TIFTON 85 BERMUDAGRASS GRAZING MANAGEMENT EFFECTS ON ANIMAL PERFORMANCE AND PASTURE CHARACTERISTICS

By

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To my loving wife, Erin, and son, Lucas

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TIFTON 85 BERMUDAGRASS GRAZING MANAGEMENT EFFECTS ON ANIMAL PERFORMANCE AND PASTURE CHARACTERISTICS

By

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Interest in pasture-based dairy systems using Tifton 85 bermudagrass (Tifton 85) is increasing in Florida. Field observations indicate that spring growth of Tifton 85 can be compromised by competition from ryegrass. The objectives of this research were i) to evaluate different management practices of Tifton 85 pastures under rotational stocking and animal supplementation on pastures characteristics and animal performance, and ii) to evaluate AR removal methods and AR removal dates on Tifton 85 forage persistence during spring and early summer. Study 1 consisted of a rotational stocking grazing trial evaluating two grazing rest periods (RP; 14, and 21 d) and two supplementation rates (SUP; High and Low). In 2010, average daily gain (ADG) was not affected by SUP (0.62 vs. 0.63 kg d-1 for low and high, respectively) or RP. However, in 2011 supplementation level had an effect on ADG (0.61 vs. 0.51 kg d-1 for high and low, respectively). Greater stocking rate (SR) was achieved in pastures where heifers were fed a high SUP rate. Heifers fed at higher SUP rate had greater live weight gains per hectare than those fed at a lower SUP rate (800 vs. 690 kg of LW ha-1, respectively).

The second study examined spring competition of annual ryegrass (AR) overseeded on Tifton 85 pastures. This evaluation looked at AR removal methods and removal dates on regrowth parameters of Tifton 85. Early spring (D1) removal of ryegrass resulted in greatest Tifton 85 light interception. Among removal methods, chemical removal of AR resulted in greater Tifton 85 cover compared to mowing or grazing. Tifton 85 herbage accumulation was affected by removal method in 2011 and 2012. Greater herbage accumulation was associated with non-overseeded Tifton 85.

Data from these two studies suggest that i) animals grazing Tifton 85 at either 14 or 21 d under high SUP can achieve daily gains close to targeted ADG of 0.7 kg, ii) Tifton 85 possess high nutritive value and suitability for stocking of dairy animals and iii) annual ryegrass removal method affects Tifton 85 regrowth during spring with chemical removal eliminating all competition from ryegrass.

CHAPTER 1
INTRODUCTION

Florida dairy producers have been challenged to search for new ways to reduce costs due to the increased economics of traditional confinement feeding operations. As a result, interest in pasture-based systems is increasing and many dairy farmers have transitioned partially or totally to grazing operations with the goal to remain profitable and sustainable (Ricks and Hardee, 2012). The most common approach has been the implementation of rotational stocking, using high-quality hybrid bermudagrasses for lactating and non-lactating cows, and replacement heifers (Hill et al., 2001). Lately, rearing programs for replacement heifers have received more attention (Greter et al., 2008) as they represent the foundation of the dairy herd, and one of the major costs (Heinrichs et al., 1994). Usually, heifers represent the second largest input after feed costs for the milking herd, accounting for approximately 20% of the total operation expenses (Goodger and Theodore, 1986; Heinrichs, 1993). Most of the research in pasture-based systems has been done with lactating dairy cows and information regarding grazing management strategies on a pasture-based system for growing heifers is limited.

One the most important warm-season perennial grasses in the southeastern United States for grazing dairies has been ‘Tifton 85’ bermudagrass (*Cynodon* spp.) because of the superior nutritive value. Studies have evaluated grazing management practices of Tifton 85 documenting its superior quality, having both greater dry matter (DM) yield, and nutritive value than other bermudagrass cultivars, including ‘Tifton 78’, ‘Coastal’, and ‘Florakirk’ (Mandebvu et al., 1999). However, when raising replacement heifers, matching the feed resources to the nutrient needs of the animal is important, as animal performance is largely determined by nutrient consumption (Mertens, 1994). In general, most warm-season grasses alone are unable to supply sufficient amount of crude protein (CP) and total digestible nutrients (TDN) to support proper gain by growing animals, although Tifton 85 CP concentrations are greater than most tropical grasses grown in the region (Mislevy and Martin, 2006; Johnson et al., 2001; Marsalis et al., 2007). Supplying additional minerals and a small amount of concentrate is important for dairy heifers to achieve adequate daily gains under grazing (Staples et al., 1994). Grazing studies looking at the stocking potential of this grass have been conducted for North Florida (Pedreira et al., 1998; Vendramini et al., 2007). These studies evaluated the relationship between pasture attributes and animal performance in which a wide range of animal-pasture characteristics were studied. Results from those initial grazing studies suggest measuring the maximum production potential under rotational stocking.

Despite the abundant production of Tifton 85 during the summer months, there may be a shortage of forage during the cool season. Conditions in the region allow for overseeding with cool-season forage crops during winter months, reducing the need for stored forages (DeRouen et al., 1991). This overseeding of winter forage into warm-season perennial grasses allows producers to extend the grazing season an additional 75 to 150 d during the critical period of winter through spring (Fontaneli et al., 2000), thus improving the seasonal forage distribution. Annual ryegrass (*Lolium multiflorum* Lam.) is a cool-season grass that is commonly used in grazing dairies to increase the CP and digestibility of forage offered (Fontaneli et al., 2000; Vendramini et al., 2006), resulting in greater or better animal performance (Fales et al., 1995).

Although overseeding annual ryegrass into bermudagrass pastures may extend the production window the spring transition from annual ryegrass to Tifton 85 bermudagrass can be difficult and inconsistent due to overlapping growth periods of annual ryegrass and emerging bermudagrass. In Florida, early to late spring time is a period when the growing seasons of the cool-season annual and warm-season perennial grass overlap; a late maturing annual ryegrass is very competitive during this period of time. In some cases, stand reduction and slow spring regrowth of Tifton 85 pastures have been observed when overseeded with cool-season forages and grazed during the cool-season (Chamblee and Muller, 1999).

Despite abundant documentation about nutritive value, forage production, and quality of Tifton 85 bermudagrass, research evaluating the interaction of resting periods under rotational stocking and its interactions with supplementation on animal and pasture performance, as well as spring grass competition, are necessary. Specific studies are needed addressing supplement concentrate rates that maximize nutrient intake from pasture, while decreasing substitution of forage for concentrate. As a result, applied and fundamental knowledge will be gained, providing the producer with information related to grazing management of dairy heifers, stocking rate, and concentrate feeding rate in pasture-based systems using Tifton 85. Additionally, greater fundamental understanding will be gained about the spring regrowth dynamics when overseeding this warm-season perennial with annual ryegrass.

CHAPTER 2
LITERATURE REVIEW

Pasture-Based Dairy Systems in Florida

Overview

Historically, meat and milk production systems have utilized forage-based diets as their major source of nutrients. However, since the end of World War II this has not been the case. In the USA, during the 1950s, the scientific knowledge led the way toward a more intensified agricultural production, increasing the use of synthetic, soluble fertilizers and other chemicals. Also, the use of plant breeding technology and machinery led to more efficient tillage and harvesting, which increased corn yields and subsequent low corn prices (Rinehart, 2006). In this era, the dairy industry in the U.S. underwent very intensive consolidation and industrialization pressure to maximize the efficiencies that came with large-scale production; dairy farms got bigger, and relied on harvested grain and forages.

Later, during the 1980s and 1990s, profitability of dairy farms declined. In order to maintain or increase farm income, expansion of the herd size was a common practice adopted by farmers; this strategy increased the demand for feed and forage on a fixed land base, leading to use of confinement systems. During this period of time, grain consumption increased milk production per cow greatly. Simultaneously, cattle genetics improved dramatically and animal nutritionists formulated diets that more accurately and uniformly met the nutritional requirements of the lactating cow (Mertens, 1986). However, evolving systems based on mechanized harvesting and forage conservation for total mixed rations (TMRs) increased public perception that dairies have a negative effect on the environment (Russelle et al., 1997). Rising costs of machinery and animal housing, however, reduced profit margin (Parker et al., 1992) and were triggering points contributing to revived interest in pasture-based systems. Staples et al. (1994) pointed out several reasons for greater interest in grazing including 1) lower expenses for feed, equipment, and buildings potentially leading to greater income per cow, 2) reported improvements in animal health and reproduction (less culling), 3) growing pressure from regulatory agencies and environmental interests to reduce centralized accumulation of cattle wastes, and 4) improved quality of life for managers (less stress, more leisure time, etc.).

Grazing operations, although generally producing less milk, enjoyed equal or greater net farm income than confinement-based operations due, primarily, to lower expenses or less debt (Parker et al., 1992). Fontaneli et al. (2005) compared productive and metabolic responses of lactating dairy cows managed on two pasture-based systems using a concentrate supplement with a freestall housing system. In this study despite greater milk yield by cows housed in freestalls compared to those on pasture, milk income minus feed costs including that of pastures was similar for the three management systems. In a different study using a variety of feeding treatments that included pasture and TMR combinations, Tozer et al. (2003) reported expenses to be least for the pasture-only scenario.

More recently, there has been renewed international interest in grazing production systems (MacDonald et al., 2007) as a result of different factors such as reductions in milk prices in many countries, increasing production costs (Dillon et al. 2005), and perceived environmental and animal welfare concerns associated with intensive dairying (Dillon, 2006). In the US, however, there are at least two factors that have revived the interest in pasture-based dairying: a boost in demand for organic milk, and a willingness of consumers and dairy product manufacturers in some U.S. markets to pay premium prices for milk from pasture-based (yet non-organic) systems (Gillespie et al., 2009).

Defining Pasture-Based Dairying

When trying to define the concept of pasture-based dairying there is no clear consensus on a specific definition, but a general agreement exists on the overall concept. Taylor and Foltz (2006) categorized pasture-based dairies based on pasture utilization as either “management intensive grazing”, more properly rotational stocking (Allen et al., 2011), or “mixed feed” operations. A grazing-based dairy production system can be simply defined as land use and feed management system that optimizes the intake of forages directly harvested by grazing cows as the main source of nutrients. Pasture-based dairies use pasture as the primary forage source during the grazing period. Under this method the sward characteristics are maximized for production and nutritive value.

Grazing Management Systems

The grazing system is an array of interactions among its components that make the system quite complex and sometimes challenging to describe or define. When looking at the interaction of two components such as plants and animals managed within a system, their responses and behavior may differ from that observed when they are managed alone. For example, two forages that grow at different times of the year can provide a more uniform forage distribution of feed over an extended period of time than either forage alone could provide, thus affecting animal performance. This is because each component of a system behaves as a consequence of its relationship with other parts of the system (Allen and Collins, 2003).

Grazing management has been defined as the process by which the soil-plant-animal complex of the grazing land can be manipulated in pursuit of a long term defined objective (Sollenberger and Newman, 2007). The effect of forage utilization method on the output per animal and the effect of the grazing animal on the pasture are critical in grazing management. Generally, grazing management is described in terms of grazing intensity, grazing frequency, and the timing of grazing relative to plant growth stage or season of the year. There are several other management practices, such as fertilization or supplementation for example, which can be used in conjunction with grazing management to optimize the grazing system.

Adequate grazing management practices translate into increased plant productivity. A study by Liu et al. (2011) showed that intermediate levels of stubble height (SH) (16 cm) and rest period (21 d) provided relatively greater Tifton 85 herbage accumulation and nutritive value while minimizing negative impacts on persistence-related responses. They evaluated three postgraze SH (8, 16, and 24 cm) and three rest periods (14, 21, and 28 d) on Tifton 85 bermudagrass. In this study, the shortest stubble with the longest rest period or the tallest stubble with shortest rest period produced the greatest herbage accumulation (11–15 Mg DM ha-1 yr-1). Intermediate levels of rest period or stubble produced consistent herbage accumulation regardless of level of the other factor. Nutritive value was primarily affected by rest period; that is crude protein (CP; 150 to 108 g kg-1) and in vitro digestible organic matter (IVDOM; 602 to 582 g kg-1) concentrations decreased as rest period increased. Organic matter and nutrient mass of storage organs increased with increasing stubble height, but the taller stubble exhibited greater reduction in percentage cover (~43% units) than the other stubble treatments (~22% units) after 3 yr of grazing.

In a different study, Clavijo et al. (2010) evaluated Tifton 85 bermudagrass for use in hay or greenchop systems. They reported that greatest yields occurred with larger interval between harvests (35 d) and when shorter SH (7.5 cm) were used. Also, greater nutritive value was achieved with defoliation at 24- to 27-d intervals to 15-cm stubble. Nevertheless, shorter stubble heights (7.5 cm) were associated with greater weed encroachment and are generally not recommended. Inadequate grazing management decisions may lead to grass degradation and reduction in persistence of forage species in the pasture (Wu and Tiessen, 2002; Newman and Sollenberger, 2005).

Rotational Stocking

Definition

In the literature, different terms are used to describe rotational stocking, including phrases such as management intensive rotational grazing (Paine et al., 1999), rotational grazing (Mueller and Green, 1987), or intensive grazing (Volesky et al., 1990). Rotational stocking by definition is a grazing method that utilizes recurring periods of grazing and rest among two or more paddocks in a grazing management unit throughout the period when grazing is allowed (Allen et al., 2011). In other words, this grazing method consists of dividing the total pasture area into several smaller subunits (called paddocks) for rotation of livestock which are grazed sequentially. After grazing each subdivided area, a rest period follows. This period refers to the length of time that a specific land area is not stocked between stocking periods (Allen et al., 2011).

The objective of rotational stocking is to increase production or utilization per unit area or production per animal through a relative increase in stocking rates, forage utilization and labor resources (Sollenberger and Newman, 2007). Several studies in the dairy industry where rotational stocking was implemented suggested that, if managed properly, under certain circumstances farms with rotational stocking systems can be as, or possibly more profitable than similar farms using a conventional system despite less production (Knoblauch et al., 1999; Conneman et al., 1997; King, 1997). Additionally, studies in the beef industry also point out that rotational stocking can increase profitability for beef operations (Fales et al., 1995; Phillip et al., 2001).

Grazing Frequency

When rotational stocking is implemented a key question to be asked is how long should be the rest periods between grazing events in a given paddock. According to Voisin (1988), there should be sufficient interval between grazing events to allow plants to replenish reserves of labile carbohydrates in the roots and crown and to develop leaf area to intercept radiation. Grazing frequency has a direct impact on herbage accumulation. Mislevy et al. (2008) reported that stargrass (*Cynodon nlemfuensis* Vanderyst) and bermudagrass production increased linearly as grazing frequency decreased from 2 to 7 wk. Herbage accumulation of Tifton 85 increased from ~8 at 2 wk to 17 Mg DM ha^{-1} at 7 wk per year.

Also, relatively long intervals between defoliation events reduce forage CP and IVDOM. Because the process of plant maturation involves a decline in leaf:stem ratio as well as the quality of stem (Minson, 1990), timely grazing that minimizes the proportion of stem issue will positively influence forage nutritive value (Green and Detling, 2000; Fales and Fritz, 2007). Pedreira et al. (1999) reported lower concentrations of CP and

IVDOM in Florakirk bermudagrass pastures with longer intervals between grazing events.

Benefits

Among some of the benefits perceived by farmers in adopting rotational stocking are: improved quality of life, larger net farm income, a closer relationship with the cows, the surrounding community, and the land, as well as a greater focus on individual knowledge and innovation (Ostrom and Jackson-Smith, 2000). Improved quality of life for ‘graziers’ comes from such things as greater flexibility in work hours, more time for leisure, family and community activities, and the involvement of children in on-farm operations. Authors report that rotational stocking allows farmers to retain managerial and decision making control (Hinrichs and Welsh, 2003), and that farmers report this type of farming to be intellectually challenging and rewarding of ingenuity rather than endurance (Hassanein and Kloppenburg, 1995).

Also, animals in grazing systems are often healthier than animals housed in confinement. It is well documented in the scientific and popular press that herds in grazing systems generally have fewer hoof and leg problems relative to herds in confinement-feeding systems (Fitzgerald et al. 2000; Parker, 1993). Hoof and leg problems, which seem to be accentuated by prolonged time spent on concrete floors, can lead to clinical lameness and increased culling rates which has become a major problem in the dairy industry (Fitzgerald et al., 2000). The problems of lameness among confined livestock have become a serious animal welfare concern (Wells et al., 1998).

In addition to the social, animal health and welfare benefits, rotationally stocked pastures often produce more forage (Ortega et al., 1992), are less weedy, and the desired forage lives for more years than if the pastures were stocked continuously

(Mathews et al., 1994). By adopting rotational stocking, grazing pressure can be controlled and less forage is wasted (CIAT, 1985).

Barnes et al. (1995) stated that there are three major ecological benefits of forage-based systems such as rotational stocking: (1) nutrient cycling and storage in pools to minimize nutrient loss, (2) protection and improvement of the hydrologic cycle, and (3) improvement and support of diverse population dynamics of soil and plant organisms. Researchers in Minnesota and Wisconsin have found that fecal coliform and turbidity were reduced with the use of rotational grazing practices (Sovell et al., 2000) and that well-managed pastures acted as very large riparian buffers to protect water quality (Lyons et al., 2000)

Despite the benefits of rotational stocking, its adoption has not been widespread. Perhaps the large structural capital investment required to convert a conventional dairy operation into a grazing one, and the cost associated with subdividing larger pastures into smaller paddocks, number of cross fences, etc., constitute the main barriers for adoption (Faulkner, 2000).

Tifton 85' Bermudagrass

General

Tifton 85 bermudagrass (*Cynodon* spp.) is a warm-season perennial grass. Since its release in 1992 (Burton et al., 1993a) it has been considered to be among the most important grasses in the southeastern USA. Tifton 85 possesses larger, thicker stems, broader leaves, and a more erect growth habit than most other bermudagrass cultivars (Burton et al., 1993a), associated with its hybrid character. This grass is an interspecific hybrid sterile pentaploid (2n=5x=45) arising from a bermudagrass and stargrass cross.

Tifton 85 produces larger but fewer rhizomes than Coastal. It is propagated by above-ground stems or below-ground rhizomes.

In addition, Tifton 85 has much greater cold tolerance than its stargrass parent Tifton 68. Burton et al. (1993b) reported that Tifton 85 survived environmental temperatures as low as -16°C in the southeastern USA. Burns and Fisher (2007) reported that even though Tifton 85 is less cold tolerant that Tifton 44, successful stands have been maintained as far north as North Carolina. Also, it has shown greater drought tolerance (Marsalis et al., 2007) and late-season DM production (Evers et al., 2004) than other hybrid or seeded bermudagrasses.

In the southern USA, a long warm season and mild winters favor production of warm-season perennial grasses such as Tifton 85. Because its great biomass production, rapid establishment, tolerance to defoliation and drought (Hill et al., 2001; Redfearn and Nelson, 2003) many producers have adopted this grass for hay production and grazing operations. Currently in north-central Florida, large areas are being planted to Tifton 85 for grazing purposes as dairy producers are transitioning to a grazing dairy type operation (Ricks and Hardee, 2012).

Herbage Accumulation and Nutritive Value

Throughout the years, Tifton 85 has shown greater productivity compared to other bermudagrasses (Burton et al., 1993a; Hill et al., 1993; Mandebvu et al., 1999). Hill et al. (1993) reported Tifton 85 produced an average of 26% more DM than Coastal bermudagrass in a 3-yr trial in Georgia. Mandebvu et al. (1999) measured defoliation frequency effects on Tifton 85 and Coastal bermudagrass production. In this study, herbage accumulation increased with increasing regrowth interval for both cultivars, but Tifton 85 produced 34% more than Coastal. Mislevy and Martin (1998) evaluated herbage accumulation and persistence responses of two bermudagrasses (Tifton 85 and Florakirk) and two stargrasses (Florona and Florico) to defoliation frequency in South Florida. As length of regrowth period increased, herbage accumulation of all grasses increased linearly. More recently DM yields of Tifton 85 have been reported in the 16 to 26 Mg ha^{-1} yr^{-1} range (Woodard et al., 2007; Marsalis et al., 2007). Also, Vendramini et al. (2007) reported herbage accumulation values of 45 to 133 kg DM ha^{-1} d^{-1} in a 2-yr grazing trial looking at performance of weaned calves under supplementation grazing Tifton 85. In Florida, a recent study by Liu et al. (2011) determined that Tifton 85 bermudagrass herbage accumulation was affected by the interaction of grazing cycle and stubble height. The greatest herbage accumulation occurred with short stubble height (8 cm) if grazing cycle was 28 d or when stubble height was 24 cm and grazing cycle was 14 d.

Besides Tifton 85 having greater productivity than other bermudagrasses in Southeast US, it also has great nutritive value. In many studies where different management practices have been implemented, Tifton 85 has showed excellent nutritive value (Hill et al., 1993, 2001; Sollenberger et al., 1995; Mandebvu et al., 1999; Clavijo et al., 2010, Liu et al., 2011). Hill et al. (1993) reported that Tifton 85 was 11% more digestible than Coastal bermudagrass in a 3-yr trial in Georgia. Also, it has been reported that crude protein (CP) concentrations of this grass are greater than most tropical grasses grown in the region (Mislevy and Martin, 2006; Johnson et al., 2001; Marsalis et al., 2007), frequently exceeding 160 g kg^{-1}. Although, Tifton 85 has an elevated fiber concentration similar to other tropical grasses, neutral detergent fiber (NDF) digestibility is much greater than most of the warm-season grasses. For some researchers (Mandebvu et al., 1999; Hill et al., 2001) the great nutritive value showed by Tifton 85 has been attributed in part to relatively low concentrations of ether-linked ferulic acid and decreased ether bonding in lignin, which result in greater cell wall and total forage digestion. This characteristic makes Tifton 85 an excellent choice as forage for grazing livestock particularly for grazing dairies (Mandebvu et al., 1999).

Animal Performance Studies

Tifton 85 bermudagrass has become important for raising animals under grazing conditions for portions of the southern United States. When comparing Florakirk and Tifton 85 bermudagrass in a 3-yr grazing study, Pedreira et al. (1998) reported no differences in average daily gain (ADG) between cultivars (0.6 kg d^{-1}), but Tifton 85 pastures supported greater average stocking rates (ASR) (6.0 vs. 4.0 heifers ha^{-1}), resulting in greater gain ha^{-1} (648 vs. 371 kg). Similar results were reported by Rouquette et al. (2003), where no differences were found in ADG of crossbred weaned calves that grazed Tifton 85 only and those that grazed Coastal bermudagrass plus 0.91 kg d^{-1} of a 3:1 maize:soybean (*Glycine max* L.) meal concentrate. However, Tifton 85 supported twice the stocking rate (8 vs. 4 hd ha^{-1}) when compared with Coastal plus supplementation. In a second trial by the same authors, performance of crossbred beef heifers and steers was tested for four grazing treatments that included Coastal with and without supplementation and Tifton 85 with and without supplementation. Cattle grazing Tifton 85 plus supplementation had the highest ADG of 0.84 kg compared to Tifton 85 alone (0.72 kg), Coastal plus supplementation (0.54 kg), and Coastal alone (0.41 kg).

Vendramini et al. (2007) evaluated calf responses to dietary supplement level [10, 15, and 20 g kg^{-1} of calf body weight (BW)] while grazing Tifton 85 bermudagrass. In this study pastures were rotationally stocked using a 7-d grazing and 14-d rest period, and a variable stocking rate was used to maintain similar herbage allowances across treatments. There were no differences among treatments in pregraze herbage mass, herbage accumulation rate, or herbage CP and in vitro digestible organic matter (IVDOM) concentrations. Average daily gain (0.52-0.65 kg d^{-1}), stocking rate [SR, 11.1-13.7 animal units (AU) ha^{-1}], and liveweight gain (LWG, 1080-1550 kg ha^{-1}) increased linearly as supplementation increased from 10 to 20 g kg^{-1}.

Grazing animals are often fed supplements for various reasons one of them being the non-uniform forage distribution within and among growth seasons. This lack of uniform distribution impacts the quantity and quality of a given grass. Therefore, an adequate grazing management is required for the success of a grazing operation; including adjustments of the stocking rate, maintenance of forage height and density for optimum rate of intake, and use of supplementary feeds to reduce the effects of shortfalls of forage (Noller, 1997). Supplemental feeding is also desirable when energy and protein requirements of cattle increase due to lactation, pregnancy, and growth (Fontaneli, 1999). When cattle consume forages as their only energy source, intake of available energy may not be adequate to meet desired rates of animal performance. Staples et al. (1994) stated that forages high in nutritive value can provide most nutrients required by growing heifers, but the addition of minerals and a small amount of concentrate may be needed to achieve adequate ADG. Providing supplement may be profitable, but factors such as pasture quantity and quality and animal management should be included when considering the efficacy of supplementation.

Annual Ryegrass

General

Annual ryegrass (*Lolium multiflorum* Lam)), also called Italian ryegrass, is an erect, cool-season bunchgrass that has an extensive, fibrous root system (Sattell et al., 1998) and is native to southern Europe. It is most productive in cool, moist climates with temperatures between 20 to 25°C. It is closely related to perennial ryegrass (*Lolium perenne* L.). Both are widely distributed throughout the world, including North and South America, Europe, New Zealand, and Australia. In the USA, annual ryegrass serves as a primary forage resource for livestock producers throughout the southeastern USA during the winter season. Annual ryegrass is established in the fall and is frequently over-seeded on warm-season perennial pastures near the end of their growing season (Evers et al., 1997). According to Hannaway et al. (1999) about 90% of the 1.2 million hectares of annual ryegrass in the United States is used for winter pasture in the Southeast. The most common practice is to overseed annual ryegrass into perennial warm-season grasses such as bermudagrass [*Cynodon dactylon* (L.) Pers.] and bahiagrass (*Paspalum notatum* Flügge) (Evers, 1995; Hannaway et al., 1999).

One of the main reasons why annual ryegrass is so widely used has to do with its high yields and high nutritive value. Redfearn et al. (2002) reported yields between 6,000 and 12,000 kg DM ha^{-1} when annual ryegrass cultivars were harvested six times beginning in December. Cuomo et al. (1999) reported yields of ~6,500 and 8,100 kg DM ha^{-1} when annual ryegrass was sown into tilled, warm-season perennial grass. While it has high production potential, it requires high moisture and fertility. Morris et al. (1994) reported herbage accumulation of 10.5 Mg DM ha^{-1} when 280 kg of N ha^{-1} was applied; showing that N application generally increased DM yield and CP concentration during the season. In addition to its high yields, annual ryegrass is also noted for its excellent nutritive value (Hannaway et al., 1999). In its vegetative stage, CP concentrations often exceed 200 g kg^{-1}, while acid detergent fiber and neutral detergent fiber concentrations remain below 220 and 400 g kg^{-1}, respectively (Mooso et al., 1990; Lippke, 1995). In a different study by Haby and Robinson (1997), CP of annual ryegrass ranged from 150 to 200 g kg^{-1} with no N applied and increased to 280 g kg^{-1} at N rates of 448 kg ha^{-1}. Lippke and Evers (1986) reported that ryegrass forage in vegetative stages usually has IVDOM > 700 g kg^{-1}. Redfearn et al. (2002) analyzed nutritive value of different cultivars of ryegrass and the IVOMD values exceeded 800 g kg^{-1} in the month of January for all the cultivars. These traits of high nutritive value and high soluble fiber make it a preferred winter grass for overseeding by dairy operations (Ricks and Hardy, 2012).

The potential for spring competition in an overseeding situation can be assessed in studies where it was used as a cover crop. Hively and Cox (2001) found that annual ryegrass provided 63 to 78% ground cover in the fall and 76 to 83% ground cover in the spring when inter-seeded into soybean. In a different cover crop study looking at annual ryegrass, black medic (*Medicago lupulina* L.), sudan grass (*Sorghum sudanense* L.), crimson clover, and a mix of cereal rye and Austrian winter pea (*Pisum sativum* L.) in Vancouver, researchers found the lowest weed weight by late winter in the annual ryegrass treatment (Miles and Nicholson, 2003). Annual ryegrass can be used to accumulate residual N from the soil during the fall and winter, thus reducing N losses caused when rains leach nitrate below the root zone. Shipley et al. (1992) evaluated the assimilation of corn residual fertilizer N by different cover crops. The corresponding percent recoveries of the fall N in the aboveground DM were 45% for cereal rye, 27%

for annual ryegrass, 10% for hairy vetch (*Vicia villosa* Roth), 8% for crimson clover, and 8% for native weed cover. Together with cereal rye, annual ryegrass has a high capacity to conserve fertilizer N.

Overseeding

A common practice in the southeastern United States is to overseed warm-season perennials grasses in the fall with cool season annuals; extending the grazing season and reducing winter feeding expenses (DeRouen et al., 1991). Thus, this practice improves the seasonal distribution of forage and increases the CP and digestibility of forage on offer, resulting in higher animal performance (Fales et al., 1995)

Many studies have looked at animal performance on annual ryegrass. Rouquette et al. (1992) in a 5-yr study 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. Average daily gains of suckling calves were similar among treatments and ranged from 1.0 to 1.4 kg d^{-1} for ryegrass and arrowleaf pastures at stocking rates of 6.0 to 2.4 animal units (AU) (680 kg liveweight) ha^{-1}. Although overseeding has a great impact on animal performance, forage production from winter annual forages varies considerably across forages and climatic conditions, and inter-seeding these forages into warm-season perennial grasses generally increases this variability (Moyer and Coffey, 2000).

Spring Competition

Growing seasons of warm-season perennial grasses and cool-season annuals overlap in fall during cool-season annual establishment and in spring when warm-season perennial grasses initiate growth, resulting in competition for moisture, nutrients, and light. Fall competition can influence cool-season forage establishment, seedling growth, and early forage production, which affects the length of the grazing season and economic return on winter pasture input costs (Evers, 2012). On the other hand, the spring transition from annual ryegrass to bermudagrass can be troublesome due to heat-tolerant annual ryegrass overlapping with Tifton 85 bermudagrass regrowth. As Tifton 85 bermudagrass survives on carbohydrates and other photosynthates accumulated during the previous growing season, shading of the bermudagrass canopy by actively growing annual ryegrass along with root competition could result deleterious because bermudagrass is a C_4 grass that has a higher photosynthetic rate and efficiency at high radiation than C_3 forages (Nelson, 1995). Most of the work looking at the spring transition of overseeded bermudagrass with cool-season forages has been done in turf grasses. Duble (1996) concluded that the major environmental factors affecting bermudagrass post-dormancy recovery are temperature, shade, moisture, soil conditions, competition, and traffic.

Bermudagrass forage production can decrease during early summer when overseeded. In Florida, Reis et al. (2009) showed reduction in spring/early summer bermudagrass production of 300 to 600 kg ha^{-1} when compared to non-overseeded plots but there was no indication of stand deterioration associated with overseeding. Muir et al. (2011) reported 41 to 80% spring first-harvest Tifton 85 DM yields reduction due to overseeding with cool-season forages. In contrast, McLaughlin et al. (2005) in a 3-yr study examining effects of extending the haying season by spring haying of fall-overseeded annuals concluded that overseeding common bermudagrass with berseem clover or annual ryegrass can improve hay yield and P removal. As evidenced by the studies above, the effect of overseeding on spring/summer productivity and persistence of bermudagrass is not conclusive.

Supplementation of Forage Diets

A supplement is a feedstuff added to the base diet in order to provide additional nutrients required to support desired production (Ensminger et al., 1990). Supplements are usually rich in energy, protein, minerals, vitamins, or a combination of part of all these to improve the value of base diet and support the desire level of production (Ensminger et al., 1990). The main goal of supplementing is to optimize performance, improve animal health, increase feed intake, increase feed efficiency, or alter some physiological process in the animal that stimulates production and/or improves the quality of available forages, and digest or metabolize the same more feed efficiently (Beaty et al., 1994).

Grazing animals are often fed supplements for various reasons, as forage distribution within and among growth seasons is not uniform. This phenomenon impacts the quantity and quality of a given grass. Therefore, an adequate grazing management is required for the success of a grazing operation; including adjustments of the stocking rate, maintenance of forage height and density for optimum rate of intake, and use of supplementary feeds to reduce the effects of shortfalls of forage (Noller, 1997). Thus, supplemental feeding is also desirable, when energy and protein requirements of cattle increase due to lactation, pregnancy, and growth (Fontaneli et al., 2005). When cattle consume forages as their only energy source, intake of available energy may not be adequate to meet desired rates of animal performance. Staples et al. (1994) stated that forages high in nutritive value can provide most nutrients required by growing heifers, but the addition of minerals and small amount of concentrate is needed to achieve adequate ADGs. Providing supplement is usually profitable, but factors such as pasture quantity and quality and animal management should be included when considering the efficacy of supplementation.

Energy

In general a pasture-based system is energy demanding. Animals require energy for grazing, traveling, fetal development, milk production, growth, thermo-regulatory processes, maintenance, reproduction, digestion, and excretion. According to Moore et al. (1999) energy intake of cattle consuming forages as their only energy source may not be adequate to meet desired rates of animal performance. Usually, when high quality pasture is available in adequate quantities, metabolizable energy is the most limiting factor for milk production (Kolver and Muller, 1998). In addition, warm-season forages typically do not contain enough energy to meet nutrient requirements of developing heifers; therefore energy is usually the limiting factor to achieving adequate ADG and target BW (Rice, 1991). Also, most data support the concept that available energy is the first limiting factor in summer pasture forages, and protein (amino acid) quality and availability is the second (Hill et al., 1991). In agreement, Noller (1997) attributes energy as the most limiting performance factor when forages are the major component of a lactating cow's diet.

Supplementation of energy might alter the energy required by grazing ruminants by altering their grazing behavior or influencing their efficiency of nutrient use (Caton and Dhuyvetter, 1997). The efficiency of dietary metabolizable energy (ME) for maintenance and gain is influenced by the ratio of forage to concentrate in the diet, with greater proportions of concentrate leading to improved efficiency (Caton and Dhuyvetter, 1997). Working with sheep (*Ovis aries*), Henning et al. (1980) reported that low rates of corn (*Zea mays*) supplementation (7.8% of DM intake) actually increased forage intake. However, with greater levels of corn supplementation (greater than 23% of DM intake) forage intake was reduced compared with that of control sheep. 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 BW d^{-1}. Fieser and Vanzant (2004) looked at tall fescue (*Lolium arundinaceum* Scherb.) hay maturity effects on intake, digestion, and ruminal fermentation responses to different supplemental energy sources fed to beef steers. Supplement increased digestible OM intake and was greater with soybean (*Glycene max*) hulls than with corn.

Protein

Protein supplements usually are feedstuffs that are used to increase quantity and/or quality of the base diet (Ensminger et al., 1990). Protein supplements can be provided to the grazing animal by different sources such as plants (grains, meals, etc), non-protein nitrogen (urea), and animal sources (feather meal or fish meal). Protein is the second largest nutrient required after energy. Thus, protein is necessary for rumen microbes to digest fiber and other feedstuff components. Petersen (1987) in a review of protein supplementation of grazing livestock describes how protein supplements enhance forage utilization. Protein supplements provide amino acids, carbon skeletons, and minerals to rumen microbes, resulting in microbial growth and/or fermentation.

Additionally, protein supplements may also increase the quantity of protein reaching the small intestine through undegraded or bypass protein.

Forages high in nutritive value may possess CP concentration exceeding 250 g kg^{-1}; however, 650 to 850 g kg^{-1} of total protein is degradable in the rumen, with 150 to 350 g kg^{-1} escaping the rumen. Anderson et al. (1988) reported that gain was increased by 0.13 kg d^{-1} when escape protein was fed to steers grazing smooth bromegrass (*Bromus inermis* Leyss.), a cool-season grass that had a ruminal (in situ) protein degradation of approximately 85%. Supplemental CP often increases performance of ruminants consuming low quality forages. Owens et al. (1991) suggested that enhanced performance in response to protein supplementation may be attributed to increased intake of digestible DM from the supplement directly. Moore et al. (1999) developed a data base from 30 publications which included results from 58 dried grasses or straws fed alone with supplements. When forage CP was less than 7 g kg^{-1}, voluntary intake decreased, but above that level, there was little relationship between intake and CP. In agreement, Minson (1990) reported an average 40% increase in intake due to protein supplement and a 34% increase due to supplementary urea, after compiling several studies in which CP was below 62 g kg^{-1}.

Interactions between Supplements and Forages

Also called associative effects, these phenomena refer to the interaction among ingredients in mixed diets. For instance, when animal are offered forages ad libitum and supplemental concentrates are offered in restricted amounts, forage DMI may either increase, decrease, or remain the same (Moore, 1992). Therefore, animal responses to supplements are either greater or less than expected. These deviations are usually explained by associative effects of supplements upon voluntary intake and digestibility of the total diet (Moore et al., 1999). Associative effects can be either positive or negative. The changes in forage intake (substitution effects) may be a consequence of changes in the rate of digestion of the fibrous components (Moore, 1994; Dixon and Stockdale, 1999). While supplementation can cause substitution of supplement for a basal diet, it can still have a positive effect on overall DMI. This increase in total DMI has been observed for cattle that were either grazing or fed forage diets and supplemented with concentrate or fiber-based supplements (Bodine et al., 2000; Gekara et al., 2001).

Moore et al. (1999), in a review of research with cattle consuming forage, concluded that energy-based supplements decreased voluntary forage intake when supplemental TDN intake was greater than 0.7% of BW, the TDN:CP was less than 7, or when voluntary forage intake was greater than 1.75% of BW. In addition, Horn and McCollum (1987) summarized that concentrates can be fed up to 0.5% of BW without causing large decreases in forage intake in grazing ruminants. Likewise, feeding grain-based supplements above 0.25% of BW resulted in decreasing forage utilization (Bowman and Sanson, 1996). Different intake of metabolize energy (ME) when forages and grains are fed together to ruminants is due to digestive and metabolic interactions (Dixon and Stockdale, 1999). Bargo et al. (2002) observed that dairy cows grazing at high and low forage allowances had increased total DMI as concentrate was supplemented at 8.63 kg d^{-1}, but DMI was greater for cows at the lower than the higher forage allowance. Royes et al. (2001) also reported that supplementation with corn or soy hulls caused a linear decrease in hay intake while increasing total DMI. Although, the linear decrease in hay DMI per cow was small at 1.4 kg supplement d^{-1}, the difference was larger when 2.8 kg supplement d^{-1} was fed, indicating that substitution rate changes with increasing supplementation.

Other effects of substitution on forage intake by concentrate supplementation may be caused by negative associative effects such as lower rumen pH, lower rate of forage digestion, lower NDF digestibility, and decreased grazing time (Bargo et al., 2002; Gekara et al., 2001). Royes et al. (2001) reported decreasing apparent digestibility of ADF and NDF of stargrass hay supplemented with increasing rates of corn. Thus, Bargo et al. (2002) found that when greater substitution rate was observed, it was associated with the diet having reduced rumen degradable N without affecting total bacterial N flow. Nevertheless, negative associative effects can be minimized by supply of essential microbial substrates, feeding management, and modification of grain to reduce the effects on fiber digestion (Dixon and Stockdale, 1999).

An observation less common by concentrate supplementation is when both total DMI and forage intake increase. Stafford et al. (1996) observed increasing forage and total DMI when supplementing a high CP supplement to steers. He stated that, the effect could have been caused by a 96% increase in forage digestibility. In a different study, Matejovsky and Sanson (1995) also reported an increase in low quality forage intake when supplemented with protein above the intake of the non-supplemented lambs. Thus, Bodine et al. (2000) found that steers supplemented with protein increased total OM intake and improved BW gain. 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, however when low nutritive value forages are fed in junction with small amount of concentrates, voluntary intake may increase (Moore, 1994).

CHAPTER 3
GRAZING MANAGEMENT EFFECTS ON TIFTON 85 BERMUDAGRASS PASTURE CHARACTERISTICS AND PERFORMANCE OF DAIRY HEIFERS

Introductory Remarks

Several studies suggest that well-managed rotational stocking systems on dairy farms can be as, or possibly more, profitable than conventional systems despite less milk production (Knoblauch et al., 1999; Conneman et al., 1997; Frelich et al., 2011; Macoon et al., 2011). Additionally, studies in the beef industry also point out that rotational stocking can increase profitability (Fales et al., 1995; Phillip et al., 2001; Stewart et al., 2005).

Replacement heifers have a tremendous economic impact on dairy operations, whether animals are raised on farm or by outsourcing using a custom heifer grower. Replacement heifers represent the second largest input after feed cost for the dairy farm, accounting for approximately 20% of the total operation expenses (Goodger and Theodore, 1986; Heinrichs, 1993). As replacement heifer costs continue to increase, selecting the most economic method of raising replacement heifers has major implications on dairy operation profitability (Gabler et al., 2000).

Recently, more dairy farmers in the USA are showing increased interest in pasture-based systems, as it provides an alternative to reduce production costs. According to a survey in 2001, 27% of USA custom dairy heifer growers were already raising replacement heifers under grazing conditions (Wolf, 2002). Florida has followed this national trend and many dairy farmers have adopted this approach, including implementing rotational stocking systems. In the Southeast USA, the use on dairies of high-quality hybrid bermudagrasses [*Cynodon dactylon* (L.) Pers.] by lactating and non-lactating animals and replacement heifers has increased (Hill et al., 2001).

Since its release in 1992 (Burton et al., 1993a), ‘Tifton 85’ bermudagrass (*Cynodon* spp.), has been considered among the most important grasses in the southeastern USA. Studies evaluating grazing management practices for Tifton 85 have shown its superiority in dry matter (DM) yield and nutritive value compared with other bermudagrass cultivars, including ‘Tifton 78’, ‘Coastal’, and ‘Florakirk’ (Mandebvu et al. 1999). In Florida, a recent study by Liu et al. (2011) determined that relatively short grazing intervals (14-21 d) of Tifton 85.Bermudagrass are conducive to high nutritive value without negatively impacting persistence. In addition, Rouquette et al. (2003) reported no differences in average daily gain (ADG) of crossbred weaned calves that grazed Tifton 85 only and those that grazed Coastal bermudagrass and received 0.91 kg d^{-1} of a 3:1 maize:soybean (*Glycine max* L.) meal concentrate. In the same trial, Tifton 85 supported a higher stocking rate (8 vs. 4 head ha^{-1}) than Coastal with 1.4 kg d^{-1} supplementation. Vendramini et al. (2007) showed a linear increase in ADG and live weight gain (LWG) as level of supplement feed increased when early-weaned beef calves were grazing Tifton 85 forage.

When raising replacement heifers, matching the feed resources to the nutrient needs of the animal is important, as animal performance is largely determined by nutrient consumption (Mertens, 1994). Forages high in nutritive value can provide most nutrients required by growing heifers, but the addition of minerals and small amounts of concentrate are needed to achieve adequate ADG (Staples et al., 1994). The use of supplementary feed is a common management practice aimed at overcoming nutritional shortfalls of the forage component of the diet. Determining how much supplement to provide can be challenging, however, because when concentrate supplements are offered in restricted amounts to grazing animals forage DM intake (DMI) can increase, decrease, or remain the same (Caton and Dhuyvetter, 1997; Moore, 1992). Thus, the resulting animal performance can deviate from the expected animal performance based solely on the sum of the individual ingredients of the diet (Moore, 1992).

Because of high nutritive value and dry matter production, Tifton 85 bermudagrass has become the forage of choice on many grazing dairies, prompting research on grazing management focused on the interaction of grazing cycle and concentrate supplementation. The hypothesis of this research is that shorter rest periods and greater supplementation rate will result in greater animal performance by dairy heifers grazing Tifton 85 bermudagrass pastures. The objective of this experiment was to evaluate length of rest period (RP) between grazing events and animal supplementation rate effects for Tifton 85 pastures on pasture characteristics and dairy heifer performance under rotational stocking.

Materials and Methods

Study Site

The study was conducted during the summer of 2010 (June – September) and 2011 (July – September) at the University of Florida Beef Research Unit (BRU), 18 km northeast of Gainesville, FL (30° N lat, 82°21’ W) on established pastures of Tifton 85 bermudagrass (~ 5-yr old). Soils were Ultisols from the Plummer series (loamy, siliceous, thermic Grossarenic Paleaquults) and Sparr series (loamy, siliceous, hyperthermic Grossarenic Paleudults). At the beginning of the study, average soil pH was 5.7 and Mehlich 1 extractable P, K, Mg, and Ca concentrations were 44, 29, 49, and 566 mg kg^{-1}, respectively. Based on soil test and intended use of the area, all pastures were fertilized each year at the initiation of summer. In 2010, all pastures received 200 kg of N ha^{-1} yr^{-1}, in four equal applications of 50 kg N ha^{-1}. The fertilizer was broadcast on 27 April, 8 June, 13 July, and 11 August. In 2011, all treatments received 120 kg of N ha^{-1} yr^{-1}, split in three applications of 40 kg of N ha^{-1}. Each year, a one-time application of 17 kg P and 66 kg K ha^{-1} was done with the first N application. The fertilizer was broadcast on 20 June, 22 July, and 17 August.

Precipitation and temperature data were collected daily on site. The 30-yr average rainfall for the area is 1,229 mm; however, both years received less total annual precipitation (1,024 and 1,029 mm, for 2010 and 2011 respectively) than the 30-yr average. The experimental period (June - September) in 2010 received 33% more rainfall (486 mm) than the experimental period (July – September) in 2011 (326 mm). Although average monthly temperatures were similar in both years during the experimental periods, 2011 was hotter during the day and cooler during the night compared to 2010 (Table 3-1).

Experimental Procedures and Design

In this grazing study the RP together with the grazing or stocking period made up the grazing cycle. Due to synonymies of accepted used terms (Allen et al., 2011), the terms grazing period and cycle will be used. The grazing period was fixed to 7 d and the RP were either 14 or 21 d. The four treatments were the factorial combinations of two RP (14 and 21 d) and two supplementation rates (SUP, low and high, corresponding respectively to 0.64 and 0.96% of heifer BW as fed). These combinations were arranged in a randomized complete block design with two replications. The RP selected for this study had been reported (Liu et al., 2011) to allow high nutritive value and adequate forage accumulation for Tifton 85 bermudagrass without compromising persistence of the stand. The SUP rates values were chosen to support 0.7 kg d^{-1} of BW gain (NRC, 2001) assuming forage DMI from pastures of 1.25% of BW d^{-1}. The supplement composition in 2010 consisted of ground corn, whole cottonseed, citrus pulp, and a mineral-vitamin mix whereas it consisted mainly of hominy feed, cottonseed hulls, soybean meal, soybean hulls, and molasses in 2011 (Table 3-2). The experimental unit was 0.25 ha subdivided into three or four paddocks to accommodate the two RP treatments (Fig 3-1). A full rotation within the experimental unit was considered a grazing or stocking cycle.

Grazing Management

To impose the experimental treatments, rotational stocking and put-and-take stocking methodology were used. This method uses a variable stocking number of animals per experimental unit to maintain among experimental units similar post-graze stubble height. In contrast to the put-and-take animals, tester animals were assigned to treatment pastures and remained in the experimental unit for the entire experimental period.

In 2010, a total of 40 Holstein heifers (267±11.2 kg mean BW) were utilized and a total of 40 F1 Jersey x Holstein crossbred heifers (233±14.3 kg mean BW) were used in 2011. Additional heifers were added and removed from the pastures to achieve the target stubble height of ~20 cm by, but not before, the end of a given grazing cycle. The stocking adjustments were made primarily on weigh days (every 28 d), but occasionally adjustments were necessary between weigh days. When removed from experimental units, these additional heifers were maintained on reserved non-experimental Tifton 85 bermudagrass pastures. Heifers in all pastures received their supplement individually each morning. Portable shade and misting structures, water, and supplemental feed bunks were provided in each paddock.

In spring of each year all pastures were mowed to a 20-cm stubble and grazing was initiated on a given experimental unit when average sward height was approximately 20 cm taller than the target stubble height (20 cm) and adequate forage was available to support three 6- to 8-mo-old dairy heifers (testers) per pasture; grazing ended for the season when pastures could no longer support the testers. Grazing seasons were from 15 June through 6 Oct. 2010 (112 d) and 6 July through 28 Sept. 2011 (84 d). There were five grazing cycles for the 14-d rest period treatment and four for the 21-d rest period treatment during 2010. In 2011, there was one less cycle in each treatment. The length of the grazing seasons varied primarily because of spring moisture conditions; grazing was initiated later in 2011 because of spring drought.

Pasture Measurements

Before and after each grazing event, the paddocks were sampled to determine herbage mass using a double sampling technique (Santillan et al., 1979). In each paddock three sites were selected and 0.25-m^2 quadrats were used for destructive sampling both pre- and post-grazing. Site selection criterion was to represent the range of herbage mass in the paddock; therefore, samples were collected at low, intermediate, and high herbage mass sampling units in each paddock. Plate meter height readings were recorded at each site. The herbage at these sites was then clipped to 5-cm stubble height and put into separate bags. Clipped samples were dried at 60°C for 48 h and weighed to determine herbage mass. The relationship between plate meter readings and herbage mass was used to develop regression equations to estimate forage mass. Separate calibration equations were developed for pre-graze and post-graze herbage mass. An additional 30 randomly selected sites within each paddock were sampled using the plate meter, and the average of those 30 measurements was entered into prediction equations to estimate herbage mass. Herbage accumulation for a given grazing cycle was calculated by subtracting post-graze herbage mass at the end of the grazing cycle from pre-graze herbage mass of the following cycle. Herbage accumulation for the first grazing cycle (Cycle 1) was the pre-graze herbage mass of Cycle 1.

To estimate nutritive value, hand-plucked herbage samples were taken from the pre-grazed paddocks to represent the area to be grazed and portion of the canopy to be removed during the grazing period. In each paddock, 20 to 30 hand-plucked samples were taken to make a composite sample every 2 wk. This practice usually resulted in two, and occasionally three sampling events per 28 d. The samples were dried at 60°C for 48 h and then ground to pass a 1-mm screen using a Wiley mill. Nitrogen was determined by using a micro-Kjeldahl technique (Gallagher et al., 1975). Crude protein concentration was calculated as N x 6.25. In vitro organic matter digestibility (IVOMD) analyses were conducted using the modified two-stage procedure (Moore and Mott, 1974) of Tilley and Terry (1963).

Animal Measurements

Heifers were weighed at 0900 h following overnight feed and water deprivation (16 h) at initiation of grazing and at 28-d intervals throughout the trial each year for calculation of shrunk weights (Hughes, 1976). Shrunk weights were obtained for all animals. Blood samples from coccygeal vessels were collected via tail venipuncture into evacuated tubes (Becton Dickinson, Franklin Lakes, NJ, USA) containing K_2^+ EDTA from testers only at the time of weighing. Blood samples were immediately placed in ice until processing. Plasma was separated by centrifugation at 3,000 x g at 5°C for 20 min (Allegra X-15R Centrifuge, Beckman Coulter). Plasma was stored at -20°C for subsequent blood urea N (BUN) determination using an AutoAnalyzer (Technicon Instruments Corp., Chauncey, NY). The BUN was expressed in mg dL^{-1}. The change in shrunk weights of the testers was used to calculate ADG. The average stocking rate (SR) was calculated using both tester and put-and-take heifers, and expressed in animal units (AU = 450 kg of LW). Heifer days per hectare was determined by multiplying the average SR by the number of days of grazing and dividing that product by the mean weight of the testers on that pasture. Gain per hectare was calculated as the product of tester ADG for a given pasture by heifer days per hectare, and expressed in kg of live weight per hectare. Forage allowance was expressed as kg of forage DM per kg of animal live weight, and was computed as herbage mass [(pre-graze + post-graze)/2] divided by heifer BW on the experimental unit during the grazing period (Sollenberger et al., 2005).

Statistical Analyses

To determine the effects of RP and SUP on pasture and animal responses, data were analyzed by fitting mixed effects models using the PROC GLIMMIX procedure of SAS (SAS Inst. Inc., Cary, NC). To evaluate response variables, full models with year in the model were analyzed. Analyses for each year were run separately if treatment interactions with year were significant. Rest period, supplement rate, and their interactions were considered fixed effects. Replications (blocks) and its interactions were considered random effects. Treatments were considered different at P values ≤ 0.05 and trends are reported for P values > 0.05 and ≤ 0.10. All data are reported as least squares means, and the PDIFF function of the LSMEANS procedure was used to compare differences.

Results and Discussion

Pasture Responses

Pre and postgraze herbage mass

Pre-graze herbage mass was greater (P < 0.01) in 2010 (3.1 Mg DM ha^{-1}) than in 2011 (2.5 Mg DM ha^{-1}), but there were no treatment effects in either year. In 2010, pre-graze herbage mass ranged from 3.0 to 3.3 Mg DM ha^{-1} and in 2011 from 2.5 to 2.6 Mg DM ha^{-1}. Greater herbage mass in 2010 than in 2011 may have been associated with greater rainfall received or greater N fertilizer applied during the 2010 experimental period. A slightly lower range for pre-graze herbage mass (1.6 to 2.6 Mg DM ha^{-1}) had been reported under rotational stocking in a study with beef calves grazing Tifton 85 bermudagrass at 14- and 28-d rest periods (Vendramini et al., 2008).

Post-graze herbage mass was greater (P < 0.01) in 2010 (1.8 Mg DM ha^{-1}) than in 2011 (1.1 Mg DM ha^{-1}), but similar to pre-graze herbage mass, there were no treatment effects in either year. During 2011 Tifton 85 pastures were grazed more intensively compared to 2010 resulting in very low residual forage DM after each grazing cycle.

Herbage accumulation rate

Total herbage accumulation rate in this study ranged from 61 to 78 kg DM ha^{-1} d^{-1} and was similar to those reported by Vendramini et al., 2007 and Pedreira et al., 1998. Herbage accumulation rate also was affected by the interaction of RP and SUP with year (P < 0.01). When analyzed by year, in 2010, herbage accumulation rate was greater when pastures were grazed by animals receiving a low SUP rate than those receiving high SUP rate (Table 3-3). Low stocking rates in 2010 when animals were grazing low SUP pastures very likely resulted in less defoliation and greater residual leaf area which resulted in greater herbage accumulation rates compared to high SUP treatments. Also, herbage accumulation rate had a trend toward an RP x SUP interaction ($P = 0.10$). The interaction occurred because herbage accumulation rate was greater when pastures were grazed at 21-d RP under high SUP rate but lesser when pastures were grazed at 14-d RP under high SUP (Figure 3-2A). This outcome could be attributed to a severe attack of army worm (*Spodoptera frugiperda*) in the 14-d RP high SUP treatment in one of the replicates, reducing the total forage output of that pasture. In 2011, herbage accumulation rate did not differ for animals receiving higher supplementation, and the rate was the same as for the high rate of supplementation the previous year. In 2011, herbage accumulation rate was greater when pastures were grazed every 14 d compared with 21 d ($P < 0.05$). As in 2010, herbage accumulation rate had a tendency for the RP x SUP interaction ($P = 0.06$). The interaction occurred because herbage accumulation was greater when pastures were grazed at 14-d RP under high SUP, but it was lesser when grazed at 21-d RP under high SUP (Figure 3-2B). This could be attributed to a shorter regrowth interval, adequate rainfall and probably better nitrogen uptake, allowing grazed pastures to recuperate faster and produce more herbage mass compared to a relatively longer regrowth interval. Although there were interactions between year, RP and SUP treatments, grazing Tifton 85 Bermudagrass pastures at 14- or 21-d resulted in adequate herbage accumulation rates to sustain high stocking rates.

Nutritive value

Year affected herbage CP ($P < 0.01$) and IVOMD ($P = 0.07$) concentrations. Crude protein and IVOMD were greater in 2011 than in 2010. These differences likely occurred to some extent due to a short but moderate water stress before trial initiation during June of 2011, increasing herbage nutritive value (Wilson, 1983) early in the grazing season. For instance, CP concentration in July of 2010 was 163 vs. 196 g kg^{-1} in July of 2011. Also, differences can be attributed to low herbage mass values and heavier grazing during 2011, leading to probably more leaf to stem ratio. Similar response has been reported in stargrass (*Cynodon nlemfuensis Vanderyst*), for which CP increased with increasing stocking rate (Garay et al., 2004). In 2010 and 2011 shorter RP (14 d) had greater CP concentrations than longer RP (21 d) ($P < 0.01$) (Table 3-4). Similar trends have been reported for Florakirk bermudagrass (Pedreira et al., 1999), 'Jiggs' bermudagrass, Florona stargrass (Mislevy et al., 2008), and Tifton 85 (Vendramini et al., 2008; Liu et al., 2011) when looking at different regrowth intervals. Forage chemical composition and digestibility are influenced by plant age, therefore as rest period or regrowth increases, forages mature and the ratio between leaves and stems is reduced (Minson, 1990).

In terms of IVOMD, forage from 14-d RP had greater IVOMD concentration than that from 21-d RP (624 vs. 602 g kg^{-1}, $P = 0.05$). As observed for herbage CP, IVDOM decreased as RP increased from 14 to 21 d. Decreasing digestibility in tropical grasses as regrowth or rest period increases between grazing or defoliation events has been associated with the reduction in leaf to stem ratio and the accumulation of secondary cell wall and lignin. (Akin et al., 1990; Buxton and Redfearn, 1997; Mandebvu et al., 1999).

Herbage allowance

Herbage allowance was greater in 2010 than 2011 (0.73 vs. 0.53 kg of DM kg^{-1} of BW, respectively; $P < 0.01$). Additionally, herbage allowance was less for high SUP treatments compared to low SUP treatments (0.59 vs. 0.67 kg of DM kg^{-1} of BW, respectively). Pastures were heavily stocked in 2011 in response to high herbage mass early in the grazing season. This increase in stocking resulted in reduction of herbage allowance, which carried over until the end of the grazing season in 2011. Lesser herbage allowance with high SUP is expected when pastures are grazed to the same endpoint of grazing. In this situation, high SUP will likely decrease forage intake per animal, allowing a greater stocking rate at the same level of forage mass resulting in lesser herbage allowance. Although herbage allowance in 2010 was 40% greater compared to 2011, it was below 1 kg of DM kg^{-1} of BW in both years. This value has been associated with greater gains in unsupplemented heifers grazing Tifton 85 under continuous stocking (Pedreira, 1995). Also, McCartor and Rouquette (1977) reported that increasing herbage allowance up to 1 kg forage DM per kg of animal LW resulted in linear increases in ADG. It is important to keep in mind that heifers in the current study were supplemented, so the herbage allowance requirements were likely to be lower.

Animal Responses

Stocking rate and live weight gain per hectare

Average SR was different ($P < 0.05$) between years. In 2010 SR was 9.4 AU ha^{-1} compared with 10.6 AU ha^{-1} in 2011. This difference is attributed to pastures being grazed heavier in 2011. Stocking rate was greater in pastures where heifers were fed a high SUP rate compared to a low SUP rate (10.6 vs. 9.5 AU, respectively). The greater stocking rates in the high SUP treatments were likely the result of greater substitution of supplement for forage associated with greater amount of concentrate fed to heifers compared to low SUP treatments. Stocking rate presented a trend toward an effect by RP in 2010 but not in 2011 ($P = 0.08$). Animals that grazed pastures with 21-d RP had greater SR than pastures with 14-d RP. This could be attributed to a relatively greater pre-graze herbage mass present in the 21-d RP pastures compared to the 14-d RP (although no statistical different) during 2010.

Live weight gain per ha was greater in 2010 (989 kg ha^{-1}) than in 2011 (500 kg ha^{-1}) ($P < 0.01$). This could be attributed to greater stocking rates in 2011 that resulted in lesser ADG compared to 2010. Heifers fed at higher SUP rate resulted in greater ($P < 0.05$) live weight gains per hectare than those fed at a lower SUP rate (800 vs. 690 kg of LW ha^{-1}, respectively). However, these values are similar to those reported by Vendramini et al. (2007) when supplementing at 10 g kg^{-1} of BW. Hill et al. (1993) also reported gain per hectare values of 1,156 kg of LW ha^{-1} of unsupplemented steers (269 kg) grazing Tifton 85 under continuous stocking.

Average daily gain

Average daily gains were greater in 2010 compared to 2011 (0.65 vs. 0.55 kg $animal^{-1}$ d^{-1}, respectively) (Table 3-6). Although ADG was affected by year by SUP interaction ($P = 0.05$); this interaction was driven by lower ADG of animals grazing Tifton 85 at 21 d under low SUP. Average daily gain presented a trend toward an effect by RP and SUP ($P = 0.07$). Animals that grazed pastures with a 14-d RP had slightly better gains than those grazing 21-d RP (0.62 vs. 0.57 kg d^{-1}, respectively). Higher nutritive value is associated with shorter herbage regrowth intervals, and accounts for a significant portion of ADG if quantity is not limiting (Sollenberger and Vanzant, 2011). Also, animals that were fed high SUP had greater ADG compared to low SUP (0.62 vs. 0.57 kg d^{-1}, respectively).

Blood urea nitrogen

The length of RP did not influence BUN in either year (Table 3-7). Supplement rate had an interaction with year ($P = 0.02$). In 2010 there were no main effects of RP or

SUP for BUN. However, in 2011 SUP had an effect on BUN (*P* = 0.05). Animals that received higher SUP rate had slightly greater values of BUN compared to low SUP (11.9 vs. 10.9 mg dL^{-1}, respectively). This outcome could be attributed to the differences in ingredients composition of the supplement fed each year. The heifer BUN concentrations in this study reflected concentrations which fall into suggested ranges of 11 to 15 mg dL^{-1} (Byers and Moxon, 1980; Preston et al., 1978) and 8 to 12 mg dL^{-1} (Hammond et al., 1994) for maximizing animal performance, indicating that animals were not protein deficient.

Research Implications

During the 2-yr study, different rates of supplement fed to dairy heifers grazing Tifton 85 pastures did not affect nutritive value of the forage nor Tifton 85 pre-graze herbage mass. Herbage accumulation in 2010 was affected by SUP. Lowest herbage accumulation occurred when dairy heifers were fed at a high supplementation rate. Herbage accumulation was affected by RP in 2011, and greater herbage accumulation was associated with shorter RP. Herbage allowance was lower in the high SUP rate, as a result of greater number of put-and-take heifers, and therefore SR was greater in those pastures treatments. Additionally, the low herbage allowances in 2011 appeared to negatively impact ADG, especially in the low SUP treatments. This could be attributed to the high stocking rate maintained in 2011.

Greater SR and gain per hectare were achieved under high supplementation rate. Average daily gain had a trend toward an effect for both, RP and SUP treatments. Greater ADG was associated with shorter RP and higher SUP rates.

Blood urea N concentrations did not differ among RP treatments. However, slightly greater BUN concentrations were associated with feeding more concentrate in

2011 compared to 2010. This can be explained by the differences in CP concentration in concentrates fed both years.

Although targeted ADG of 0.7 kg was not achieved, data obtained in this study support the use of Tifton 85 for raising dairy heifers under rotational stocking when grazed either at 14- or 21-d and supplemented at 0.96% of BW. Additionally, even though Tifton 85 is able to maintain high stocking rates and achieve high gains per unit of land area as reported in the literature, data in this study from year 2011 suggests that average stocking rates beyond 10 AU are not conducive to adequate gains, and therefore should be avoided.

Table 3-1. Monthly rainfall and minimum (Min), maximum (Max), and average temperatures at the University of Florida Beef Research Unit, Gainesville Florida during 2010 and 2011 and the 30-yr average for Gainesville. Gray shading indicates the experimental period each year.

Month	Rainfall		Ambient temperature						30-yr average	
			2010			2011				
	2010	2011	Min	Max	Average	Min	Max	Average	Rainfall	Temperature
	--------mm-------		-------------------------------------°C-------------------------------------						mm	° C
January	174	115	0.8	17.0	8.7	2.1	17.2	9.7	89	12.4
February	107	116	3.8	16.6	9.2	8.9	21.1	14.6	86	14.2
March	100	76	6.7	20.4	13.5	10.3	25.8	17.4	108	16.8
April	5	39	11.9	26.8	19.4	14.0	29.3	20.9	73	19.8
May	203	72	18.8	30.8	24.5	15.1	31.9	23.1	82	23.7
June	167	130	21.6	33.7	26.6	19.8	34.7	26.2	172	26.5
July	163	123	22.7	32.9	27.0	21.2	33.4	26.5	155	27.3
August	132	139	23.9	32.9	26.9	22.1	34.0	27.2	168	27.2
September	24	64	19.4	32.2	24.9	18.9	32.1	24.6	111	25.7
October	0	85	12.2	29.8	19.4	12.1	27.5	18.4	64	21.6
November	21	55	10.0	25.6	15.1	10.6	26.2	16.1	55	17.1
December	8	15	-0.5	16.2	7.2	6.9	22.3	14.3	66	13.4
Trial Total	**486**	**326**	**21.9**	**32.9**	**26.4**	**20.5**	**33.2**	**26.1**		
Total	**1104**	**1029**							**1229**	

Table 3-2. Ingredient composition of supplements (SUP) offered to dairy heifers on pasture.

Item	2010		2011	
	High-SUP	Low- SUP	High-SUP	Low- SUP
Ingredients (% of DM)				
Corn, ground	47.6	46.4	-	-
Whole cottonseed	23.8	23.2	-	-
Citrus pulp	23.8	23.2	-	-
Mineral and Vitamin mix[1]	4.8	7.1	-	-
Hominy Feed	-	-	36.35	36.35
Cottonseed Hulls	-	-	25.50	25.50
Soybean meal, 47.5% CP	-	-	18.26	18.26
Soy hulls	-	-	9.00	9.00
Molasses	-	-	6.00	6.00
Aureo Bovatec Blend[2]	-	-	1.65	1.65
Calcium Carbonate	-	-	1.20	1.20
Monodical 21%	-	-	0.50	0.50
Salt	-	-	0.50	0.50
Fat	-	-	0.50	0.50
Mineral and Vitamin mix[3]	-	-	0.45	0.45
ClarifFLY 0.67%[4]	-	-	0.09	0.09

[1] Each kg contained 3.20% of CP, 8.80% of Ca, 4.20% of P, 11.40% of Mg, 8.10% of Na, 12.40% of Cl, 0.50% of K, 0.4% of S, 58 mg of Co, 263 mg of Cu, 1933 of Fe, 26 mg of I, 923 mg of Mn, 8.50 mg of Se, 1109 mg of Zn, 259,000 IU of vitamin A, 70,000 IU of vitamin D, 2377 IU of vitamin E, and 1430 mg of monensin.
[2] Each kg contained 7.8 g of Chlortetracycline HCL, and 4.5 g of Lasalocid
[3] Each kg contained 4.28% of CP, 9.78% of Ca, 2.54% of P, 1.81% of Mg, 3.97% of Na, 3.97% of Salt, 26 mg of Co, 146 mg of Cu, 667 mg of Mn, 300,000 IU of vitamin A, 60,000 IU of vitamin D, and 1602 IU of vitamin E.
[4] Central Liffe Sciences, Schaumburg, IL. Each kg contained 6.8 g of Diflubenzuron

Table 3-3. Pre-graze herbage mass and herbage accumulation of Tifton 85 bermudagrass pastures grazed by dairy heifers as affected by rest period (RP) and supplement rate (SUP).

Effect	Pre-graze herbage mass†		Post-graze herbage mass‡		Herbage accumulation§	
	2010	2011	2010	2011	2010	2011
Rest period	----Mg DM ha^{-1}----		-----Mg DM ha^{-1}-----		------kg DM ha^{-1} d^{-1}------	
14	3.0	2.5	1.9	1.1	65	78 a
21	3.2	2.6	1.8	1.0	69	66 b
SE					3.0	2.2
Supplement rate						
High	3.2	2.6	1.9	1.0	61 b	74
Low	3.0	2.5	1.8	1.0	74 a	70
SE					3.0	2.2
Mean¶	3.1 a	2.5 b	1.8 a	1.1 b		
SE	0.16		0.08			

† Significant effects: year (P < 0.05)

‡ Significant effects: year (P < 0.05)

§ Significant effects: year by RP by SUP (P < 0.05); supplement rate 2010 (P < 0.05) and RP 2011 (P < 0.05). Means followed by different letter are significantly different (P < 0.05)

¶ Year means across RP and SUP. Means followed by different letter are significantly different (P < 0.05)

Table 3-4. Crude protein (CP) and in vitro digestible organic matter (IVDOM) concentration of Tifton 85 bermudagrass pastures grazed by dairy heifers as affected by rest period (RP) and supplement rate (SUP).

Effect	Herbage CP†				Herbage IVOMD‡			
	2010	2011	Mean§	SE	2010	2011	Mean¶	SE
Rest period	---------g kg^{-1}---------				---------g kg^{-1}---------			
14	167	182	174 a	2.9	609	638	624 a	9.0
21	151	171	161 b		597	608	602 b	
Supplement rate								
High	159	175			604	613		
Low	160	178			603	632		
Mean#	159 b	176 a			603	623		
SE	4.0							

† Significant effects: year and rest period ($P < 0.05$)
‡ Significant effects: rest period ($P < 0.05$)
§ Rest period means across years. Means followed by different letter are significantly different ($P < 0.05$)
¶ Rest period means across years. Means followed by different letter are significantly different ($P < 0.05$)
# Year means across RP and SUP. Means followed by different letter are significantly different ($P < 0.05$)

Table 3-5. Herbage allowance and stocking rate of Tifton 85 pastures grazed by dairy heifers as affected by rest period (RP) and supplementation rate (SUP).

Effect	Herbage allowance†				Stocking rate‡			
	2010	2011	Mean§	SE	2010	2011	Mean¶	SE
Rest period	-----kg DM kg LW^{-1}--------				-----AU# ha^{-1}-------			
14	0.73	0.52			9.0	10.7		
21	0.74	0.54			9.9	10.6		
Supplement rate								
High	0.68	0.49	0.59 b	0.02	9.8	11.3	10.5 a	0.2
Low	0.78	0.57	0.67 a		9.1	10.0	9.6 b	
Mean††	0.73 a	0.53 b			9.4 b	10.6 a		
SE	0.02				0.2			

† Significant effects: year and SUP ($P < 0.05$)
‡ Significant effects: year and SUP ($P < 0.05$)
§ Supplement rate means across years. Means followed by different letter are significantly different ($P < 0.05$)
¶ Supplement rate means across years. Means followed by different letter are significantly different ($P < 0.05$)
# AU = 450 kg
†† Year means across RP and SUP. Means followed by different letter are significantly different ($P < 0.05$)

Table 3-6. Average daily gain (ADG) and live weight gain (LWG) ha^{-1} of dairy heifers grazing Tifton 85 bermudagrass pastures as affected by rest period (RP) and supplementation rate (SUP).

Effect	ADG[†]				BUN[‡]		LWG[§]			
	2010	2011	Mean[¶]	SE	2010	2011	2010	2011	Mean[#]	SE
Rest period	-------------kg d^{-1}------------				-------mg dL^{-1}-------		--------------kg ha^{-1}---------------			
14	0.65	0.58	0.62 a	0.03	9.0	11.3	984	518		
21	0.60	0.54	0.57 b		8.5	11.5	993	482		
Supplement rate										
High	0.62	0.61	0.62 a	0.03	8.5	11.9 a	1024	572	800 a	38
Low	0.63	0.51	0.57 b		9.0	10.9 b	952	427	690 b	
Mean[††]	0.63 a	0.56 b					989 a	500 b		
SE	0.02				0.3	0.3	38			

[†] Significant effects: year (P < 0.05), RP (P = 0.07) and SUP (P = 0.07).
[‡] Significant effects: year by SUP (P < 0.05); supplement rate in 2011 (P < 0.05). Means followed by different letter are significantly different (P < 0.05)
[§] Significant effects: year and SUP (P < 0.05)
[¶] Rest period and SUP means across years. Means followed by different letter are significantly different (P < 0.10)
[#] Supplement rate means across years. Means followed by different letter are significantly different (P < 0.05)
[††] Year means across RP and SUP. Means followed by different letter are significantly different (P < 0.05)

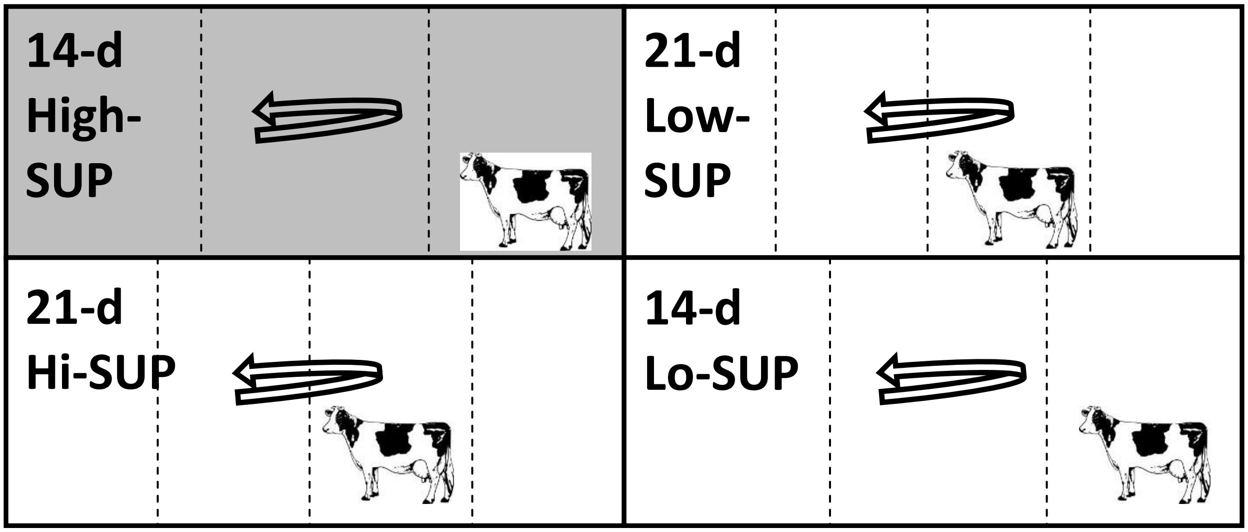

Figure 3-1. Layout per replicate of experimental units (represented in gray), subdivision into paddock for implementation of rest periods (14 or 21 d). Arrows indicate the systematic movement of all dairy heifers per grazing cycle (rest period + 7-d stocking period). Supplementation per experimental unit is represented as High-SUP (0.96 % of BW) or Low-SUP (0.64% of BW).

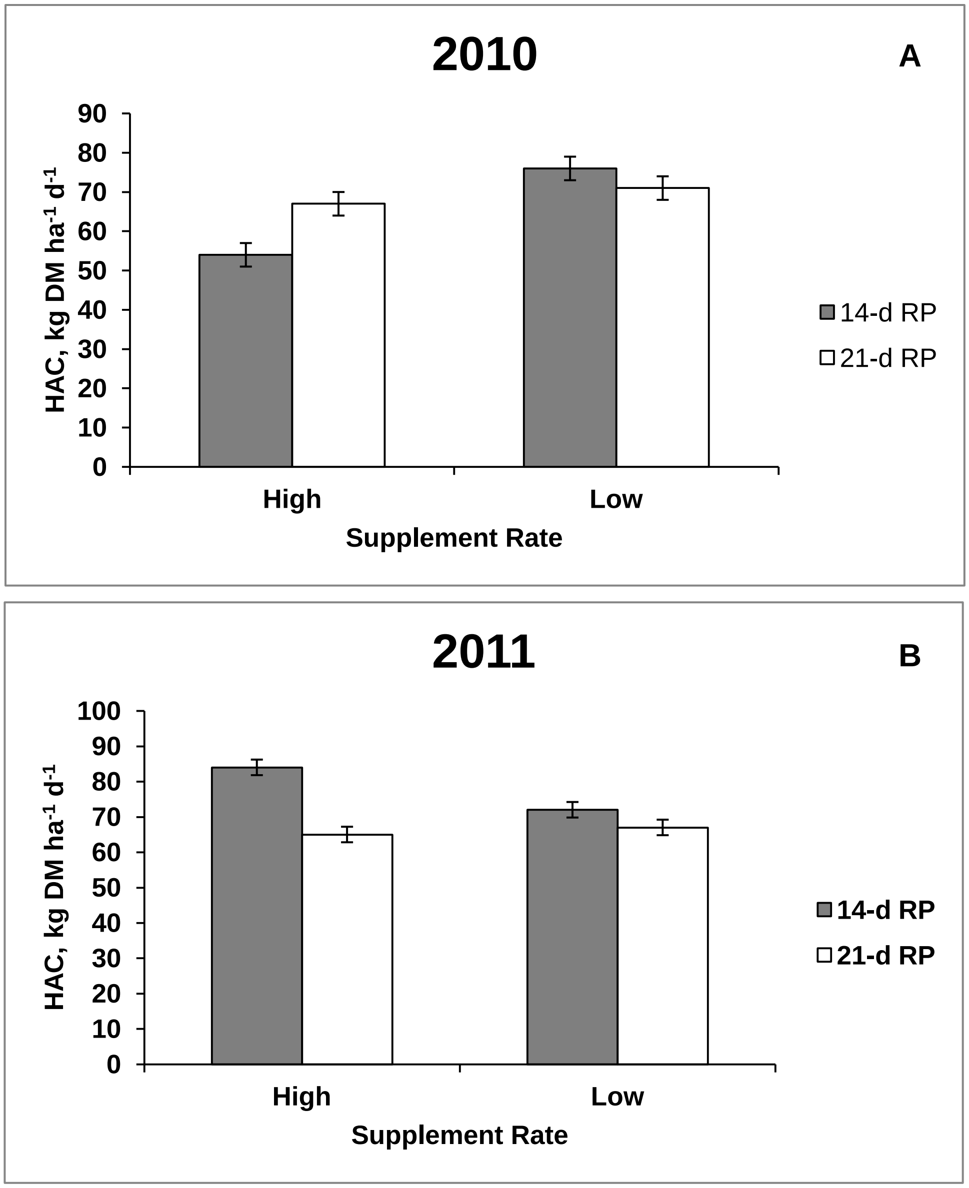

Figure 3-2. Rest period x supplement rate effect on Tifton 85 herbage accumulation (HAC) in 2010 (A) (P = 0.10) and 2011 (B) (P = 0.06).

CHAPTER 4
ANNUAL RYEGRASS REMOVAL EFFECTS ON REGROWTH OF OVERSEEDED BERMUDAGRASS

Introductory Remarks

‘Tifton 85’ (T85) bermudagrass (*Cynodon* spp.) is most productive during June, July, and August, (Clavijo et al., 2010), but forage accumulation rate slows markedly during the fall and winter. The practice of overseeding cool-season forages into perennial warm-season grasses during fall/early-winter months is advantageous to producers for reducing the need for stored forages (DeRouen et al., 1991) and providing an opportunity to extend the grazing season an additional 75 to 150 d during winter through spring (Fontaneli et al., 2000). Using two forage species with different optimal growth temperature ranges, such as bermudagrass and annual ryegrass (AR; *Lolium multiflorum*), can improve the seasonal distribution of forage and increase the nutritive value of forage on offer (Fontaneli et al., 2000), with the end result being greater animal performance (Fales et al., 1996).

While overseeding may extend the overall forage production window, the spring transition from annual ryegrass to T85 bermudagrass can be troublesome and inconsistent (Chamblee and Muller, 1999). In Florida, early to late spring is a period when there is an overlap between the cool-season annuals that are peaking in herbage accumulation and the warm-season perennial grass that is starting to break dormancy (Myers, 1974). A cool-season annual forage that extends growth into late spring such as annual ryegrass is very competitive for moisture, nutrients, and light during this time (Myers, 1974).

Field observations by Chamblee and Muller (1999) described stand reduction and slow spring regrowth of T85 pastures that were overseeded with cool-season forages and grazed during the cool-season. Reis et al. (2009) suggests that this reduction could be due to removal of bermudagrass cover and greater exposure to cold in late fall and early winter, to competition from cool-season species during bermudagrass regrowth in spring, or to grazing during early bermudagrass growth. Although dormant, bermudagrass survives on carbohydrates and other photosynthates accumulated during the previous growing season. Light requirements also are high for warm-season C_4 grasses particularly during the time when breaking dormancy (Long, 1999). The shading of the bermudagrass canopy by actively growing annual ryegrass along with root competition could have significant negative impact because of the higher photosynthetic rate and efficiency at high radiation associated with C_4 grasses like bermudagrass compared to C_3 forages (Nelson, 1995).

Most of the research looking at the transition from annual ryegrass to bermudagrass during early spring has been conducted in turf grass. Duble (1996) working with bermudagrass turf concluded that the major environmental factors affecting bermudagrass post-dormancy recovery are temperature, shade, moisture, soil conditions, competition, and traffic. In the same study, bermudagrass post-dormancy re-growth began when night time temperatures remained above 15.6°C for several days in the spring and soil temperature reached 17.8°C at the 10-cm depth. Green et al. (1998) studied seeded bermudagrass and reported that post-dormancy transition occurred naturally when soil and air temperatures were above 26.7°C, and perennial ryegrass roots began to decline.

These observations led to the formulation of the hypothesis that the presence of an overseeded cool-season forage in full production during the early spring significantly deprives bermudagrass emerging tillers of much needed sunlight during the spring which can delay soil warming and post-dormancy re-growth. Thus, late removal of the cool-season forage will retard and possibly compromise regrowth of the bermudagrass stand in the spring. As more producers are interested in overseeding T85 in Florida with cool-season annual forages, it is important to understand the effects of fall and winter harvesting management approaches on subsequent T85 bermudagrass regrowth. The objective of this study was to evaluate AR removal methods and AR removal dates on T85 forage persistence and production during spring and early summer.

Material and Methods

Study Site

This experiment was conducted from December to September for two seasons (2010-2011 and 2011-2012) at the Plant Science Research and Education Center in Citra, FL, (29º23’60’’ N, 82º12’0’’ W). For each season, a well-established, 2-year-old stand of T85 bermudagrass was used. At the site, the soils were from the Arredondo series (loamy, siliceous, hyperthermic Grossarenic Paleudults). At the beginning of the study, average soil pH was 6.4 and Mehlich 1 extractable P, K, Mg, and Ca concentrations were 90, 57, 43, and 600 mg kg^{-1}, respectively. The study was planted on a different site each year on the same soil type to avoid any residual effects from the previous year’s treatments. The pre-experimental period (November-February) in 2011 received 72% more rainfall (210 mm) than the same period in 2012 (122 mm). Average soil temperatures during this period were also much cooler than in 2012 (Table 4-1). The experimental period (March-April) in 2011 also received more rainfall (15.7%; 155 mm) than the experimental period in 2012 (134 mm). The average monthly soil temperatures were greater in 2012 than in 2011 from November through May. Relative to the summer period in 2011, 2012 could be considered a cooler and wetter year compared to 2011.

Experimental Procedures and Design

Treatments included the factorial combinations of three AR removal management methods [chemical, mechanical, and simulated grazing (hand removed)] and three AR removal dates starting the second week of March in each year [first week, Date 1; second week, Date 2, (Date 1 + 7d); and third week, Date 3, (Date 2 + 7d)]. In addition, there were two controls (AR not harvested, and T85 not overseeded with AR). The treatments were arranged in a split-plot design with three replications. Annual ryegrass removal dates were assigned to whole plots and AR removal management methods to sub plots (Figure 4-1).

Winter and Spring Defoliation Treatments

A timeline for field procedures in both years is provided to follow the chronological activities performed throughout the study (Figure 4-2 and 4-3). On 29 Nov. 2010 and 6 Dec. 2011 'Jumbo' AR was drilled into 0.18 ha of a 2-yr-old stand of dormant T-85 using a Sukup grain drill. Both years, AR was planted at a seeding rate of 35 kg ha^{-1} and received 40 kg of N and K_20 ha^{-1} at planting. Planting occurred in a different location within the field each year. In 2011 prior to treatment application, all overseeded AR was mowed on 17 January and 10 February using a flail chopper and fertilized with 40 kg of N ha^{-1} after each time. During 2012, plots were fertilized with 80 kg of N ha^{-1} split in two applications on 4 and 31 January. Lack of rain and high temperatures reduced AR growth and therefore AR was not harvested.

Each year, the 0.18-ha overseeded area of AR was subdivided into three equal sections. Each section was subdivided into three equal main plots, and each main plot was divided into three sub-plots of 4 x 4 m (16 m^2) and assigned to AR removal management methods. Treatments were imposed at corresponding defoliation dates. Specifically, simulated grazing treatments were imposed to 8-10 cm stubble height on each treatment defoliation date and every 15 d after that. The grazing simulation was conducted by manually gathering the leaves and tearing them. The grazing simulation mimicked the leaf wrapping action of the cow's tongue. Mechanical removal involved harvesting plots every 21 d to a ~ 5 cm stubble height using a sickle-bar mower. Chemically treated plots were sprayed with Cimarron Plus (metsulfuron-methyl + chlorsulfuron) at 35 g ha^{-1} using a CO_2 back pack sprayer when wind was calm. Annual ryegrass control plots were not harvested while spring defoliation treatments were being imposed. Tifton 85 control plots were not overseeded and were not harvested until the end of the spring trial.

Spring Data Collection

Herbage mass was sampled prior to defoliation at initial defoliation date and every 14 d for grazing, and every 21 d for mechanical defoliation. Two 0.25-m^2 quadrats per plot were clipped at 3-cm stubble height and samples were dried at 55°C for 48 h. The samples were composed of AR and T85 bermudagrass. Spring herbage accumulation for each treatment was calculated by summing across harvest dates. Tifton 85 and AR cover was estimated every 14 d for grazing and every 21 d for mechanical defoliation, using visual ratings each time before treatments were imposed by placing a 1-m^2 quadrat divided into 25 (20 x 20 cm) counting squares with ratings based on a 0 to 100 percent scale. In each plot two quadrat readings were recorded and then averaged. Tifton 85 and AR season cover averages were calculated by averaging all readings within a season for each experimental unit.

Indicators of T85 persistence included storage organ mass (root + rhizomes) and total non-structural carbohydrate (TNC) concentration. A soil core sample (40 x 20 x 20-cm) was taken from each plot at three times including the beginning of the trial (before treatments were imposed), 8 weeks after first AR defoliation, and at the end of the T85 bermudagrass growing season. The core samples were washed with water and separated into two fractions, specifically the above-ground stem base mass and below-ground root + rhizome. Samples were dried at 60ºC in a force-air dryer, weighed, and ground to pass a 1-mm screen using a Wiley mill prior to analysis of TNC concentrations. Storage organ TNC concentration was determined using a modification of the procedure of Christiansen et al. (1988) that was described in detail by Chaparro et al. (1996). Tifton 85 root-rhizome mass and TNC concentration are reported by season. Spring values correspond to averages of the first two samplings, and summer values correspond to the averages of the second and third samplings.

Canopy light interception was measured under the AR canopy between 1100 and 1400 h using a Delta-T SunScan device (Delta-T Devices, Cambridge, UK; Potter et al., 1996) at four sites per plot. Measurements were taken before each defoliation event during 8 wk. At each site, a 1-m-long probe was first held horizontally above the top of the canopy to record the amount of incident photosynthetically active radiation (PAR) and then the probe was inserted immediately underneath the canopy parallel to the ground and across rows of AR in a diagonal manner to record the amount of PAR reaching the probe. Percent light interception was calculated as the amount of intercepted light at soil level (total incident PAR minus PAR reaching the soil surface) divided by total incident PAR and then multiplied by 100. The light interception for a given plot was calculated as the average of the four sites and the number of harvest cycles per treatment.

Tifton 85 Bermudagrass Management

On 4 May 2011 and 28 April 2012 all plots in the experiment were staged at a 10-cm stubble height. Measurements on T85 were continued throughout the end of the summer season to evaluate the carry over effects of the treatments imposed during spring. All plots were harvested every 28 d using a sickle-bar mower by cutting a strip (0.8 x 4 m) at 15-cm stubble height. Fresh weights were measured, and subsamples of approximately 400 to 500 g were taken from the harvested material and dried at 60°C for 48 h for dry weight determination of herbage mass. Total summer herbage harvested was calculated by summing herbage harvested across harvests. Both years after each harvest, all plots received 40 kg of N ha^{-1}. The N source was NH_4NO_3. In 2011, the fertilizer was broadcast on 8 June, 7 July, 4 August, and 26 August. In 2012, the fertilizer was broadcast on 31 May, 28 June, 30 July, and 23 August.

Statistical Analyses

To determine the effects of AR removal date and removal management method on T85 regrowth, production, and persistence, data were analyzed by fitting mixed effects models using the PROC GLIMMIX procedure of SAS (SAS Inst. Inc., Cary, NC). Year, AR removal date, AR removal method, and their interactions were considered fixed effects with replicate and its interactions considered as random effects. Treatments were considered different at P values ≤ 0.05 and trends are reported for $P \leq 0.10$. When treatment x year interaction was significant, data were analyzed and reported by year. All data are reported as least squares means, and the PDIFF function of the LSMEANS procedure was used to compare differences.

Results and Discussion

Spring

Tifton 85 cover

Annual ryegrass removal date and AR removal method interacted with year (*P* < 0.02; Figure 4-4 and *P* < 0.01; Figure 4-5), therefore data were analyzed by year. In 2011, AR removal date had an effect on T85 cover (*P* < 0.05). Later ryegrass removal (Date 3; 29 March) had greater spring T85 cover compared to the earlier AR removal dates [Date 1 (15 March) and Date 2 (22 March)] during this year. In 2012, environmental conditions were different than those in 2011. A much warmer and drier winter resulted in a very thin and low producing ryegrass stand. Under these conditions, AR removal date had no effect on T85 cover. Despite colder ambient and soil temperatures during winter of 2011 that benefitted ryegrass production compared to 2012 (Table 4-1), the lower cover of T85 observed with earlier AR removal [Date 1 (15 March) and Date 2 (22 March)] could be attributed to colder soil and ambient temperatures present during the first two experimental dates. The colder environmental conditions, and to a lesser extent photoperiod length, likely delayed T85 regrowth such that early removal of AR had less impact than later removal of AR when environmental conditions favored T85 growth. As described by Sinclair et al. (2001) cool temperatures, low levels of solar radiation and low rainfall are among the environmental constraints that decreased growth of warm-season forage grasses during subtropical winters. It has been reported that short-daylength inhibited the growth under field conditions of bahiagrass and bermudagrass in central Florida (Sinclair et al., 2003; Newman et al., 2007). Esmaili and Salehi (2012) working with turf grasses reported that decreasing ambient temperature and photoperiod decreased dry matter (DM), shoot height, tiller density, and leaf area of bermudagrass.

Annual ryegrass removal management method had an effect on T85 cover in both years ($P < 0.01$). Overall, greater T85 cover was achieved in non-overseeded T85 as expected, and chemical removal had the greatest T85 percent cover compared to grazing and mechanical removal methods. However, grazing removal had better coverage compared to mechanical removal in 2011 but not in 2012. The interplant competition for light in these species appeared to be influenced most by differences in ryegrass stubble heights imposed in each removal method which influenced, to a great extent, the amount of light intercepted at soil level. For instance, Cudney et al. (1991) reported that wild oat (*Avena fatua* L.) reduced light penetration and growth of wheat (*Triticum aestivum*) by having greater height than wheat. When wild oat was clipped to the height of wheat, light penetration in a mixed canopy was similar to that in monoculture wheat. Lack of ryegrass competition by not overseeding or total plant elimination through herbicide application, increased the light environment in these two treatments. In addition, the advantage of simulated grazing vs. mechanical removal in the year with greatest AR growth and competition (2011) was likely a function of greater frequency of simulated grazing events (14 d) than mechanical defoliation events (21 d). This would be expected to reduce the overall average level of shading experienced by T85 in the simulated grazing treatment during the spring.

Ryegrass cover

Annual ryegrass removal method interacted with year ($P < 0.01$) therefore AR cover data were analyzed by year. When analyzed by year, AR removal date presented interaction with AR removal method in both years ($P < 0.01$). In 2011 the interaction occurred because ryegrass cover varied among removal methods in each removal date (Figure 4-6A). When chemically removed, Date 1 (15 March) showed the least amount of ryegrass cover compared with Date 2 (22 March) and Date 3 (29 March), which did not differ. Grazing removal of AR on Date 3 showed the least amount of ryegrass cover compared with Dates 1 and 2 which did not differ. Ryegrass cover in mechanical AR removal treatment decreased significantly from Date 1 (15 March) to Date 3 (29 March). In 2012, AR cover did not differ among dates within chemically treated plots. For grazed plots the amount of AR cover did not differ between Dates 1 (13 March) and 2 (20 March), but decreased in Date 3 (27 March). The amount of AR cover decreased significantly from Date 1 (13 March) to Date 3 (27 March) only for mechanically removed plots (Figure 4-6B).

Ryegrass cover was highly variable and subject to differing environmental conditions present throughout the experimental period as well as removal method. In terms of removal method, ryegrass cover was very susceptible to herbicide application which reduced it almost completely, providing the best method to reduce competition for light. Although, grazing and mowing were not as effective at eliminating AR compared to herbicide removal, these two AR removal methods reduced significantly AR cover.

Light interception

Light interception at soil level during the 8-wk trial was affected by the interactions of AR removal date and AR removal method with year ($P < 0.01$) therefore data were analyzed by year. Annual ryegrass removal date interacted with AR removal management method in 2011 ($P < 0.01$) (Figure 4-7). The interaction occurred because light interception varied among AR removal methods depending upon AR removal date. When AR was chemically removed, Date 3 (29 March) removal resulted in less light intercepted than Dates 2 (22 March) and 1 (15 March), which were not different. When grazing was used to remove AR, Date 2 (22 March) resulted in greater light intercepted compared with Dates 1 (15 March) and 3 (29 March), which did not differ. When mowing was used to remove AR, the amount of light intercepted was less at Date 3 (29 March) compared with Dates 1 (15 March) and 2 (22 Mar), which were not different from one another.

During 2012, AR removal date ($P < 0.05$) and AR removal management method ($P < 0.01$) affected light interception at soil level. Early removal (Date 1, 13 March) resulted in greater light intercepted at soil level compared with Date 3 (27 March), but it did not differ from Date 2 (20 March) (Figure 4-8). In addition, non-harvested T85 and chemically treated plots resulted in greater light interception at soil level compared with grazed, mowed, and non-removed AR treatments (Figure 4-9).

Differences in light interception at soil level were associated with differences in stubble heights, and also to the impact of those removal methods on ryegrass foliage characteristics. Indeed, plant height alone can often determine competitive outcome (Benjamin, 1984). Cudney et al. (1991) showed that wild oat (*Avena fatua* L.) reduced light penetration and growth of wheat (*Triticum aestivum*) by having greater height than wheat. When wild oat was clipped to the height of wheat, light penetration in a mixed canopy was similar to that in monoculture wheat. The short stubble heights in each removal method provided greater opportunity for T85 bermudagrass to compete for light and spread.

Annual ryegrass and Tifton 85 herbage accumulation

Removal method had a significant effect on herbage accumulation ($P < 0.01$). Grazing removal allowed the greatest herbage accumulation among all removal methods in the spring (Table 4-2). This result could be attributed to differences in residual stubble heights and defoliation frequencies of the different removal methods and controls in this study. It has been established that herbage production is inversely related to defoliation frequency in cut swards (Binnie and Chestnutt, 1991; Vinther, 2006). This explains the difference in herbage accumulation between non-harvested AR and 21-d harvest interval in mechanical treatment. However, results in this study show that removal through grazing resulted in greater herbage accumulation compared to non-removed AR and mechanical treatments. This outcome may be associated with the taller stubble height used for simulated grazing and the likely greater residual leaf area following defoliation events for this treatment than the mechanical treatment. Zarrough et al. (1983) evaluated the relationship between tiller density and forage yield of tall fescue (*Festuca arundinacea* Schreb.) and reported that increasing the cutting height from 5 to 10 cm did not affect tiller density but did increase yield/tiller and forage yield for the season. It is important to note that grazing treatments were simulated, and, as the season progressed, AR tiller density increased (although this variable was not quantified), ryegrass became more mature and lignified, challenging the grazing simulation.

Spring Tifton 85 root-rhizome mass

Spring T85 root-rhizomes in 2011 were approximately half the mass of those in 2012 (356 vs. 741 g m^2, respectively; Table 4-3). This difference is likely the result of the combination of an early thin stand of ryegrass and warmer ambient and soil temperatures in the 2012 winter, which resulted in early T85 regrowth in February. Early reports (Youngner, 1959) reference increasing bermudagrass root growth with increasing temperatures in the range from 10 to 23°C. It may be pertinent to mention that T85 remained actively growing for approximately 2 wk before a freeze event late in February in 2012.

Spring T85 root-rhizome mass was affected by AR removal method ($P < 0.01$). Greatest T85 root-rhizome mass occurred in non-overseeded T85, but surprisingly it was not different from non-removed AR treatments (Table 4-3). Annual ryegrass removal management methods did not differ and surprisingly were not different from the non-removed AR treatment. The lack of differences may be masked by the high root-rhizome mass obtained in non-removed AR plots during 2012.

Spring Tifton 85 root-rhizome TNC

Spring T85 root-rhizome TNC was affected by the interaction between year and AR removal management method ($P < 0.01$) (Table 4-4). The interaction occurred because during 2011 TNC concentration for non-removed AR was significantly lower compared to all removal management methods and non-overseeded T85, but during 2012 treatments were not different. The low root-rhizome TNC concentration in non-removed AR plots during 2011 was likely due to the shaded conditions created by the thick stand of AR. In a study of ‘Coastal’ bermudagrass by Burton et al. (1959) evaluating different degrees of shading, below-ground reserves decreased as shade increased from 29 to 64%.

Summer

Tifton 85 herbage accumulation

There was interaction of AR removal method with year ($P < 0.01$); therefore data were analyzed by year. In 2011, T85 herbage accumulation was greatest for chemical treated plots and not-harvested T85 plots and lowest for grazed and mowed plots and non-removed AR control plots (Table 4-2). In 2012, non-harvested T85 plots had the greatest accumulation compared with all overseeded treatments which were lower and not different among them. This outcome could be explained by lack of competition from AR root system for water and nutrients in the non-overseeded control. Although individual harvests are not reported, there was less Tifton 85 forage mass during the first two harvests when plots were overseeded compared to non-overseeded plots. Similar findings of low initial herbage mass when T85 was overseeded with cool-season grasses have been reported (Reis et al., 2009; Muir and Bow, 2011).

Tifton 85 root-rhizome mass

Summer T85 root-rhizome mass had year by AR removal method interaction (P < 0.05). During 2011 greater T85 root-rhizome mass was associated with the non-overseeded T85 treatment (Table 4-3). In 2012, T85 root-rhizome mass did not differ among AR removal methods or control plots.

Tifton 85 root-rhizome TNC

Tifton 85 root-rhizome TNC concentration in summer was affected by year (P < 0.05) and also presented a trend toward an effect for AR removal method (P = 0.09). In 2011, TNC root-rhizome concentrations were greater than in 2012 (69 vs. 62 g kg^{-1}, respectively; Table 4-4). When analyzing the 2 yr together, the lowest T85 root-rhizome TNC concentrations were associated with non-removed AR treatments during the spring, and the greatest TNC concentration in T85 root-rhizomes when AR was chemically removed. This lower TNC concentration in the non-removed AR treatment is likely associated with an extended period of early shading of T85.

Total-Season Herbage Accumulation

Year by AR removal management method interaction (P < 0.05) had an effect on total-season herbage accumulation. The interaction occurred because in 2011, chemical and grazing AR removal were better in terms of herbage accumulation than not removing AR whereas in 2012, chemical removal was worse than not removing AR. As previously discussed for spring and summer seasons, weather conditions and AR removal management method in each season affected total-season herbage accumulation. Although AR overseeding showed a decrease in early T85 herbage accumulation, the overall impact of this AR overseeding practice is a major contributor to the total season herbage accumulation.

Research Implications

During the 2-yr study, AR removal date affected spring T85 accumulation only in the year (2011) when AR established well and formed thick stands. The combination of well-established AR and warm spring temperatures will require early removal of AR to favor T85 bermudagrass rapid regrowth during spring. The AR removal method did have a significant impact on T85 percent cover during spring. Tifton 85 cover was greatest when AR was removed chemically followed by grazing and mowing removal methods. Annual ryegrass spring cover had a significant effect on the light environment at soil level; in overseeded treatments greatest light interception was achieved when competition was removed chemically.

Tifton 85 root-rhizome mass and TNC concentration were affected by removal method only during the spring when cool spring temperatures and a solid ryegrass cover occurred (2011). Thus, there was a seasonal trend in root-rhizome TNC concentrations. Lower TNC values were associated with AR not being removed during spring. However, one year suggests detrimental effects when T85 was overseeded with AR, but this could not be corroborated in the second year. Likely, this was due to relatively poor stands of AR during the second year (2012) that did not exert the same level of competition with T85 as observed in the first year.

Spring herbage accumulation was strongly affected by removal method. The simulated grazing removal method resulted in greater herbage accumulation compared with other methods. During summer 2011, reduced early T85 herbage production was observed when AR was grazed, mowed, or not removed during spring time. However, in 2012 all overseeded treatments caused a reduction in T85 herbage accumulation compared to non-overseeded management. Total-season herbage accumulation in 2011 was less when AR was not removed compared to other AR removal management methods. This effect was less prominent in 2012 likely associated to the lack of early competition from AR. Year 2011 presented rainfall and temperature conditions that favored AR growth compared to 2012.

Overall, data obtained in this study support the use of AR overseeding in T85 bermudagrass pastures but AR removal in late winter and spring is required. Longer term evaluation is needed to corroborate the early removal effects on bermudagrass spring growth. Additionally, removal method will affect T85 regrowth during early spring; therefore selection of removal method is important. Annual ryegrass removal either by grazing every 14-d or mowing every 21-d is recommended to guarantee adequate T85 regrowth. However, if growing conditions favor AR growth and early T85 regrowth in spring is preferred, chemical removal of AR is recommended.

Table 4-1. Monthly rainfall and minimum (Min), maximum (Max), and average (Avg) ambient and soil temperatures at Plant Science Research and Education Unit in Citra, Florida.

Months	2010 – 2011							2011 – 2012						
	Rainfall	Ambient temperature			Soil temperature			Rainfall	Ambient temperature			Soil temperature		
		Min	Max	Avg	Min	Max	Avg		Min	Max	Avg	Min	Max	Avg
	mm	-------------------------°C----------------------						mm	------------------------°C----------------------					
November	15	0.9	30.7	16.8	14.8	27.5	20.6	47	-1.3	31.1	17.2	15.1	25.4	20.2
December	25	-6.8	25.6	8.3	7.0	23.0	14.2	6	1.6	29.5	15.6	13.2	22.6	18.2
January	117	-4.8	26.0	11.4	9.0	19.8	14.6	19	-7.2	29.6	13.1	10.1	21.9	16.2
February	53	-0.9	30.3	15.7	10.2	25.8	18.0	50	-6.3	29.6	16.6	10.3	24.5	18.9
Pre-trial Total	**210**							**122**						
March	95	0.2	32.7	18.2	14.1	27.0	21.6	33	1.1	31.5	20.2	15.6	29.3	23.2
April	60	3.8	34.7	22.1	16.3	31.1	25.1	101	6.1	33.9	21.4	17.1	32.7	26.0
Spring-trial Total	**155**							**134**						
May	42	10.7	37.8	24.4	21.6	35.1	28.5	106	13.4	35.6	24.5	22.9	36.5	28.9
June	126	15.6	39.8	27.2	26.2	36.4	30.5	381	16.6	34.8	25.5	23.6	37.0	29.5
July	75	17.9	39.2	27.5	26.2	37.1	30.7	149	19.0	35.8	26.7	22.1	37.1	30.5
August	166	21.5	38.9	28.1	26.3	36.8	30.6	287	18.0	35.0	26.1	24.1	34.1	28.4
September	99	16.9	36.2	25.7	25.9	34.0	28.9	119	14.0	34.6	25.3	22.7	32.1	27.2
Summer-trial Total	**508**							**1042**						

Table 4-2. Spring, summer, and total-season herbage accumulation of annual ryegrass (AR) and Tifton 85 bermudagrass in response to AR removal management method during 2011 and 2012.

Effect	Spring†				Summer‡		Total-season§	
	2011	2012	Mean¶	SE	2011	2012	2011	2012
	-------------------------------Mg DM ha^{-1}							
Removal management method								
Chemical	1.9	1.8	1.8 d	0.2	13.6 a	8.6 b	15.5 a	10.4 c
Grazing	4.5	4.5	4.3 a		10.4 bc	8.0 b	14.9 ab	12.1 a
Mowing	3.1	2.7	2.9 c		10.1 c	8.1 b	13.2 bc	10.8 bc
Controls								
Non-overseeded T85	0.8	1.1	1.0 e		12.1 ab	10.3 a	12.8 bc	11.4 abc
Non-removed AR	3.5	3.4	3.4 b		8.5 c	8.4 b	11.9 c	11.8 ab
SE					0.7	0.5	0.9	0.5

† Significant effects: annual ryegrass removal management method ($P < 0.05$)
‡ Significant effects: Year by AR removal management method ($P < 0.05$); annual ryegrass removal management method 2011 and 2012 ($P < 0.05$). Within columns, means followed by the same letter are not significantly different ($P < 0.05$)
§ Significant effects: Year by AR removal management method ($P < 0.05$); annual ryegrass removal management method 2011 and 2012 ($P < 0.05$). Within columns, means followed by the same letter are not significantly different ($P < 0.05$)
¶ Removal method means across years periods and AR removal dates. Within columns, means followed by different letter are significantly different ($P < 0.05$)

Table 4-3. Spring and summer Tifton 85 bermudagrass root-rhizome mass in response to annual ryegrass (AR) removal method during 2011 and 2012.

Effect	Spring†				Summer‡	
	2011	2012	Mean§	SE	2011	2012
	---g m⁻²				---	
Removal management method						
Chemical	245	682	463 b	65	453 b	701
Grazing	347	632	490 b		295 b	777
Mowing	248	737	493 b		326 b	790
Controls						
Non-overseeded T-85	592	816	704 a		772 a	816
Non-removed AR	345	839	592 ab		401 b	813
Mean¶	356 b	741 a				
SE	52				75	72

† Significant effects: year and AR removal management method (*P* < 0.05)

‡ Significant effects: Year by AR removal management method (*P* < 0.05); removal management method 2011 (*P* < 0.05). Within columns, means followed by the same letter are not significantly different (*P* < 0.05)

§ Annual ryegrass removal management method means across years and AR removal dates. Within columns, means followed by the same letter are not significantly different (*P* < 0.05)

¶ Annual ryegrass removal management method means across years and AR removal dates. Means followed by different letter are significantly different (*P* < 0.05)

Table 4-4. Spring and summer Tifton 85 bermudagrass total non-structural carbohydrates (TNC) concentration in response to annual ryegrass (AR) removal method during 2011 and 2012.

Effect	Spring†		Summer‡			
	2011	2012	2011	2012	Mean§	SE
	------------------------------------g kg^{-1}------------------------------------					
Removal management method						
Chemical	49 a	38	76	68	72 a	3.7
Grazing	44 a	38	72	63	68 ab	
Mowing	46 a	39	70	65	67 ab	
Controls						
Non-overseeded T-85	53 a	38	67	59	63 ab	
Non-removed AR	22 b	37	60	57	58 b	
Mean¶			69 a	62 b		
SE	5.3	1.3	2.3			

† Significant effects: Year by AR removal management method ($P < 0.05$); annual ryegrass removal method 2011 ($P < 0.05$). Within columns, means followed by the same letter are not significantly different ($P < 0.05$)
‡ Significant effects: Year ($P < 0.05$) and AR removal management method ($P < 0.10$)
§ Annual ryegrass removal method means across years and AR removal dates. Within columns, means followed by the same letter are not significantly different ($P < 0.05$)
¶ Year means AR removal management methods and AR removal dates. Means followed by different letter are significantly different ($P < 0.05$)

Rep			C-T85			C-T85				C-T85	
I	G	M	H	C-AR	H	G	M	C-AR	H	G	M
II	H	G	M	C-AR	G	M	H	C-AR	G	H	M
III	M	G	H	C-AR	H	G	M	C-AR	M	H	G
		C-T85				C-T85			C-T85		

Date 1 **Date 2** **Date 3**

Figure 4-1. Experimental layout. Within a replicate (indicated in roman numeral) AR removal date is the main plot. Ryegrass removal management method [chemical, H; mechanical, M; simulated grazing, G; plus, controls (non-harvested T85, C-T85; non-removed AR, C-AR)] are the subplots. Each square equals 16 m2.

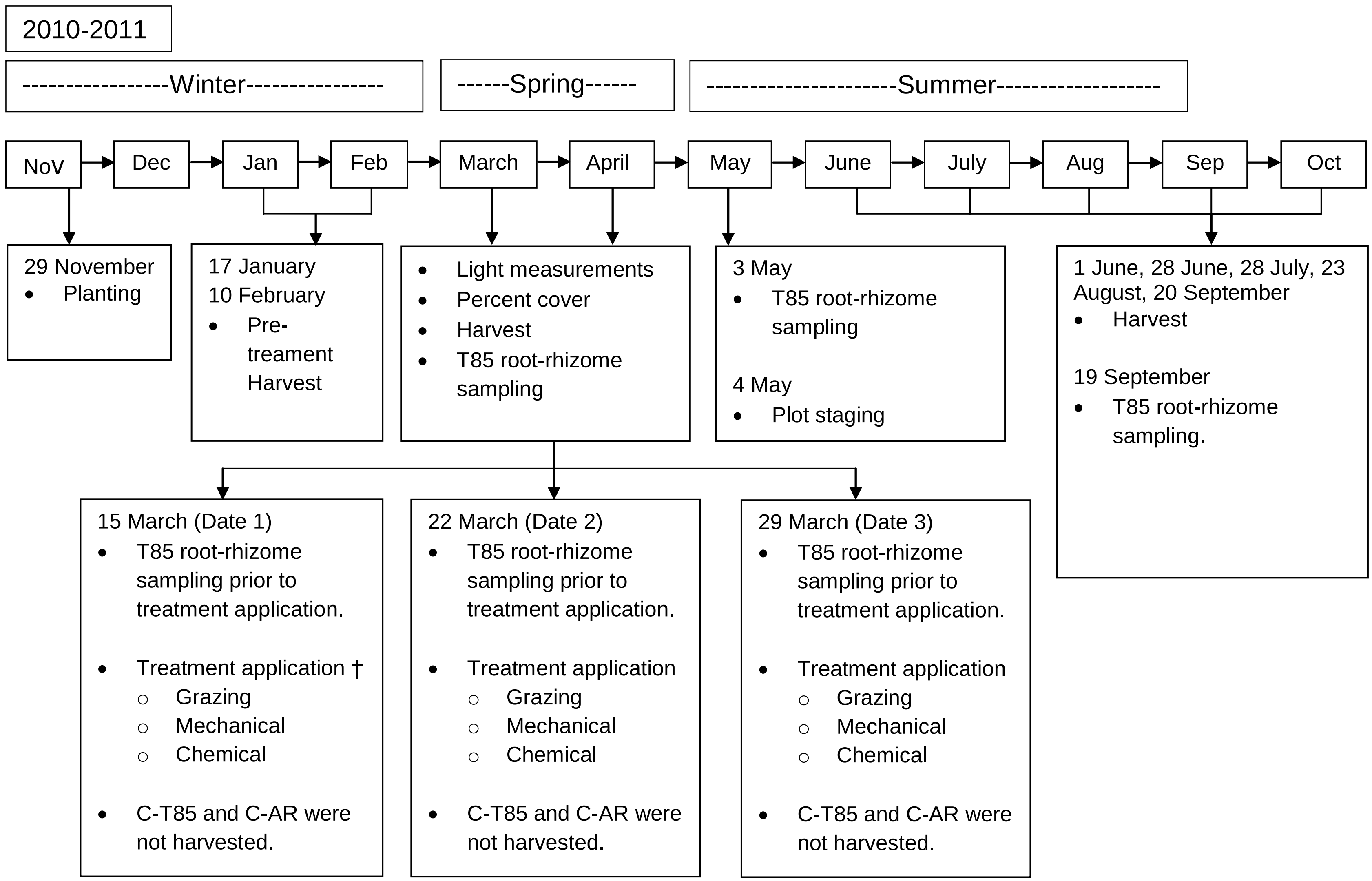

Figure 4-2. Experimental time line season 2010-2011. † Treatments were imposed at corresponding defoliation date, and every 14 d for grazing, and every 21 d for mechanical defoliation

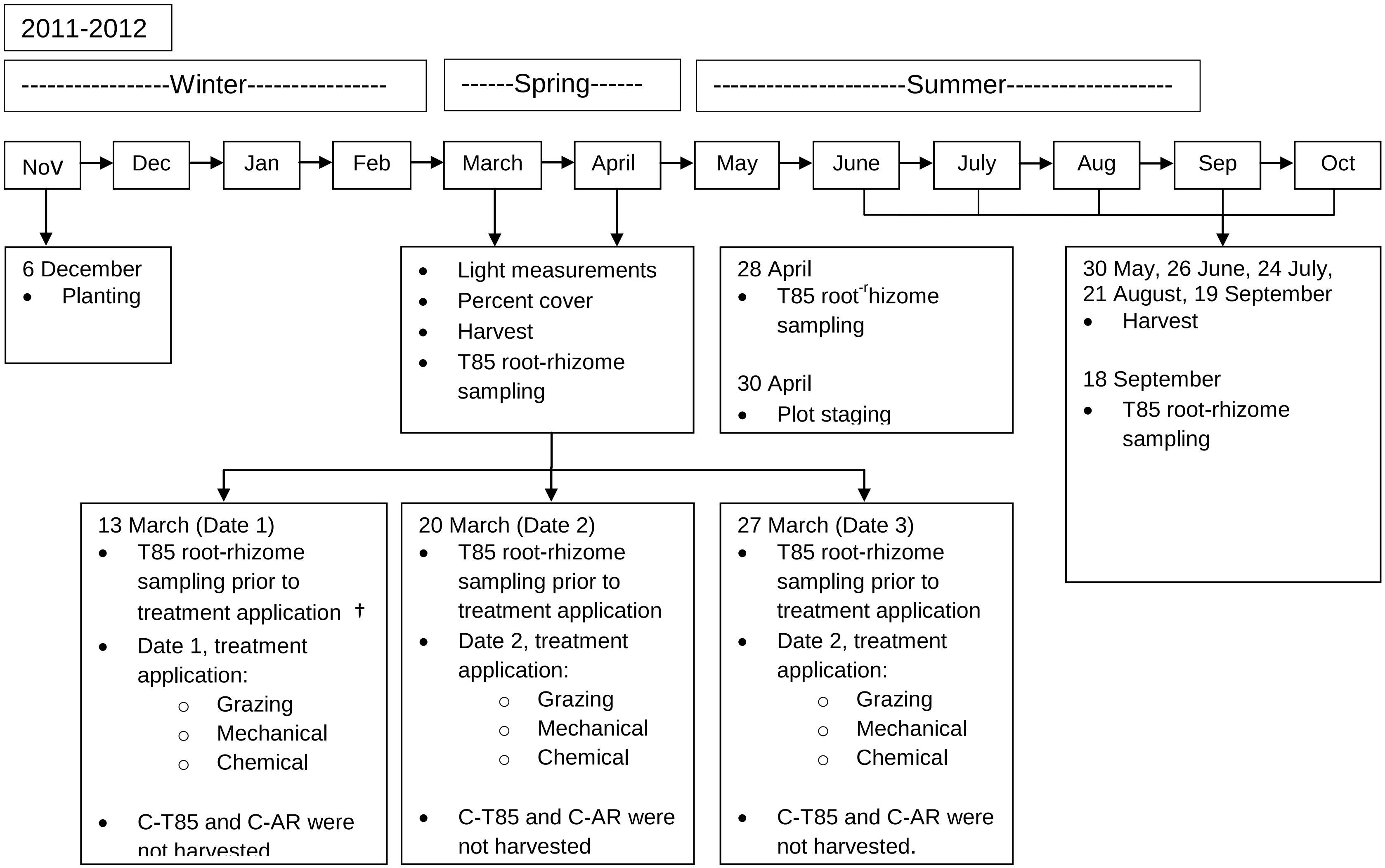

Figure 4-3. Experimental time line season 2011-2012. † Treatments were imposed at corresponding defoliation date, and every 14 d for grazing, and every 21 d for mechanical defoliation

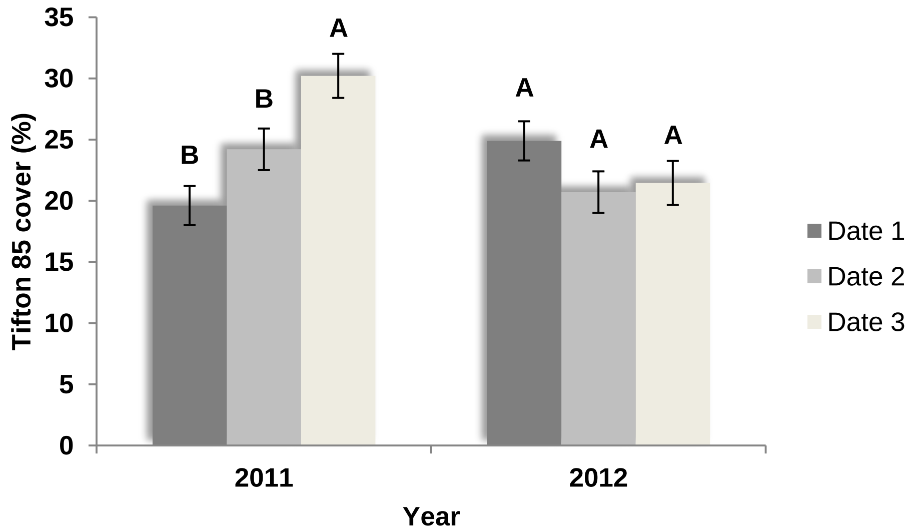

Figure 4-4.Year x AR removal date interaction effect on spring Tifton 85 cover ($P < 0.05$). Removal date effect within year; same letter are not significantly different ($P > 0.05$).

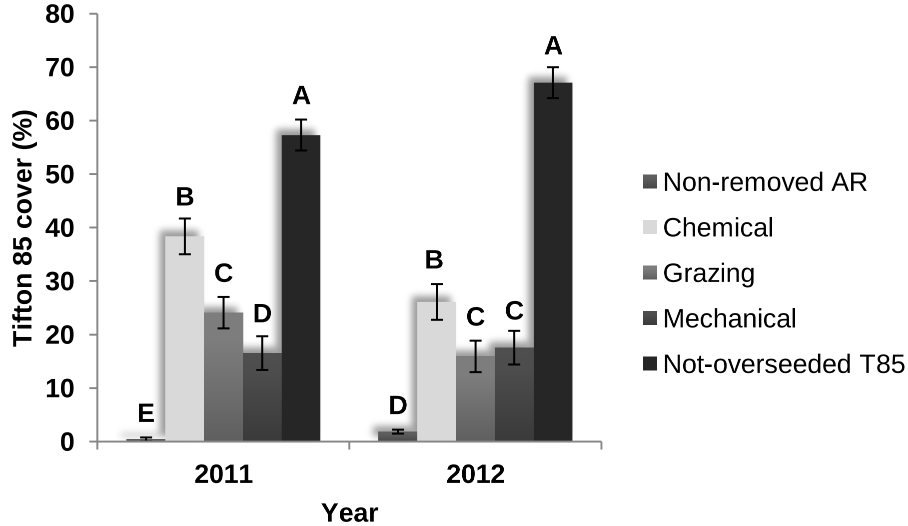

Figure 4-5. Year x AR removal management method interaction effect on spring Tifton 85 cover ($P < 0.01$). Removal management method within year; same letter are not significantly different ($P > 0.05$).

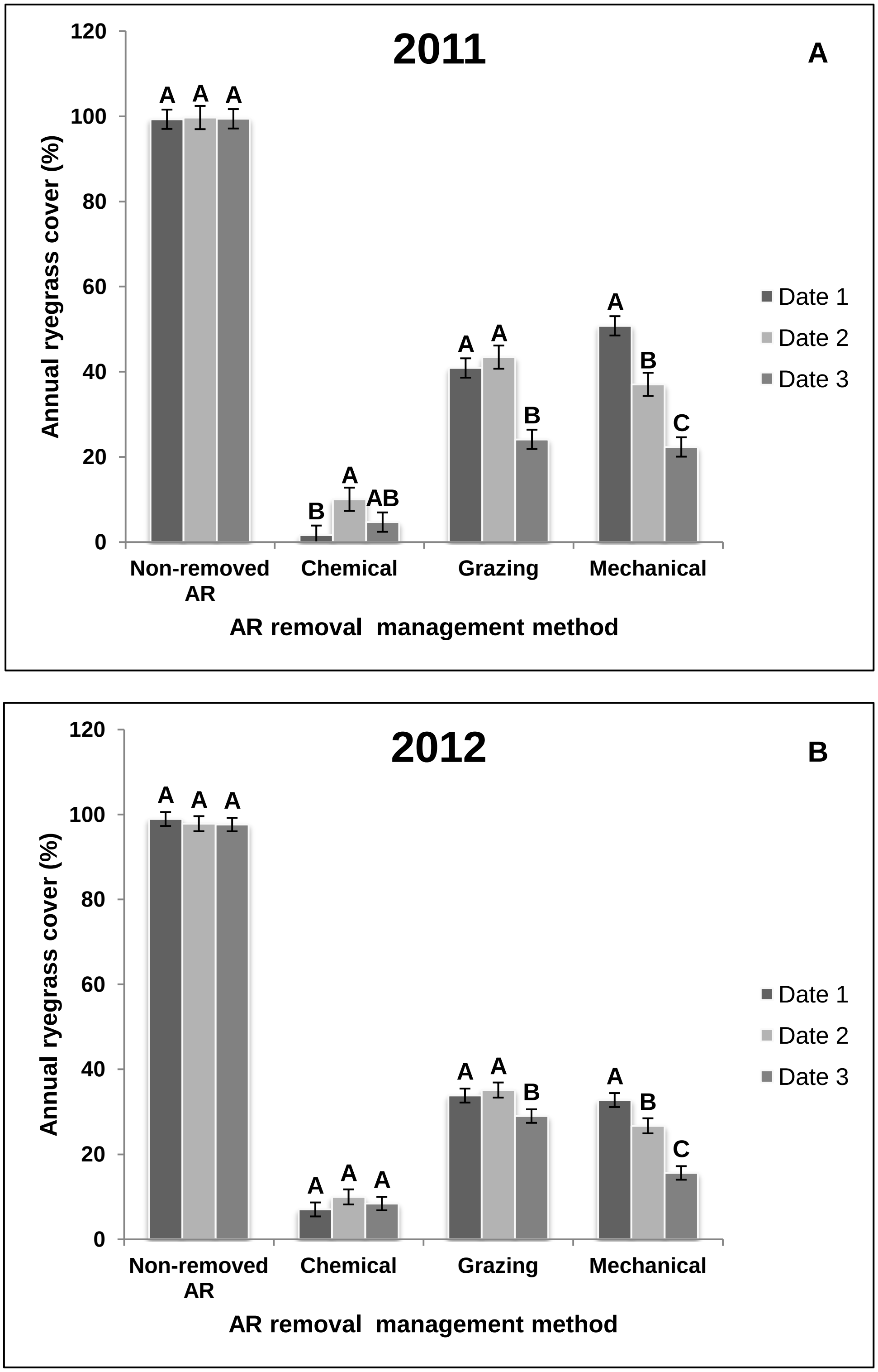

Figure 4-6. Annual ryegrass removal date x AR removal management method interaction effect on annual ryegrass cover ($P < 0.01$) in 2011 (A) and 2012 (B). Date effect within method; same letter are not significantly different ($P > 0.05$).

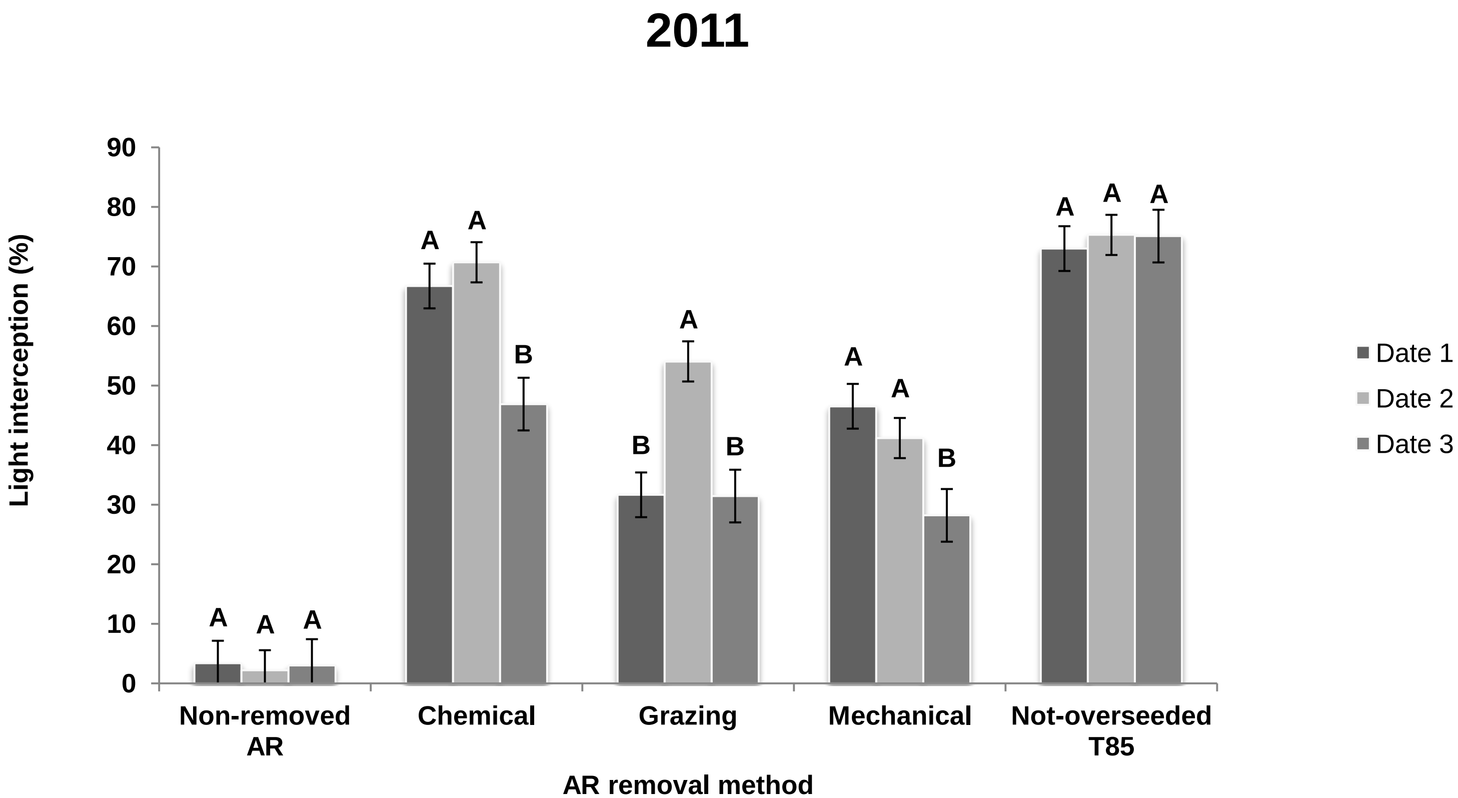

Figure 4-7. Annual ryegrass removal date x AR removal management method interaction effect on light interception ($P < 0.01$). Date effect within method; same letter are not significantly different ($P > 0.05$).

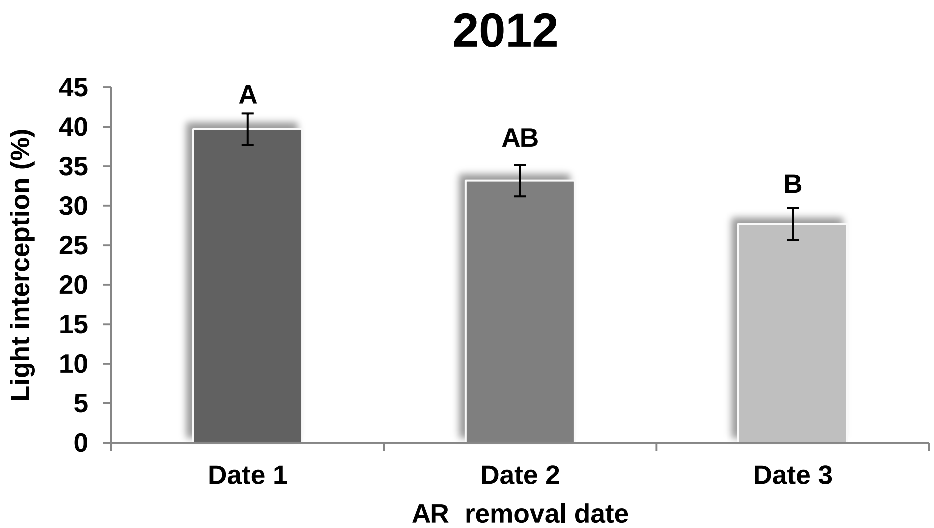

Figure 4-8. Annual ryegrass removal date effect on light interception at soil level (P < 0.05). Same letter are not significantly different (P > 0.05).

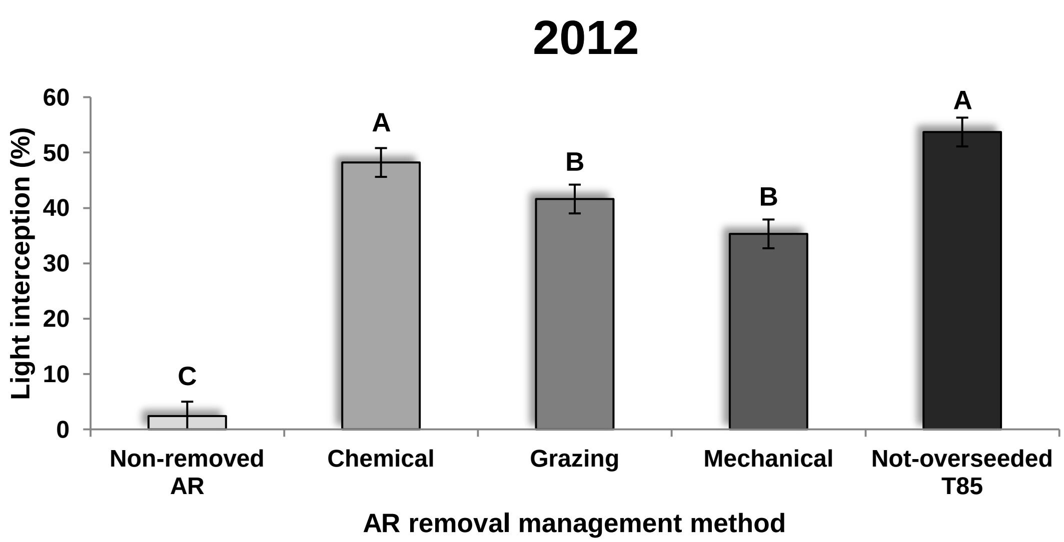

Figure 4-9. Annual ryegrass removal management effect on light interception at soil level (P < 0.01). Same letter are not significantly different (P > 0.05).

CHAPTER 5
SUMMARY AND CONCLUSIONS

Tifton 85 bermudagrass (*Cynodon* spp) is a warm-season perennial grass. It has been considered to be among the most important grasses in the southeastern USA for grazing dairies. Many studies have evaluated grazing management practices of Tifton 85, showing its superior quality, and herbage production. Florida dairy producers have been challenged to search for new ways to reduce costs due to the economics involved with confinement dairy farming. As a result, interest in pasture-based systems has increased and many dairy farmers have transitioned partially or totally to grazing operations with the goal to remain profitable. Most of the research in pasture-based systems has been done with lactating dairy cows and information regarding grazing management strategies on a pasture-based system for growing heifers is limited. Also, despite production of Tifton 85 during the summer months, if used as the only pasture species it results in a shortage of forage during the cool-season months. Conditions in the region allow for overseeding of cool-season forage crops during winter months such as annual ryegrass. While overseeding annual ryegrass into bermudagrass pastures may extend the production window; the spring transition from annual ryegrass to Tifton 85 bermudagrass can be difficult and inconsistent due to growth overlapping of annual ryegrass at time of Tifton 85 bermudagrass spring emergence. The objectives of this research were to evaluate rotationally stocked Tifton 85 bermudagrass pastures (14 and 21 rest period) under two supplementation strategies (0.64 and 0.96 % of BW) on dairy heifer performance and sward characteristics. Additionally, to evaluate the factorial combination of three ryegrass removal dates (early March, D1; mid March, D2; and late

March, D3) and three removal methods (chemical, H; mechanical, M; and simulated grazing, G) on regrowth of Tifton 85 bermudagrass.

Tifton 85 grazing study

During the 2-yr study, different rates of supplement fed to dairy heifers grazing Tifton 85 pastures did not affect nutritive value of the forage nor Tifton 85 pre-graze herbage mass. Herbage accumulation in 2010 was affected by SUP. Lowest herbage accumulation occurred when dairy heifers were fed at a high supplementation rate. Herbage accumulation was affected by RP in 2011, and greater herbage accumulation was associated with shorter RP. Herbage allowance was lower in the high SUP rate, as a result of greater number of put-and-take heifers, and therefore SR was greater in those pastures treatments. Additionally, the low herbage allowances in 2011 appeared to negatively impact ADG, especially in the low SUP treatments. This could be attributed to the high stocking rate maintained in 2011.

Greater SR and gain per hectare were achieved under high supplementation rate. Average daily gain had a trend toward an effect for both, RP and SUP treatments. Greater ADG was associated with shorter RP and higher SUP rates.

Blood urea N concentrations did not differ among RP treatments. However, slightly greater BUN concentrations were associated with feeding more concentrate in 2011 compared to 2010. This can be explained by the differences in CP concentration in concentrates fed both years.

Although targeted ADG of 0.7 kg was not achieved, data obtained in this study support the use of Tifton 85 for raising dairy heifers under rotational stocking when grazed either at 14- or 21-d and supplemented at 0.96% of BW. Additionally, even though Tifton 85 is able to maintain high stocking rates and achieve high gains per unit of land area as reported in the literature, data in this study from year 2011 suggests that average stocking rates beyond 10 AU are not conducive to adequate gains, and therefore should be avoided.

Annual ryegrass competition study

During the 2-yr study, AR removal date affected spring T85 accumulation only in the year (2011) when AR established well and formed thick stands. The combination of well-established AR and warm spring temperatures will require early removal of AR to favor T85 bermudagrass rapid regrowth during spring. The AR removal method did have a significant impact on T85 percent cover during spring. Tifton 85 cover was greatest when AR was removed chemically followed by grazing and mowing removal methods. Annual ryegrass spring cover had a significant effect on the light environment at soil level; in overseeded treatments greatest light interception was achieved when competition was removed chemically.

Tifton 85 root-rhizome mass and TNC concentration were affected by removal method only during the spring when cool spring temperatures and a solid ryegrass cover occurred (2011). Thus, there was a seasonal trend in root-rhizome TNC concentrations. Lower TNC values were associated with AR not being removed during spring. However, one year suggests detrimental effects when T85 was overseeded with AR, but this could not be corroborated in the second year. Likely, this was due to relatively poor stands of AR during the second year (2012) that did not exert the same level of competition with T85 as observed in the first year.

Spring herbage accumulation was strongly affected by removal method. The simulated grazing removal method resulted in greater herbage accumulation compared with other methods. During summer 2011, reduced early T85 herbage production was observed when AR was grazed, mowed, or not removed during spring time. However, in 2012 all overseeded treatments caused a reduction in T85 herbage accumulation compared to non-overseeded management. Total-season herbage accumulation in 2011 was less when AR was not removed compared to other AR removal management methods. This effect was less prominent in 2012 likely associated to the lack of early competition from AR. Year 2011 presented rainfall and temperature conditions that favored AR growth compared to 2012.

Overall, data obtained in this study support the use of AR overseeding in T85 bermudagrass pastures but AR removal in late winter and spring is required. Longer term evaluation is needed to corroborate the early removal effects on bermudagrass spring growth. Additionally, removal method will affect T85 regrowth during early spring; therefore selection of removal method is important. Annual ryegrass removal either by grazing every 14-d or mowing every 21-d is recommended to guarantee adequate T85 regrowth. However, if growing conditions favor AR growth and early T85 regrowth in spring is preferred, chemical removal of AR is recommended.

APPENDIX A
DATA TABLES A

Table A-1. Levels of probability (*P*) for the effects of year, rest period (RP), supplementation ratel (SUP), and their interactions on Tifton 85 bermudagrass pre-graze herbage mass, post-graze herbage mass, herbage accumulation, herbage allowance, crude protein (CP) and in vitro organic matter digestibility (IVOMD) .

Effect	Pre-graze HM	Post-graze HM	Herbage accumulation	Herbage allowance	CP	IVOMD
RP	0.172	0.504	0.087	0.409	0.001	0.051
SUP	0.405	0.688	0.085	0.002	0.564	0.414
Year	0.001	<0.001	0.062	<0.001	<0.001	0.072
RP x SUP	0.920	0.874	0.507	0.745	0.201	0.729
Year x RP	0.458	0.664	0.005	0.651	0.507	0.416
Year x SUP	0.641	0.162	0.004	0.482	0.863	0.363
Year x RP x SUP	0.455	0.567	0.008	0.164	0.358	0.092

Table A-2. Levels of probability (*P*) for the effects of year, rest period (RP), supplementation rate (SUP), and their interactions on Tifton 85 bermudagrass average daily gain (ADG), blood urea nitrogen (BUN), stocking rate (SR) and live weight gain per hectare (LWG ha^{-1}).

Effect	ADG	BUN	SR	LWG ha^{-1}
RP	0.074	0.627	0.118	0.725
SUP	0.074	0.390	0.006	0.024
Year	0.021	<0.001	0.002	<0.001
RP x SUP	0.750	0.852	0.732	0.829
Year x RP	0.750	0.413	0.075	0.578
Year x SUP	0.054	0.020	0.320	0.363
Year x RP x SUP	0.915	0.272	0.961	0.867

Table A-3. Regression equations and associated r-square values for predicting Tifton 85 bermudagrass herbage mass (kg ha^{-1}) from disk settling height (cm) during the grazing seasons of 2010, and 2011.

Grazing season	Treatment (RP-SL)	Equation			
		Pre-graze	r-square	Post-graze	r-square
			2010		
Early	14-High	y = 184.14x - 641.28	0.82	y = 108.19x + 477.31	0.78
	14-Low	y = 197.35x - 1506.5	0.90	y = 124.92x - 271.44	0.85
	21-High	y = 162.01x + 198.27	0.75	y = 127.13x + 454.62	0.87
	21-Low	y = 222.03x - 1504.9	0.82	y = 117.37x + 709.42	0.80
Middle	14-High	y = 121.94x + 1606.8	0.85	y = 201.79x + 127.32	0.83
	14-Low	y = 162.95x + 1755.7	0.85	y = 103.52x + 1031.6	0.91
	21-High	y = 100.88x + 1496.5	0.80	y = 369.80x - 1790.6	0.95
	21-Low	y = 246.44x - 321.46	0.80	y = 218.39x - 791.77	0.90
Late	14-High	y = 221.83x - 278.59	0.85	y = 140.62x + 231.55	0.81
	14-Low	y = 331.16x - 1018.1	0.77	y = 147.47x + 912.29	0.79
	21-High	y = 239.44x + 41.11	0.90	y = 151.38x + 552.62	0.88
	21-Low	y = 249.47x - 560.94	0.79	y = 155.01x - 51.078	0.82
			2011		
Early	14-High	y = 183.07x - 554.88	0.85	y = 181.47x - 746.01	0.86
	14-Low	y = 92.276x + 822.94	0.76	y = 143.52x - 227.27	0.69
	21-High	y = 100.43x + 363.67	0.79	y = 176.20x - 463.23	0.69
	21-Low	y = 204.44x - 815.64	0.95	y = 268.23x - 1529.7	0.83
Middle	14-High	y = 140.54x + 1095	0.73	y = 271.93x - 1926.4	0.69
	14-Low	y = 282.44x - 1848.8	0.81	y = 196.49x - 1016.9	0.83
	21-High	y = 312.20x - 2385.6	0.81	y = 154.00x - 1042	0.76
	21-Low	y = 216.56x - 1017.2	0.88	y = 145.71x - 618.57	0.77
Late	14-High	y = 320.83x - 2154.9	0.74	y = 167.08x - 560.35	0.71
	14-Low	y = 289.93x - 2011.4	0.85	y = 283.95x - 2234.4	0.82
	21-High	y = 352.69x - 3007.2	0.85	y = 35.831x + 550.61	0.73
	21-Low	y = 333.42x - 3007.5	0.91	y = 201.88x - 1024	0.72

Table A-4. Number of grazing cycles during the grazing seasons of 2010 and 2011.

Rest Period	2010		2011	
	Supplement level		Supplement level	
	High	Low	High	Low
d	---------------------------Number of grazing cycles---------------------------			
14	5	5	4	4
21	4	4	3	3

Table A-5. Levels of probability (*P*) by year for the effects of rest period (RP), supplementation rate (SUP), and their interactions on Tifton 85 bermudagrass pre-graze herbage mass, post-graze herbage mass, and herbage accumulation.

Effect	Pre-graze HM		Post-graze HM		Herbage accumulation		Herbage allowance	
	2010	2011	2010	2011	2010	2011	2010	2011
RP	0.243	0.168	0.254	0.839	0.372	0.011	0.627	0.519
SL	0.904	0.020	0.247	0.053	0.047	0.131	0.005	0.117
RP x SUP	0.809	0.835	0.469	0.434	0.102	0.064	0.204	0.382

Table A-6. Levels of probability (*P*) by year for the effects of rest period (RP), supplementation rate (SUP), and their interactions on Tifton 85 bermudagrass crude protein (CP), and in vitro organic matter digestibility (IVOMD).

Effect	CP		IVOMD	
	2010	2011	2010	2011
RP	0.008	0.050	0.348	0.097
SUP	0.779	0.566	0.940	0.297
RP x SUP	0.130	0.782	0.273	0.220

Table A-7. Levels of probability (*P*) by year for the effects of rest period (RP), supplementation rate (SUP), and their interactions on Tifton 85 bermudagrass average daily gain (ADG), blood urea nitrogen (BUN), stocking rate (SR) and live weight gain per hectare (LWG ha^{-1}).

Effect	ADG		BUN		SR		LWG ha^{-1}	
	2010	2011	2010	2011	2010	2011	2010	2011
RP	0.243	0.168	0.254	0.839	0.020	0.883	0.914	0.296
SUP	0.904	0.020	0.247	0.053	0.045	0.079	0.380	0.014
RP x SUP	0.809	0.835	0.469	0.434	0.667	0.882	0.844	0.952

APPENDIX B
DATA TABLES B

Table B-1. Levels of probability (*P*) for the effects of year, removal date, removal method, and their interactions on Tifton 85 bermudagrass spring cover, Annual ryegrass spring cover and light interception.

Effect	Spring Cover		Light Interception
	Tifton 85	Annual Ryegrass	
Date	0.162	0.031	0.031
Method	<0.001	<0.001	<0.001
Year	0.953	0.032	0.001
Date x Method	0.203	<0.001	0.003
Year x Date	0.032	0.364	0.001
Year x Method	<0.001	0.001	0.001
Year x Date x Method	0.248	0.439	0.002

Table B-2. Levels of probability (*P*) by year for the effects of removal date, removal method, and their interactions on Tifton 85 bermudagrass spring cover, Annual ryegrass spring cover and light interception.

Effect	Spring Cover				Light interception	
	Tifton 85		Annual Ryegrass			
	2011	2012	2011	2012	2011	2012
Date	0.040	0.134	0.071	0.139	0.047	<0.028
Method	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Date x Method	0.462	0.575	0.001	0.002	<0.001	0.169

Table B-3. Levels of probability (*P*) for the effects of year, removal date, removal method, and their interactions on spring, summer and total season herbage accumulation.

Effect	Herbage Accumulation		
	Spring	Summer	Total Season
Date	0.274	0.571	0.434
Method	<0.001	<0.001	0.061
Year	0.168	0.001	<0.001
Date x Method	0.212	0.986	0.922
Year x Date	0.516	0.285	0.461
Year x Method	0.262	0.003	0.020
Year x Date x Method	0.197	0.898	0.834

Table B-4. Levels of probability (P) by year for the effects of removal date, removal method, and their interactions on spring and summer herbage accumulation.

Effect	Herbage Accumulation			
	Spring		Summer	
	2011	2012	2011	2012
Date	0.475	0.008	0.408	0.882
Method	<0. 001	<0.001	<0.001	0.008
Date x Method	0.073	0.124	0.876	0.977

Table B-5. Levels of probability (*P*) for the effects of year, removal date, removal method, and their interactions on spring and summer Tifton 85 root-rhizome mass.

Effect	Tifton 85 Root-rhizome Mass	
	Spring	Summer
Date	0.110	0.742
Method	0.008	0.007
Year	<0.001	<0.001
Date x Method	0.715	0.541
Year x Date	0.446	0.288
Year x Method	0.203	0.021
Year x Date x Method	0.859	0.982

Table B-6. Levels of probability (*P*) by year for the effects of removal date, removal method, and their interactions on spring and summer Tifton 85 root-rhizome mass.

Effect	Tifton 85 Root-rhizome Mass			
	Spring		Summer	
	2011	2012	2011	2012
Date	0.760	0.182	0.273	0.815
Method	0.011	0.208	<0.001	0.793
Date x Method	0.938	0.690	0.761	0.843

Table B-7. Levels of probability (*P*) for the effects of year, removal date, removal method, and their interactions on spring and summer Tifton 85 root-rhizome total non structural carbohydrates (TNC).

Effect	Tifton 85 TNC	
	Spring	Summer
Date	0.320	0.644
Method	0.001	0.086
Year	0.060	0.048
Date x Method	0.742	0.611
Year x Date	0.410	0.960
Year x Method	0.002	0.980
Year x Date x Method	0.328	0.437

Table B-8. Levels of probability (*P*) by year for the effects of removal date, removal method, and their interactions on spring and summer Tifton 85 root-rhizome total non structural carbohydrates (TNC).

Effect	Tifton 85 TNC			
	Spring		Summer	
	2011	2012	2011	2012
Date	0.425	0.785	0.787	0.772
Method	0.001	0.867	0.233	0.544
Date x Method	0.505	0.797	0.147	0.981

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BIOGRAPHICAL SKETCH

Eduardo Ignacio Alava Hidalgo was born in 1982, in Portoviejo, Ecuador; the only son of Eduardo Alava and Marja Hidalgo de Alava. He was raised with his two sisters in Guayaquil, Ecuador. During his youth, he was an avid and competitive athlete, competing in tennis, basketball, and swimming until the age of 18. He completed his secondary education at the Liceo Naval High School, a private school associated with the Ecuadorian Navy, graduating in 2000. Later that year he was accepted at ESPOL University where he pursued his B.S. in “Ingenieria Agropecuaria” and graduated in 2005. During his last two years at the University, he started working with the family cattle ranch which continued until the end of 2006. He also participated actively in the Litoral y Galapagos Cattlemen Association, for the 2005 – 2006 periods, as a Brahman committee member and cattle show coordinator.

In the spring of 2007, he began a master’s degree under Dr. Timothy Olson at the University of Florida studying genetic improvement in cattle. After completing his master’s, Eduardo entered the Agronomy Department in 2009 to pursue his Ph.D. at the University of Florida, under the tutelage of Dr. Yoana Newman.

While completing his Ph.D., Eduardo married Erin (Mckinniss) Alava and started a family. Eduardo and Erin are the proud parents of Lucas Ignacio Alava. After graduation Eduardo plans to return to Ecuador to continue his work in the field of beef cattle production and research.