sup>
2003	Jan.	y=354 x - 265	0.89
	Feb.	y=150 x + 278	0.89
	Mar.	y=206 x - 180	0.94
	Apr.	y=154 x + 287	0.81
2004	Jan.	y=243 x + 347	0.86
	Feb.	y=230 x + 322	0.87
	Mar.	y= 141 x + 364	0.86
	Apr.	y=277 x + 538	0.86

When x=height (cm); y=kg DM ha<sup>-1</sup>

Table A-3. Total chromium output of Captec controlled release device in early weaned calves submitted to total feces collection. Year 2003.

Calf #	Days							<b>Avg</b>
	1	2	3	4	5	6	7	
g d <sup>-1</sup>								
1	0.084	0.094	0.070	0.152	0.114	0.092	0.173	<b>0.111</b>
2	0.085	0.036	0.105	0.109	0.121	0.030	0.075	<b>0.080</b>
3	0.167	0.064	0.085	0.085	0.102	0.094	0.159	<b>0.108</b>
4	0.099	0.077	0.139	0.093	0.104	0.093	0.126	<b>0.105</b>
<b>Avg</b>	<b>0.109</b>	<b>0.068</b>	<b>0.100</b>	<b>0.110</b>	<b>0.110</b>	<b>0.077</b>	<b>0.133</b>	<b>0.101</b>

Table A-4. Total chromium output of Captec controlled release device in early weaned calves submitted to total feces collection. Year 2004.

Calf #	Days							<b>Avg</b>
	1	2	3	4	5	6	7	
g d <sup>-1</sup>								
1	0.156	0.119	0.128	0.112	0.132	0.115	0.141	<b>0.129</b>
2	0.105	0.096	0.096	0.105	0.150	0.163	0.138	<b>0.122</b>
3	0.089	0.108	0.134	0.179	0.126	0.106	0.135	<b>0.125</b>
4	0.103	0.101	0.122	0.137	0.122	0.159	0.137	<b>0.126</b>
<b>Avg</b>	<b>0.113</b>	<b>0.106</b>	<b>0.120</b>	<b>0.133</b>	<b>0.133</b>	<b>0.136</b>	<b>0.138</b>	<b>0.125</b>

```

DATA EWC;
OPTIONS PS = 59 LS =125;
/*
TRT = treatment
PAST = pasture
YR = year
OMI = organic matter intake
FOO = fecal output observed
IVOMD
SUPINTAK = supplement intake, OM basis
dgsup = digestibility of supplement, OM basis
*/
INPUT TRT PAST YR OMI FOO IVOMD SUPINTAK dgsup;
supdig = 0.72;

FRGDIG = IVOMD;
DO FRGINTAK =1 TO 40 BY .05 UNTIL (DIFF < .01);
TOTINTAK = FRGINTAK + SUPINTAK;

EXPDIG = (FRGINTAK*FRGDIG + SUPINTAK*SUPDIG)/TOTINTAK*100;
ADJDIG = (59.71 -.8948*EXPDIG + .01399*EXPDIG**2)/100;
FOP = TOTINTAK*(1-ADJDIG);

DIFF = FOO-FOP;
END;
CARDS;
;
proc print;
run;

```

**APPENDIX B**  
**DATA TABLES B**

Table B-1. Herbage evaluation double sample equations and  $r^2$ .

	Month	Pre/Post	Equation	$r^2$
2003	May*	pre	$168x+2278$	0.74
		post	$168x+2278$	0.74
	June	pre	$191x+1753$	0.65
		post	$287x+878$	0.78
	July	pre	$260x+1045$	0.66
		post	$234x+1693$	0.66
	August	pre	$273x+1358$	0.65
		post	$226x+1668$	0.56
2004	May	pre	$179x+781$	0.82
		post	$214x+479$	0.80
	June	pre	$220x+385$	0.69
		post	$995x+2327$	0.51
	July	pre	$287x+220$	0.79
		post	$328x-106$	0.78
	August	pre	$227x+824$	0.81
		post	$261x+170$	0.82

Pre and post grazing used the same calibration curve  
When x=height (cm); y=kg DM ha<sup>-1</sup>

Table B-2. Total chromium output of Captec controlled release device in early weaned calves submitted to total feces collection. Year 2003.

Calf #	Days							<b>Avg</b>
	1	2	3	4	5	6	7	
-----g d <sup>-1</sup> -----								
1	0.108	0.143	0.149	0.153	0.165	0.1625	0.173	<b>0.150</b>
2	0.142	0.120	0.117	0.120	0.094	0.156	0.154	<b>0.129</b>
3	0.147	0.123	0.109	0.161	0.148	0.167	0.182	<b>0.148</b>
<b>Avg</b>	<b>0.132</b>	<b>0.129</b>	<b>0.125</b>	<b>0.145</b>	<b>0.136</b>	<b>0.162</b>	<b>0.170</b>	<b>0.143</b>

## LIST OF REFERENCES

- Adams, D.C. 1985. Effect of time of supplementation on performance, forage intake, and grazing behavior of yearling beef steers grazing Russian wild ryegrass in the fall. *J. Anim. Sci.* 61:1037.
- Adams, D.C., R.E. Short, M.M. Borman, and M.D. MacNeil. 1991. Estimation of fecal output with an intra-ruminal continuous release marker device. *J. Range Manage.* 44:204-207.
- Akin, D.E. 1986. Chemical and biological structure in plants as related to microbial degradation of forage cell walls. p. 139-157. *In L. P. Milligan et al., (ed.) Digestive physiology and metabolism in the ruminant.* Reston Publishing Co., Reston, VA.
- Akin, D.E., and D. Burdick. 1975. Percentage of tissue types in tropical and temperate grass leaf blades and degradation of tissues by rumen microorganisms. *Crop Sci.* 15:661.
- Allden, W.G., and I.A.M. Whittaker. 1970. The determinants of herbage intake by grazing sheep: The interrelationship of factors influencing herbage intake and availability. *Aust. J. Agric. Res.* 21:755.
- Allen, M., H.D. Ellzey, B.D. Nelson, C.R. Montgomery, and P.E. Schilling. 1974. The response of an oat-ryegrass mixture to applied nitrogen, phosphorus, and potassium. *Louisiana Agric. Exp. Stn. Bull.* 680, Louisiana Agric. Exp. Stn., Louisiana State University, Baton Rouge.
- Allison, C.D. 1985. Factors affecting forage intake by range ruminants: A review. *J. Range Manage.* 38:305-311.
- Altom, W., J.L. Rogers, W.R. Raun, G.V. Johnson, and L.T. Shannon. 1996. Long-term rye-wheat-ryegrass forage yields as affected by rate and date of applied nitrogen. *J. Prod. Agric.* 9:510-516.
- Arthington, J.D. 2002. Early weaning-A management alternative for Florida. p. 87-92. *Beef Cattle Short Course, Vol. 51, May 1-3. Gainesville, FL.*
- Arthington, J.D., and R.S. Kalmbacher. 2002. Use of ryegrass for grazing early-weaned calves in a subtropical environment. *Soil and Crop Sci. Soc. Florida Proc.* 61:1-4.

- Arthington, J. D. and R. S. Kalmbacher. 2003. Effect of early weaning on performance of three-year-old, first calf beef heifers and calves reared in the subtropics. *J. Anim. Sci.* 81:1136-1141
- Assis, M.A., G.T. Santos, U. Cecato, J.C. Damasceno, H.V. Petit, V. Bett, L.H. Gomes, M. Daniel, M.A. de Assis, and G.T. dos Santos. 1999. Degradabilidade "in situ" de gramíneas do gênero *Cynodon* submetidas ou não a adubação nitrogenada. *Acta Scient.* 21:675-663.
- Assmann, A.L., A. Pelissari, A.d. Moraes, T.S. Assmann, E.B.d. Oliveira, and I. Sandini. 2004. Beef cattle production and dry matter accumulation in the crop-pasture rotation system in presence and absence of white clover and nitrogen. *Rev. Bras. Zoot.* 33:37-44.
- Assounami, M.B., F. Vedeau, L. Jacquot, and C.J. Sniffen. 1990. Refinement of an enzymatic method for estimating the theoretical degradability of proteins in feedstuffs for ruminants. Proc. 41st Annual Meeting of European Association of Animal Production., Toulouse, France.
- Barnes, K.C., G.E. Selk, and K.S. Lusby. 1996. Early weaning fall-born beef calves for improved rebreeding or decreased winter feed. Animal Science Research Report. Oklahoma Agric. Exp. Stn. Oklahoma State Univ., Stillwater.
- Barton, R.K., L.J. Krysl, M.B. Judkins, D.W. Holcombe, J.T. Broesder, S. Gunter, and S.W. Beam. 1992. Time of daily supplementation for steers grazing dormant intermediate wheatgrass pastures. *J. Anim. Sci.* 70:538-546.
- Basurto, R.B., H.T. Purvis, T.N. Bodine, and G.W. Horn. 2001. Digestibility and estimation of undegradable intake protein (UIP) of alfalfa, bermudagrass and prairie hay using different methods. Available online [www.ansi.okstate.edu/research/2001rr/09/09.htm](http://www.ansi.okstate.edu/research/2001rr/09/09.htm) (verified 03/31/2005).
- Beever, D.E. 1984. Utilization of the energy and protein components of forage by ruminants: A United Kingdom perspective. In. G.W. Horn (ed.) National Wheat Pasture Symposium Proc. Oklahoma Agri. Exp. Sta. Oklahoma State Univ. Stillwater.
- Bertrand, J.E., and L.S. Dunavan. 1974. Triticale aloneand in a mixture, for grazing by growing beef calves. *Soil Crop Sci. Soc. Fla. Proc.* 33:48-50
- Bertrand, J.E., and L.S. Dunavan. 1977. The production of light-weight beef on winter annual pastures with and without grain supplementation. *Soil Crop Sci. Soc. Fla. Proc.* 36:138-140
- Bodine, T.N., H.T. Purvis, and C.J. Ackerman. 1999. Effects of supplementing prairie hay with two levels of corn and four leels of degradable intake protein. I. Intake and digestion by steers. *Animal Science Res. Rep.* Oklahoma State Univ., Stillwater.

- Bransby, D.I. 1993. Interactions of rotational and continuous grazing with stocking rate on warm- and cool-season pastures. p. 1285-1286. In M.J. Baker (ed.) Proc. XVII Int. Grassland Congress. Keeling and Mundy, Palmerston North, New Zealand.
- Bransby, D.I. 1996. Marshall ryegrass superior to small grains for stocker production. The Stockman Grass Farmer 53:8-12.
- Bransby, D.I., and B.E. Gamble. 1993. Comparison of rye with a rye+ryegrass mixture for grazing. p.70-75 In J.M. Phillips (ed.) Proc. Am. Forage and Grassl. Conf., Des Moines, IA, Am. Forage Grassl. Council, Georgetown, TX.
- Brown, R.H., and R.E. Simmons. 1979. Photosynthesis of grass species differing in CO<sub>2</sub> fixation pathways. I. Water-use efficiency. Crop Sci. 19:375-379.
- Brown, W.F., and W.D. Pitman. 1991. Concentration and degradation of nitrogen and fibre fractions in selected tropical grasses and legumes. Trop. Grass. 25:305-312.
- Buntinx, S.E., K.R. Pond, D.S. Fisher, and J.C. Burns. 1992. Evaluation of the Captec chrome controlled-release device for the estimation of fecal output by grazing sheep. J. Anim. Sci. 70:2243-2249.
- Burns, J.C., and L.E. Sollenberger. 2002. Grazing behavior of ruminants and daily performance from warm-season grasses. Crop Sci. 42:873-881.
- Burns, J.C., K.R. Pond, and D.S. Fisher. 1991. Effects of grass species on grazing steers. II. Dry matter intake and digesta kinetics. J. Anim. Sci. 69:1199-1204.
- Burton, G.W. 1947. Breeding bermudagrass for the southeastern United States. J. Am. Soc. Agron. 39:551-569.
- Burton, G.W. 1970. Symposium on pasture methods for maximum production in beef cattle: Breeding and managing new grasses to maximize beef production in the South. J. Anim. Sci. 30:143-147.
- Burton, G.W., R.N. Gates, and G.M. Hill. 1993. Registration of 'Tifton 85' bermudagrass. Crop Sci. 33:644-645.
- Burton, G.W., J.E. Jackson, and R.H. Hart. 1963. Effect of cutting frequency and nitrogen on yield, in vitro digestibility, and protein, fiber, and carotene content of Coastal bermudagrass. Agron. J. 55:500-502.
- Buxton, D.R., and G.C. Mertens. 1989. Forage quality of plant parts of perennial grasses and relationship with phenology. Crop Sci. 29:429-435.
- Buxton, D.R., and J.B. Russell. 1988. Lignin constituents and cell-wall digestibility of grass and legume stems. Crop Sci. 28:429-435.

- Byers, F.M., and A.L. Moxon. 1980. Protein and selenium levels for growing and finishing beef cattle. *J. Anim. Sci.* 50:1136-1144.
- Carey, D.A., J.S. Caton, and M. Biondini. 1993. Influence of energy source on forage intake, digestibility, in situ forage degradation, and ruminal fermentation in beef steers fed medium-quality brome hay. *J. Anim. Sci.* 71:2260-2269.
- Carnevalli, R.A., S.C. da Silva, C.G.S. Pedreira, J.L. Fagundes, C.A.B. De Carvalho, A.F. Sbrissia, L.F. de Moura Pinto, M.C. Uebele, and M.M. Passanezi. 1999. Pasture and animal responses of Tifton-85 swards grazed by sheep under continuous stocking. p. 357-361. *In Proc. International Grassland Ecophysiology and Grazing Ecology*, Curitiba, PR. Brazil.
- Chambliss, C.G. 1999. p. 32-35. Limpograss *In* C.G. Chambliss (ed.) Florida forage handbook. IFAS Publ. SP 253. Univ. of Florida, Gainesville.
- Chapman, W.H., and T.E. Webb. 1965. Florida rust resistant ryegrass. Florida Agric. Exp. Stn. Circ. S-169. University of Florida, Gainesville.
- Coffey, K., D. Shockley, W. Coblenz, C.J. Rosenkrans, S. Gunter, G. Montgomery, Z.B. Johnson, and D.W. Kellogg. 2000. Performance of stockers backgrounded on winter annuals or hay and grain. Arkansas Animal Sci. Dep. 470. University of Arkansas, Fayetteville.
- Coleman, S.W., T.D.A. Forbes, and J.W. Stuth. 1989. Measurements of plant-animal interface in grazing research. p. 37-52. *In* G. C. Marten (ed). *Grazing research: Design, methodology, and analysis*. CSSA, Madison, WI.
- Coleman, S.W., J.E. Moore, and J.R. Wilson. 2004. Quality and Utilization, p. 267-308., *In* L. E. Moser et al., (eds.) *Warm-Season (C4) grasses*. Agron. Monog. 45. ASA, CSSA, SSSA, Madison, WI.
- Conrad, H.R., A.D. Pratt, and J.W. Hibbs. 1964. Regulation of feed intake in dairy cows. I. Change in importance of physical and physiological factors with increasing digestibility. *J. Dairy Sci.* 47:54-62.
- Cowan, R.T., T.M. Davison, and P. O'Grady. 1977. Influence of the level of concentrate feeding on milk production and pasture utilization by Friesian cows grazing tropical grass-legumes pasture. *Aust. J. Exp. Agric. Anim. Husb.* 17:373-379.
- Craigmiles, J.P., and R.M. Weihing. 1971. Temporary winter pastures studies in the Gulf Coast rice belt. Texas Agric. Exp. Stn. MP-990. Texas A&M. Univ., College Station.
- Crampton, E.W., E. Donefer, and L.E. Lloyd. 1960. A nutritive value index for forages. *J. Anim. Sci.* 19:538-544.

- Cravey, M.D. 1993. Influence of high-starch versus high-fiber energy supplementation on forage intake and utilization by stocker cattle grazing wheat pastures. Ph.D. diss. Oklahoma State Univ., Stillwater.
- Cuomo, G.J., D.D. Redfearn, J.F. Beatty, R.A. Anders, F.B. Martin, and D.C. Blouin. 1999. Management of warm-season annual grass residue on annual ryegrass establishment and production. *Agron. J.* 91:666-671.
- Davis, C.L., and J.H. Clark. 1981. Ruminant digestion and metabolism. *Dev. Ind, Microbiol.* 22:247-259
- Davis, C.L., and J.K. Drackley. 1998. The development, nutrition, and management of the young calf. 1<sup>st</sup> Edition. Iowa State University Press. Ames, IA.
- de Faria, V.P., and J.T. Huber. 1984. Influence of dietary protein and energy on disappearance of dry matter from different forage type from dacron bags suspended in the rumen. *J. Anim. Sci.* 59:246.
- Dubeux, Jr., J.C.B., L.E. Sollenberger, R.L. Stewart, Jr., and J.M.B. Vendramini. 2003. Forage responses to different management intensities and stocking methods on Pensacola bahiagrass pastures. *In:* 2003 Annual meeting abstracts [CD-ROM]. ASA, CSSA, SSSA, Madison, WI.
- Dunavan, L.S. 1975. Production of rye and ryegrass forage with sulfur-coated urea and ammonium nitrate. *Agron. J.* 67:415-417.
- Edwards, N.C., E.G. Morrison, and F.H. Tyner. 1978. Effect of nitrogen levels and stocking rates on profitability of winter grazing. *Mississippi Agric. and For. Exp. Stn. Bull.* 856, Mississippi State Univ., Mississippi State.
- Eichhorn, M.M., and B.C. Venuto. 1999. Impact of prepared seedbeds and bermudagrass sods on performance of annual ryegrass and cereal rye. *Louisiana Agric.* 42:20-21.
- Evers, G.W., G.R. Smith, and C.S. Hoveland. 1997. Ecology and production of annual ryegrass. p. 29-44, *In* F.M.J. Rouquette and L.R. Nelson (eds.) *Ecology, Production and Management of Lolium for Forage in USA*. ASA, CSSA, and SSSA, Madison, WI.
- Feazel, J.I. 1986. Beef calf performance on overseeded winter annual pastures. *Louisiana Exp. Stn. Prog. Rep.* 86-1, Louisiana Exp. Stn., Rosepine.
- Fieser, B.G., and E.S. Vanzant. 2004. Interactions between supplement energy sources and tall fescue hay maturity on forage utilization by beef steers. *J. Anim. Sci.* 82:307-318.
- Fike, J.H., C.R. Staples, L.E. Sollenberger, J.E. Moore, and H.H. Head. 2002. Southeastern pasture-based dairy systems: housing, posilac, and supplemental silage effects on cow performance. *J. Dairy Sci.* 85:866-878.

- Fike, J.H., C.R. Staples, L.E. Sollenberger, B. Macoon, and J.E. Moore. 2003. Pastures forages, supplementation rate, and stocking rate effects on dairy cow performance. *J. Dairy Sci.* 86:1268-1281.
- Fisher, D.S. 2001. A review of key factors regulating voluntary feed intake in ruminants. *Crop Sci.* 42:1651-1655.
- Florida Agriculture Statistics: Livestock, Dairy, and Poultry. 2004. Florida Agric. Stat., Orlando FL.
- Fluharty, F.L., S.J. Moeller, T.B. Turner, and G.D. Lowe. 2000. Effects of weaning age and diet on growth and carcass characteristics in steers. *J. Anim. Sci.* 78:1759-1767.
- Follett, R.F., and S.R. Wilkinson. 1995. Nutrient management of forages p. 64. In R.F. Barnes et al. (ed.) *Forages: The science of grassland agriculture*. Iowa State University Press, Ames.
- Fontaneli, R. 1999. Forage systems for year-round grazing by lactating dairy cows. Ph.D. diss. University of Florida, Gainesville.
- Fontaneli, R., L.E. Sollenberger, and C.R. Staples. 2000. Seeding date effects on yield and nutritive value of cool-season annual forage mixtures. *Soil Crop Sci. Soc. Florida Proc.* 59:22-24.
- France, J., M.S. Dhanoa, R.C. Siddons, J.H.M. Thornley, and D.P. Poppi. 1988. Estimating production of feces by ruminants from fecal marker concentration curves. *J. Theor. Bio.* 135:383-391.
- Frizzo, A., M.G.d. Rocha, J. Restle, D.B. Montagner, F.K.d. Freitas, and D.T.d. Santos. 2003. Energy supplementation for rearing of beef heifers kept on cool season pasture. *Rev. Bras. Zoot.* 32:643-652.
- Gallaher, R.N., C.O. Weldon, and J.G. Futral. 1975. An aluminum block digester for plant and soil analysis. *Soil Sci. Soc. Am. J.* 39:803-806.
- Galloway, D.L., A.L. Goetsch, W. Sun, L.A. Forster, G.E. Murphy, E.W. Grant, and Z.B. Johnson. 1992. Digestion, feed intake, and live weight gain by cattle consuming bermudagrass supplemented with whey, molasses, and (or) corn. *J. Anim. Sci.* 70:2533-2541.
- Griffith, S.M., and T.G. Chastain. 1997. Physiology and growth of ryegrass. p. 15-28. In F.M.J. Rouquette and L.R. Nelson (ed.). *Ecology, Production, and Management of Lolium for Forage in the USA*. ASA, CSSA, and SSSA, Madison, WI.
- Grigsby, K.N., F.M. Rouquette, Jr., W.C. Ellis, and D.P. Hutcheson. 1991. Use of self-limiting fishmeal and corn supplements for calves grazing rye-ryegrass pastures. *J. Prod. Agric.* 4:476-480.

- Grimes, J.F., and T.B. Turner. 1991. Early weaning of fall-born beef calves: 2. Postweaning performance of early and normal weaned calves. *J. Prod. Agric.* 4:486:471.
- Haby, V.A., and D.L. Robinson. 1997. Soil fertility and liming practices for production of annual ryegrass. p. 45-69. *In* F.M.J. Rouquette and L.R. Nelson (eds). *Ecology, production, and management of Lolium for forage in the USA*. ASA, CSSA, and SSSA., Madison, WI.
- Hammond, A.C., E.J. Bowers, W.E. Kunkle, P.C. Genho, S.A. Moore, C.E. Crosby, and K.H. Ramsay. 1994. The use of blood urea nitrogen concentration to determine time and level of protein supplementation in wintering cows. *Prof. Anim. Sci.* 10:24-31.
- Hammond, A.C., W.E. Kunkle, D.B. Bates, and L.E. Sollenberger. 1993. Use of blood urea nitrogen concentration to predict response to protein or energy supplementation in grazing cattle. p. 1989-1991. *In* M.J. Baker (ed.) *Proc. XVII Int. Grassland Congress*. Keeling and Mundy, Palmerston North, New Zealand.
- Harvey, R.W., and J.C. Burns. 1989. Forage species, concentrate feeding level and cow management system in combination with early weaning. *J. Anim. Sci.* 66:2722-2727.
- Hernandez Garay, A., L.E. Sollenberger, D.C. McDonald, G.J. Ruegsegger, R.S. Kalmbacher, and P. Mislevy. 2004. Nitrogen fertilization and stocking rate affect stargrass pasture and cattle performance. *Crop Sci.* 44:1348-1354.
- Hill, T.M. 1991. Effects of source of supplemental nutrients on forage intake, digestive kinetics and protein supply on the small intestine of grazing calves. Ph.D. diss., Texas A&M Univ, College Station.
- Hill, G.M., R.N. Gates, and G.W. Burton. 1993. Forage quality and grazing steer performance from Tifton 85 and Tifton 78 bermudagrass pastures. *J. Anim. Sci.* 71:3219-3225.
- Hill, G.M., R.N. Gates, J.W. West, and P. Mandebvu. 1998. Research with Tifton 85 bermudagrass in cattle grazing and hay digestion experiments. *In* A.M. Peixoto and V.P. de Faria (ed.) *Proc. 15th Grazing management symposium*. Universidade de Sao Paulo, Piracicaba, SP, Brazil.
- Hill, T.M., S.D. Martin, and W.C. Ellis. 1990. Effects of supplemental sources of energy or protein for calves grazing ryegrass pasture. *Progress Report Texas Agric. Exp. Stn. Beef Cattle Res.* in Texas. Texas A&M University, College Station, Texas.
- Hodgson, J. 1982. Ingestive behavior. p. 1-10, *In* J. D. Leaver (ed). *Herbage intake handbook*. British Grassland Society, Hurley, Maidenhead, Berkshire.

- Hoffman, K., L.D. Muller, S.L. Fales, and L.A. Holden. 1993a. Quality evaluation and concentrate supplementation of lactating cows grazing rotational pastures. *J. Dairy Sci.* 76:2651-2663.
- Hoffman, P.C., S.J. Sievert, R.D. Shaver, D.A. Welch, and D.K. Combs. 1993b. In situ dry matter, protein, and fiber degradation of perennial forages. *J. Dairy Sci.* 76:2632-2643.
- Horn, G.W., M.D. Cravey, F.T. McCollum, C.A. Strasia, E.G. Krenzer, Jr., and P.L. Claypool. 1995. Influence of high-starch vs. high-fiber energy supplements on performance of stocker cattle grazing wheat pasture and subsequent feedlot performance. *J. Anim. Sci.* 73:45-54.
- Hoveland, C.S. 1992. Grazing systems for humid regions. *J. Prod. Agric.* 5:23-27.
- Hovermale, C.H. 1993. Effect of rate and date of ammonium nitrate application on yield of ryegrass. Dep. Info. Serv., Div. Agri., For., and Vet. Med. Mississippi State Univ., Starkville.
- Huston, J.E., H. Lippke, T.D.A. Forbes, J.W. Holloway, and R.V. Manchen. 1999. Effects of supplemental feeding interval on adult cows in western Texas. *J. Anim. Sci.* 77:3057-3067.
- Johnson, C.R., D.L. Lalman, J. Steele, A.D. O'Neil, and R.P. Wetteman. 2001a. Supplementation strategies for stockpiled bermudagrass: I. Cow performance. Oklahoma Cooperative Extension Service. Oklahoma State Univ., Stillwater.
- Johnson, C.R., B.A. Reiling, P. Mislevy, and M.B. Hall. 2001b. Effects of nitrogen fertilization and harvest date on yield, digestibility, fiber, and protein fractions of tropical grasses. *J. Anim. Sci.* 79:2439-2448.
- Krishnamoorthy, U., C.J. Sniffen, M.D. Stern, and P.J. Van Soest. 1983. Evaluation of mathematical model of rumen digestion and an in vivo simulation of rumen proteolysis to estimate the rumen-undegraded nitrogen content of feedstuffs. *Brit. J. Nutr.* 50:555-564.
- Krysl, L.J., and B.W. Hess. 1993. Influence of supplementation on behavior of grazing cattle. *J. Anim. Sci.* 71:2546-2555.
- Laredo, M.A., G.D. Simpson, D.J. Minson, and C.G. Orpin. 1991. The potential of using n-alkanes in tropical forages as a marker for determination of dry matter intake by grazing ruminants. *J. Agric. Sci.* 117:355-361.
- Le Du, Y.L.P., J. Combillas, J. Hodgson, and R.D. Baker. 1979. Herbage intake and milk production by grazing dairy cows. 2. The effects of level of winter feeding and daily herbage allowance. *Grass. Forage Sci.* 34:249-260.

- Lima, F.G.d.C., L.E. Sollenberger, and J.E. Moore. 1999a. Concentracao e fracionamento do nitrogenio em gramineas forrageiras tropicais e subtropicais. Anais da Reuniao Anual da Sociedade Brasileira de Zootecnia, Vol. 36. Sociedade Brasileira de Zootecnia, Porto Alegre.
- Lima, F.G.d.C., L.E. Sollenberger, W.E. Kunkle, J.E. Moore, and A.C. Hammond. 1999b. Nitrogen fertilization and supplementation effects on performance of beef heifers grazing limpograss. *Crop Sci.* 39:1853-1858.
- Lippke, H. 2002. Estimation of forage intake by ruminants on pasture. *Crop Sci.* 42:869-872.
- Lippke, H., and W.C. Ellis. 1997. Forage quality of annual ryegrass. p. 71-78. *In* F.M.J. Rouquette and L.R. Nelson (eds). Ecology, production, and management of *Lolium* for forage in the USA. ASA, CSSA, and SSSA., Madison, WI.
- Lippke, H., and G.W. Evers. 1986. Effect of pregrazing diet on early season gains by stockers steers grazing rye-ryegrass. p. 61-63. *In* Forage research in Texas, 1986. Texas Agric. Exp. Stn. CPR-4253, Txs A&M Univ., College Station.
- Lusby, K.S. 1995. The use of early weaning in practical cattle management. Oklahoma Coop. Ext. Ser. CR-3278, Oklahoma State Univ., Stillwater.
- Lusby, K.S., and R.G. Donald. 1994. Receiving and growing rations. Oklahoma Coop. Ext. Ser. E-900, Oklahoma State Univ., Stillwater
- Lusby, K.S., and R.P. Wetteman. 1980. Effects of early weaning calves from first calf heifers on calf and heifer performance. *Animal Sci. Res. Rep. Oklahoma Agric. Exp. Stn.*, Oklahoma State Univ., Stillwater.
- Macoon, B. 1999. Forage and animal response in pasture-based dairy production systems for lactating cows. PhD dissertation. University of Florida, Gainesville, FL.
- Malafaia, P.A.M., S.C. Valadares Filho, and R.A.M. Vieira. 1997. Determinação da cinética ruminal das frações protéicas de alguns alimentos para ruminantes. *Rev. Bras. Zoot.* 26:1243-1251.
- Mandebvu, P., J.W. West, G.M. Hill, R.N. Gates, R.D. Hatfield, B.G. Mullinix, A.H. Parks, and A.B. Caudle. 1999. Comparison of Tifton 85 and Coastal bermudagrass for yield, nutrient traits, intake, and digestion by growing beef steers. *J. Anim. Sci.* 77:1572-1586.
- Mathis, C.P., R.C. Cochran, E.S. Vanzant, I.E.O. Abdelgadir, J.S. Heldt, K.C. Olson, D.E. Johnson, J. Caton, D. Faulkner, G.W. Horn, S.I. Paisley, R. Mass, K. Moore, and J. Halgerson. 2001. A collaborative study comparing an in situ protocol with single time-point enzyme assays for estimating ruminal protein degradability of different forages. *Anim. Feed Sci. Tech.* 93:31-42.

- Mayes, R.W., C.S. Lamb, and M. Colgrove. 1984. The use of dosed and herbage n-alkanes as markers for the determination of herbage intake. *J. Agric. Sci.* 107:161-170.
- McCartor, M.M., and F.M.J. Rouquette. 1977. Grazing pressure and animal performance from pearl millet. *Agron. J.* 69:983-987.
- McDonald, I. 1981. A revised model for estimation of protein degradability in the rumen. *J. Agric. Sci.* 92:499-503.
- McMeniman, N.P. 1997. Methods of estimating intake of grazing animals. p. 131-168. In J.A. Gomide (ed.) *Simpósio internacional sobre produção animal em pastejo*. Univ. Federal de Vicosa. Vicosa, Brazil.
- Meijs, J.A.C. 1986. Concentrate supplementation of grazing dairy cows. 2. Effects of concentrate composition on herbage intake and milk production. *Grass. Forage Sci.* 41:229-235.
- Mertens, D.R. 1973. Application of theoretical mathematical models to cell wall digestion and forage intake in ruminants. PhD diss., Cornell Univ., Ithaca, NY.
- Mertens, D.R., and J.R. Lofton. 1980. The effect of starch on forage fiber digestion kinetics "in vitro". *J. Dairy Sci.* 63:1437-1446.
- Michalet-Doureu, B., and M.Y. Ould-Bah. 1992. Influence of hay making on in situ nitrogen degradability of forages in cows. *J. Dairy Sci.* 75:782-788.
- Minson, D.J. 1990. Forage in ruminant nutrition, Academic Press, San Diego, CA.
- Mislevy, P., and F.G. Martin. 1998. Comparison of Tifton 85 and other Cynodon grasses for production and nutritive value under grazing. *Soil Crop Sci. Soc. Florida. Proc.* 57:77-82.
- Moore, J.E. 1992. Matching protein and energy supplements to forage quality. p. 31-44. In B. Haskins and B. Harris, (ed.) *Proc. 3<sup>rd</sup> Annual Florida Ruminant Nutrition Symposium*. Univ. of Florida, Gainesville.
- Moore, J.E. 1994. Forage quality indices: development and application. p. 967-998. In G. C. Fahey, Jr., (ed.) *Forage quality, evaluation, and utilization*. ASA, CSSA, SSSA, Madison, WI.
- Moore, J.E., M.H. Brant, W.E. Kunkle, and D.I. Hopkins. 1999. Effects of supplementation on voluntary forage intake, diet, digestibility, and animal performance. *J. Anim. Sci.* 77:122-135.
- Moore, J.E., and G.O. Mott. 1974. Recovery of residual organic matter from "in vitro" digestion of forages. *J. Dairy Sci.* 57:1258-1259.

- Moore, J.E., and W.E. Kunkle. 1999. Evaluation of equations for estimating voluntary intake of forages and forage-based diets. *J. Anim. Sci. Supplement* 1:204.
- Moore, J.E., and L.E. Sollenberger. 1997. Techniques to predict pasture intake, p. 81-96. *In* J.A. Gomide (ed.) *Simpósio internacional sobre produção animal em pastejo*. Univ. Federal de Vicosa. Vicosa, Brazil.
- Morris, D.R., T.F. Brown, V.C. Baligar, D.L. Corkern, L.K. Zeringue, and L.F. Mason. 1994. Ryegrass forage yield and quality response to sulfur and nitrogen fertilizer on Coastal Plain soil. *Comm. Soil Sci. Plant Anal.* 25:3035-3046.
- Moser, L.E., and C.S. Hoveland. 1996. Cool-season grass overview; p. 1-14. *In* L. E. Moser, et al. (ed). *Cool-season forage grasses*. Agron. Monog. 34. ASA, CSSA, and SSSA., Madison, WI.
- Muehlmann, L.D., M.G. Rocha, and J. Restle. 1997. Efeito do uso exclusivo de pastagens no desempenho de bezerros desmamados precocemente. *Rev. Bras. Zoot.* 26:584-589.
- Mullahey, J.J., S.S. Waller, K.J. Moore, L.E. Moser, and T.J. Klopfenstein. 1992. In situ ruminal degradation of switchgrass and smooth bromegrass. *Agron. J.* 84:183-190.
- Myers, S.E., D.B. Faulkner, F.A. Ireland, and D.F. Parret. 1999a. Comparison of three weaning ages on cow-calf performance and steer carcass traits. *J. Anim. Sci.* 77:323-329.
- Myers, S.E., D.B. Faulkner, F.A. Ireland, L.L. Berger, and D.F. Parret. 1999b. Production systems comparing early weaning to normal weaning with or without creep feeding for beef steers. *J. Anim. Sci.* 77:300-310.
- National Research Council (NRC). 1989. Nutrients Requirements of Dairy Cattle. 7<sup>th</sup> ed. Natl. Acad. Press. Washington DC.
- National Research Council (NRC). 1996. Nutrient Requirements of Beef Cattle. 7<sup>th</sup> ed. Natl. Acad. Press, Washington DC.
- Nelson, B.D., C.R. Montgomery, E.B. Morgan, D.M. Johns, and H.D. Ellrey. 1980. Effects of harvest date on quality of coastal bermudagrass. Bull. 730., Louisiana State Univ., Baton Rouge.
- Newman, Y.C., L.E. Sollenberger, W.E. Kunkle, and D.E. Bates. 2002a. Crude protein fractionation and degradation parameters of limpograss herbage. *Agron. J.* 94:1381-1386.
- Newman, Y.C., L.E. Sollenberger, W.E. Kunkle, and C.G. Chambliss. 2002b. Canopy height and nitrogen supplementation effects on performance of heifers grazing limpograss. *Agron. J.* 94:1375-1380.

- Nocek, J.E. 1985. Evaluation of specific variables affecting in situ estimates of ruminal DM and protein. *J. Anim. Sci.* 60:1347.
- Nocek, J.E. 1988. In situ and other methods to estimate ruminal protein and energy digestibility: A review. *J. Dairy Sci.* 71:2051-2069.
- Nocek, J.E., and J.B. Russell. 1988. Protein and energy as an integrated system. Relationship of ruminal protein and carbohydrate availability to microbial protein digestion. *J. Dairy Sci.* 71:2070-2107.
- Ordonez-Tercero, J.C., L. Ramirez-Aviles, and C. Aguilar-Perez. 2003. Effect of energy supplementation and feeding pattern on duodenal microbial-N supply in cows fed a tropical grass. *Trop. Substr. Agroecos.* 2:97-98.
- Orskov, E.R., and D.C. McDonald. 1979. The estimation of protein degradability in the rumen from incubation measurements weighted according to rate of passage. *J. Agric. Sci.* 92:499.
- Overman, A.R., S.R. Wilkinson, and G.W. Evers. 1992. Yield response of bermudagrass and bahiagrass to applied nitrogen and overseeded clover. *Agron. J.* 84:998-1001.
- Owens, F.N., and C.F. Hanson. 1992. External and internal markers for appraising site and extent of digestion in ruminants. *J. Dairy Sci.* 75:2605-2617.
- Paisley, S.I., C.J. Ackerman, H.T. Purvis, and G.W. Horn. 1998. Wheat pasture intake by early weaned calves. *Anim. Sci. Res. Rep.* Oklahoma State Univ., Stillwater.
- Pedreira, C.G.S. 1995. Plant and animal response on grazed pastures of Florakirk and Tifton 85 bermudagrasses. Ph.D. diss. Univ. of Florida, Gainesville, FL.
- Pedreira, C.G.S., L.E. Sollenberger, and P. Mislevy. 1998. Performance of yearling cattle grazing 'Tifton 85' and 'Florakirk' bermudagrass. p. 150. *In* G. H. Heichel (ed.) Proc. of Annual Meeting ASA, CSSA, and SSSA. Baltimore MD. ASA, CSSA, and SSSA, Madison, WI.
- Petersen, M.K. 1987. Nitrogen supplementation of grazing livestock. p. 115-122. *In* D.J. Wallace (ed.). Proc. Grazing Livestock Nutrition Conference, Jackson, WY.
- Phillips, C.J.C. 1989. New techniques in the nutrition of grazing cattle p. 106-120. *In* C. J. C. Phillips (ed.) New techniques in cattle production. Butterworths, Boston, MA.
- Phillips, W.A., S.C. Rao, R.L. Dalrymple, and E.L. Klepper. 1996. Annual cool-season grasses. p. 178-802. *In* L. E. Moser et al. (ed.). Cool-season forage grasses. *Agron. Monog.* 34. ASA, CSSA, and SSSA, Madison, WI.
- Pichard, G., and P.J. Van Soest. 1977. Protein solubility of ruminant feeds. p. 91. *In* Proc. Cornell Nutrition Conference on Feed Manufacturing, Syracuse, NY.

- Pond, K.R., W.C. Ellis, J.H. Matis, and A.G. Deswysen. 1989. Passage of chromium-mordanted and rare earth-labeled fiber: Time of dosing kinetics. *J. Anim. Sci.* 67:1020.
- Poos-Floyd, M., T.J. Klopfenstein, and R.A. Britton. 1985. Evaluation of laboratory techniques for predicting ruminal protein degradation. *J. Dairy Sci.* 68:829.
- Poppi, D.P., and S.R. McLennan. 1995. Protein and energy utilization by ruminants at pasture. *J. Anim. Sci.* 73:278-290.
- Prine, G.M., A.R. Blount, L.S. Dunavin, P. Mislevy, and R.L. Stanley, Jr. 2002. Registration of 'Jumbo' annual ryegrass. *Crop Sci.* 42:1749.
- Prine, G.M., and G.W. Burton. 1956. The effect of nitrogen rate and clipping frequency upon the yield, protein content and certain morphological characteristics of Coastal bermudagrass [*Cynodon dactylon* (L.) Pers.]. *Agron. J.* 48:296-301.
- Purvis, H.T., K.S. Lusby, and G.W. Horn. 1996. The effects of grazing system and early weaning on productivity of fall calving cows in Oklahoma. *Anim. Sci. Res. Rep. Oklahoma State Univ., Stillwater.*
- Redfearn, D.D., L.E. Moser, S.S. Waller, and T.J. Klopfenstein. 1995. Ruminal degradation of switchgrass, big bluestem, and smooth bromegrass leaf proteins. *J. Anim. Sci.* 73:598-605.
- Redfearn, D.D., B.C. Venuto, W.D. Pitman, M.W. Alison, and J.D. Ward. 2002. Cultivar and environment effects on annual ryegrass forage yield, yield distribution, and nutritive value. *Crop Sci.* 42:2049-2054.
- Restle, J., C. Roso, A.B. Soares, G.C. Lupatini, D.C. Alves-Filho, and I.L. Brondani. 2000. Animal productivity and economic return in oat plus ryegrass pasture fertilized with sources of nitrogen. *Rev. Bras. Zoot.* 29:357-364.
- Riewe, M.E., J.C. Smith, J.H. Jones, and E.C. Holt. 1963. Grazing production curves: I. Comparison of steer gains on Gulf ryegrass and tall fescue. *Agron. J.* 55:367-372.
- Ringwall, K. 2002. Early weaning can alleviate feed management concerns [Online] <http://www.ext.nodak.edu/extnews/newsrelease/2002/080102/02beefta.htm> (verified 01/15/2005).
- Robinson, D.L., K.G. Wheat, and N.L. Hubbert. 1987. Nitrogen fertilization influences on Gulf ryegrass yields, quality and nitrogen recovery from Olivier silt loam soil. Bull. 784. Louisiana State Univ., Baton Rouge.
- Rocha, M.G.d., J. Restle, A. Frizzo, D.T.d. Santos, D.B. Montagner, F.K.d. Freitas, A. Pilau, and F.P. Neves. 2003. Alternatives of utilization of winter pasture for rearing of beef heifers. *Rev. Bras. Zoot.* 32(2):383-392.

- Roe, M.B., L.E. Chase, and C.J. Sniffen. 1991. Procedure comparison of in vitro techniques to the in situ technique for estimation of ruminal degradation of the protein. *J. Dairy Sci.* 74:1632-1640.
- Rouquette, F.M.J., D.I. Bransby, and M.E. Riewe. 1997. Grazing management and use of ryegrass. p. 79-100. *In* F.M.J. Rouquette and L.R. Nelson (ed). *Ecology, production, and management of Lolium for forage in USA.* ASA, CSSA, and SSSA, Madison, WI.
- Rouquette, F.M.J., M.J. Florence, V.A. Haby, and G.R. Smith. 1992. Sustained production from common bermudagrass pastures using clover-potassium or ryegrass nitrogen. *Texas Agric. Exp. Stn. Cons. Prog. Rep.* 5039., Texas A&M Univ., College Station.
- Rouquette, F.M.J., J.L. Kerby, G.H. Nimr, and W.C. Ellis. 2003. Tifton 85, Coastal bermudagrass, and supplement for backgrounding fall born calves during the summer. *Beef cattle research in Texas, 2003.*, Texas A&M Univ., College Station.
- Royes, J.B., W.F. Brown, F.G. Martin, and D.B. Bates. 2001. Source and level of energy supplementation for yearling cattle fed ammoniated hay. *J. Anim. Sci.* 79:1313-1321.
- SAS Inst. Inc. 1991. SAS statistic user's guide. Release version 6. SAS Inst. Inc., Cary, NC.
- SAS Inst. Inc. 1996. SAS statistic user's guide. Release version 6. SAS Inst. Inc., Cary, NC.
- Salaun, C., W.M.v. Straalen, J. Kogut, J.L. Peyraud, A.M. Van Vuuren, and W.M. Van Straalen. 1999. In situ degradation of perennial rye grass from grazed pastures during the season at two levels of nitrogen fertilization. *Annales de Zootechnie* 48:35-46.
- Salisbury, F.B., and C.W. Ross. 1991. *Plant Physiology.* 4<sup>th</sup> ed. Wadsworth Publishing Company, Belmont, CA.
- Sarker, A.B., and W. Holmes. 1974. The influence of supplementary feeding on the herbage intake and grazing behaviour of dry cows. *J. Brit. Grass. Soc.* 29:141-143.
- Schoonmaker, J.P., F.L. Fluharty, S.C. Loerch, and T.B. Turner. 2001. Effect of age at feedlot entry on performance and carcass characteristics of bulls and steers. Special Circ., Ohio Agricultural Research and Development Center. 181. Ohio State Univ., Columbus.
- Siddons, R.C., and J. Paradine. 1983. Protein degradation in the rumen of sheep and cattle. *J. Sci. Food Agric.* 34:701-708.

- Smeaton, D.C., J.B. Clayton, and A. Malthus. 1996. Pre and post-weaning growth of beef calves reared by cows on one of five lifetime nutrition levels. New Zealand Grass. Assoc.. 57:101-104.
- Sollenberger, L.E., and J.C. Burns. 2001. Canopy characteristics, ingestive behaviour and herbage intake in cultivated tropical grasslands. p. 321–327. *In* Proc. Int. Grassl. Congr., 19th, Piracicaba, Brazil. 10–21 Feb. 2001. Brazilian Sci. Anim. Husbandry, Piracicaba, Brazil.
- Sollenberger, L.E., J.E. Moore, V.G. Allen, and C.G.S. Pedreira. 2005. Reporting forage allowance in grazing experiments. Crop Sci. 45:896-900.
- Stallcup, O.T., K.F. Harrison, P. Bayley, and R. Thornton. 1986. Response in nutritive characteristics of Hardie bermudagrass to varying levels of nitrogen fertilization. p. 220-224. *In* Proc. Forage and Grassland Congress. Am. Forage Grassl. Counc., Georgetown, TX.
- Stern, M.D., A. Bach, and S. Calsamiglia. 1997. Alternative techniques for measuring nutrient digestion in ruminants. J. Anim. Sci. 75:2256-2276.
- Stern, M.D., and L.D. Satter. 1984. Evaluation of nitrogen solubility and the dacron bag technique for estimating protein degradation in the rumen. J. Anim. Sci. 58:714-724.
- Stobbs, T.H. 1975. Factors limiting the nutritional value of grazed tropical pastures for beef and milk production. Trop. Grassl. 9:141-150.
- Stockdale, C.R., A. Callaghan, and T.E. Trigg. 1987. Feeding high energy supplements to pasture-fed dairy cows. Effects of stage of lactation and level of supplement. Aust. J. Agric. Res. 38:927-940.
- Taliaferro, C.M., F.M.J. Rouquette, and P. Mislevy. 2004. Bermudagrass and stargrass. p. 417-476. *In* L. E. Moser et al. (eds). Warm-Season (C4) Grasses. Agron. Monog. 45. ASA, CSSA, and SSSA., Madison, WI.
- Tilley, J.A., and R.A. Terry. 1963. A two-stage technique for the in vitro digestion of forage crops. J. Brit. Grass. Soc. 18:104-111.
- Uden, P., and P.J. Van Soest. 1984. Investigations of the in situ bag technique and a comparison of the fermentation in heifers, sheep, ponies and rabbits. J. Anim. Sci. 58:213-221.
- Ulyatt, M.J. 1981. The feeding value of temperate pastures. *In* F.H.W. Morley (ed.) Grazing animals. Elsevier Sci. Publ. Co., Amsterdam, Netherland.
- Van Hellen, R.W., and W.C. Ellis. 1977. Sample container porosities for rumen in situ studies. J. Anim. Sci. 44:141-151.

- Van Soest, P.J. 1965. Symposium on factors influencing the voluntary intake of herbage by ruminants: Voluntary intake in relation to chemical composition and digestibility. *J. Anim. Sci.* 24:834-843.
- Van Soest, P.J. 1982. Nutritional ecology of ruminants. O & B Books Inc., Corvallis, OR.
- Van Vuuren, A.M., and J.A.C. Meijis. 1987. Effects of herbage composition and supplement feeding on the excretion of nitrogen in dung and urine by grazing dairy cows. p. 17-25. *In* H. G. v. d. Meer et al. (ed). Animal manure on grassland and fodder crops. Martinus Nijhoff, Dordrecht, Netherland.
- Van Vuuren, A.M., S. Tamminga, and R.S. Ketelaar. 1991. "In sacco" degradation of organic matter and crude protein of fresh grass (*Lolium perenne*) in the rumen of grazing dairy cows. *J. Agric. Sci.* 116:429-436.
- Vanzant, E.S., R.C. Cochran, and E.C. Tigemeyer. 1998. Standardization of in situ techniques for ruminant feedstuff evaluation. *J. Anim. Sci.* 76:2717-2729.
- Vendramini, J.M.B., J.D. Arthington, L.E. Sollenberger, R.S. Kalmbacher, and P. Mislevy. 2003. Performance of early-weaned calves grazing stargrass (*Cynodon nlemfuensis*) and atra paspalum (*Paspalum atratum*) pastures during summer. *J. Anim. Sci.* 81(Suppl. 2).
- Vieira, R.A.M., J.C. Pereira, P.A.M. Malafaia, and A.C. de Queiroz. 1997. The influence of elephant grass (*Pennisetum purpureum* Schum., Mineiro variety) growth on the nutrient kinetics in the rumen. *Anim. Feed Sci. Tech.* 67:151-161.
- Waghorn, G.C., and J.L. Burke. 2001. Screening fresh forages for protein degradation and nutritive value. p. 420-421. *In* J. A. Gomide (ed). Proc. Int. Grassl. Congr., 19th, Piracicaba, Brazil.
- Waldo, D.R. 1986. Effect of forage quality on intake and forage concentrate interactions. *J. Dairy Sci.* 69:617-631.
- Weder, C. 1997. Early weaning calves on Italian ryegrass or annual pastures [Online]. Available <http://www.forage.ab.ca/projects/25.pdf> (verified 11/10/2002).
- Wheeler, J.S., D.L. Lalman, G.W. Horn, L.A. Redmon, and C.A. Lents. 2002. Effects of supplementation on intake, digestion, and performance of beef cattle consuming fertilized, stockpiled bermudagrass forage. *J. Anim. Sci.* 80:780-789.
- Wilkinson, S.R., and G.W. Langdale. 1974. Fertility needs of warm season grass. p. 119-145. *In* D.A. Mays (ed.) Forage fertilization. ASA, CSSA, and SSSA, Madison WI.

Williams, C.H., D.J. David, and O. Iismaa. 1962. The determination of chromic oxide in faeces samples by atomic absorption spectrophotometry. *J. Agric. Sci.* 59:381-385.

Yan, T., and R.E. Agnew. 2004. Prediction of nutritive values in grass silages: II. Degradability of nitrogen and dry matter using digestibility, chemical composition, and fermentation data. *J. Anim. Sci.* 82:1380-1391.

## BIOGRAPHICAL SKETCH

Joao Mauricio Bueno Vendramini was born on 24 December 1972, in Araraquara, Sao Paulo State, Brazil. He is a son of Arnaldo and Lais P.B. Vendramini and has one brother, Jose Olavo. Joao is married to Maria Lucia Silveira, soil scientist, currently working as a chemist in the Soil and Water Science Department at the University of Florida.

He graduated from Agriculture Technical High School – UNESP in December 1989 with a Technician in Agriculture degree. In 1991, he received the Engenheiro-Agronomo B.S. degree from University of Sao Paulo – ESALQ. He worked from 1994 to 2001 at AWL Administration Company administrating six properties specializing in beef cattle, sugarcane, and crops. During 1996-1999, he worked on a Master of Science program in animal science and forages concomitantly with his job, receiving a Master of Science degree from University of Sao Paulo – ESALQ in March 1999. In January 2002, he was accepted into a Doctor of Philosophy degree program in agronomy, where he served as Graduate Research Assistant. He is currently a PhD candidate working in the area of forage management under the direction of Dr. Lynn E. Sollenberger.

Joao is a member of the American Society of Agronomy, American Society of Animal Science, and American Registry of Professional Animal Scientists.