Stockpiled 'Tifton 85' Bermudagrass for Cow-Calf Production as Influenced by Nitrogen Fertilization

by

Courteney Elise McNamee

A thesis submitted to the Graduate Faculty of Auburn University
in partial fulfillment of the
requirements for the Degree of
Master of Science

Auburn, Alabama
August 2, 2014

Keywords: forage, performance, nutrition, economics,
production, reproduction

Approved by

Russell Muntifering, Co-chair, Professor of Animal Sciences
Lisa Kriese-Anderson, Co-chair, Associate Professor of Animal Sciences
Lawrence Wayne Greene, Professor of Animal Sciences

Abstract

A 2-yr grazing study was conducted to determine effects of rate of N fertilization on productivity and nutritive value of stockpiled 'Tifton 85' bermudagrass for lactating-cow and calf performance. On October 31, 2012 (Yr 1) and November 11, 2013 (Yr 2), 16 Angus × Simmental cows (mean initial BW for both yr, 647 ± 23 kg) and their calves (mean age, 16 ± 3 d) were assigned randomly to 0.76-ha paddocks (2 cow-calf pairs/paddock) of stockpiled 'Tifton 85' bermudagrass pasture that had been cut to a 10-cm stubble height in early August and fertilized with either 56 (56N), 112 (112N), or 168 (168N) kg N/ha (2 paddocks/treatment); or to replicate 0.41-ha paddocks (2 cow-calf pairs/paddock) of dormant summer pasture with free-choice access to August-cut bermudagrass hay plus 2.7 kg whole cottonseed daily (HAY). Cows were given access to strips of ungrazed forage by moving polytape every 3 to 4 d in order to maintain a target forage DM harvest efficiency of approximately 75%. In Yr 1, mean forage mass (6,113 kg DM/ha), IVDMD (60.9%) and grazing d/ha (314) were not different ($P > 0.05$) among the stockpile treatments over the 116-d grazing period; mean forage IVDMD (60.1%) and CP concentration (12.7%) in the stockpiled treatments were greater ($P < 0.05$) than the HAY treatment. Stockpiled forage CP concentration was greater ($P < 0.05$) for the 168N than 56N and 112N treatments, and was greater ($P < 0.05$) for the 56N than 112N treatment. In Yr 2, mean forage CP concentration was greater ($P < 0.05$) for the 168N (14.5%) than 56N (11.3%), 112N (12.0%) and HAY (9.0%) treatments; mean stockpiled forage IVDMD (59.5%) was greater ($P < 0.05$) than the HAY treatment (46.3%); and mean forage mass for the 168N treatment (5,017 kg DM/ha) was 378 kg and 298 kg DM/ha greater ($P < 0.05$) than the 112N and 56N treatments, respectively. Mean cow BW (611 ± 147 kg), BCS (5.5 ± 0.6) and milk production (9.0 ± 6.0 kg/d) were not different among treatments. Mean BUN concentrations (11.2 ml/dL) were not different among treatments, but mean BUN across treatments for the last sampling date was greater ($P < 0.05$) than the first and second sampling dates. Projected calving intervals and mean 205-d adjusted calf weaning weight (249 kg) were not different across treatments. An economic evaluation between each stockpiled treatment versus the HAY treatment revealed that input costs/cow were 66, 61 and 56% greater for the hay feeding system than the 56N, 112N and 168N stockpiles, respectively. Stockpiled forages were of sufficient nutritive quality to support beef cows' lactation and reproductive performance without supplementation, and were of consistently greater quality than hay.

Acknowledgements

The completion of this thesis would not have been possible without my faith in Jesus Christ and the help of several individuals. First, I would like to thank my husband, Daniel Holland, and my family. Without their support, I would not have made it to graduate school in the first place. Second, I would like to extend my most sincere appreciation to my advisor, Dr. Russ Muntifering. Without his guidance, direction and patience, this thesis would not have been possible. I'd also like to thank him for having faith in me and for counseling me through the hard times. I would also like to thank my co-advisor, Dr. Lisa Kriese-Anderson, for doing everything in her power to make sure I am prepared for a career in Extension and for going out of her way countless times to be the "second mother". To my committee member, Dr. Wayne Greene, thank you for the countless opportunities and memories you have given me in the past several years. Also, thank you for pushing me to become "famous" one day.

I would like to extend my appreciation to Brian Gamble for his assistance in managing this project. To Dr. John Lin, Dr. Walt Prevatt, and Dr. Soren Rodning, thank you all for providing your assistance and for being vital resources during this project. I would also like to thank my fellow graduate students, Kaleb Marchant, Carla Weissend, Leanne Dillard, and Staci Degeer for all of their help and for the great memories! Finally, I would like to thank Alabama Cattlemen's Association for providing me with funding and also, thanks are due to Alabama Cooperative Extension Services for providing me with opportunities to help me become a better candidate for a career in Extension.

TABLE OF CONTENTS

List of Tables

LITERATURE REVIEW

STOCKPILING

Stockpiled Forage

Stockpiled forage is first clipped, then fertilized, and lastly allowed to grow and accumulate for use at a later time or during a period of forage deficit. Stockpiling may be implemented at any time during the year as part of a forage-management plan, but it is typically done toward the end of the growing season prior to dormancy (Ball et al., 2007). Stockpiled forage can be mechanically harvested and stored as hay, or it can be harvested by cattle in a controlled manner. Forages are generally stockpiled for use during the fall and winter, but they can also be accumulated and deferred for use during any period of expected forage deficiency. The purpose of grazing stockpiled forage is to reduce mechanization costs and waste associated with harvesting and feeding hay. Cow-calf systems that reduce harvested forage use should realize an increase in profitability, even in the case of less favorable climatic conditions (Lalman et al., 2000). Especially under growing conditions characteristic of the Gulf Coast physiographic region, significant opportunity exists for cow/calf operations to save on mechanical-harvesting and supplementation costs, and in doing so sustain the economic viability of farm operations through use of stockpiled forages for grazing in late fall and early winter. Besides its economic benefits to cow-calf producers, stockpiled forage can lengthen the grazing season and reduce the labor needed to winter beef cows by as much as 25% (Lalman et al., 2000). The success of a stockpiled forage system is largely dependent upon selection of the forage species that is best suited for stockpiling and adapted to growing conditions of a particular region.

Species Considerations

The quality of stockpiled forages is determined by multiple factors, most notably plant species, and species selection is largely dependent on the region, climate and type of production system being used. It is important to understand the differences in physiological responses between cool-season and warm-season species in order to choose a variety that is well suited for a given production system. Warm-season grasses such as bermudagrass (*Cynodon dactylon*) or bahiagrass (*Paspalum notatum*) fix atmospheric CO_2 into 4-carbon compounds and are called C_4 plants (Wilkinson and Langdale, 1974). Tall fescue (*Lolium arundinacea*) and orchardgrass (*Dactylis glomerata*) are examples of C_3 plants that fix CO_2 into 3-carbon compounds, become light-saturated at only 25 to 50% of full sunlight, and may lose up to 40% of the energy captured in photosynthesis via photorespiration (Bolton and Brown, 1980). Because C_4 plants are able to utilize photosynthetically active radiation to a greater extent, the C_4 photosynthetic pathway is more efficient than the C_3 pathway and creates the potential for much greater forage yields than in C_3 plants (Brown, 1978). For a stockpiled-forage grazing system to be successful, the chosen plant species should be able to produce at least 2,000 kg forage DM/ha for fall grazing and maintain high quality following fall frosts (Ball et al., 2007).

Examples of cool-season varieties that may be used for stockpiling in the Southeast include tall fescue, Kentucky bluegrass (*Poa pratensis*) and orchardgrass. Of these varieties, tall fescue is used most extensively for stockpiling and is comparable to orchardgrass; however, orchardgrass accumulates less autumn growth and deteriorates more rapidly in the winter than stockpiled tall fescue (Ball et al., 2007). Kentucky bluegrass is greater in nutritive quality, but yields are less (Ball et al., 2007). Tall fescue used as stockpiled forage is superior to the aforementioned species because its quality is maintained throughout adverse weather during the autumn and winter months. However, performance of cows grazing stockpiled fescue may be compromised due to elevated concentrations of an endophytic fungus (*Neotyphodium coenophialum*) that produces ergot alkaloids in the forage which can negatively impact animal performance (Tucker et al., 1973). In that regard, Burns et al., (2006) found that ergovaline concentrations were reduced in stockpiled tall fescue when grazing was delayed into late winter (i.e., mid-February).

Perennial warm-season forages such as bermudagrass and bahiagrass are the major forages that sustain beef cattle production systems in the Southeast, and they are ideally suited for autumn stockpiling (Scarbrough et al., 2006). Bermudagrass stands often persist and remain productive for more than 35 yr if properly managed, and it is a popular forage in the southern United States due to its tolerance to acidic and sandy soils, heavy grazing pressure, and variable rainfall distribution (Hill et al., 2001). Hybrid bermudagrass cultivars have dominated in the southern United States, but their use for winter grazing has been infrequently practiced because their quality is perceived as inadequate. However, Lalman et al. (2000) conducted a study in Oklahoma in which CP concentration in stockpiled bermudagrass was determined to be adequate for dry, pregnant beef cows.

Stockpiled Forage Establishment

Autumn stockpiling is a management technique where forage is allowed to accumulate throughout the late summer and early fall for subsequent grazing during the late fall and winter (Scarbrough et al., 2006). The forage is first grazed or mowed to a stubble height of approximately 8 to 10 cm in late July or early August. In mid-August or thereabouts, the forage is fertilized to maximize forage yield during the stockpiling period (Scarbrough et al., 2006). Most studies report that stockpiled forages extend the grazing season by an average of 70 d (Ball et al., 2007). Applying 110 to 132 kg N/ha has proven to be sufficient; however, soil testing is the best way to determine the amount of N needed for a particular situation. Nitrogen fertilization will reduce the amount of land required per animal, and this effect is increased when greater forage responses occur under optimal growing conditions (Lalman et al., 2000). Timing of fertilization is crucial, and N fertilizer should be applied as early as possible at the start of the stockpiling period to optimize response of the forages. Fertilization in late September will have minimal effect on stockpiled forage yields (Barnhart, 2013). However, weather conditions will influence fertilizer benefits and accumulation of stockpiled forage. During the months of August and September, it is typically not convenient for producers to sacrifice a portion of their summer pasture for stockpiling. It is important to provide sacrificed pasture as support during the accumulation period. This reserve pasture is also important if stockpiled pastures become damaged from excess mud, which may cause soil compaction and long-term damage to pasture sod if grazing continues.

Bermudagrass stem maggot (*Atherigona reversura*) has recently been discovered (Hudson et al., 2013) in bermudagrass fields in the Southeast, and it can be a problem in both bermudagrass and stargrass. The small fly (adult stage) lays eggs in the bermudagrass, and the larvae burrow in the top node of the plant (Hudson et al., 2013). Eventually, the top leaf portion will be killed and have an appearance similar to frost damage (burnt tips). The extent of injury depends on the growing conditions and cultivar of the grass, and may include yield and quality losses with no lasting damage to the plant. Injury is worse in finer-stemmed cultivars such as ‘Alicia’, ‘Coastal’, ‘Russell’, and ‘Common’. Damage almost never reaches economically important levels in coarser varieties such as ‘Tifton 85’, although these varieties are still attacked (Hudson et al., 2013). However, yield loss may occur in growth periods that are limited by poor soil and moisture. The current management recommendation for serious infestations in stockpiled bermudagrass is a foliar application of pyrethroid insecticides labeled for hayfields after the grass regrowth, two times 5 to 7 days apart to kill the adult flies (Hudson et al., 2013).

PASTURE AND GRAZING MANAGEMENT

Grazing Management Practices

Grazing management affects forage production and DM intake, digestibility and grazing behavior in ruminants (Newman et al., 2002). Stockpiled forage for winter grazing should be used under intensive grazing management that attempts to increase production or utilization per unit area, or production per animal through adjustment in stocking rates in accordance with forage availability. One option, not generally recommended for stockpiled forage systems, is continuous stocking in which grazing animals on a given pasture unit have unrestricted and uninterrupted access to the stockpile throughout the grazing period. This type of management allows animals to selectively graze and causes the forage to become excessively trampled (Ball et al., 2007). If animal numbers or pasture size are not periodically adjusted as pasture conditions change, continuous stocking may result in some plants being undergrazed and some plants being overgrazed. One method for achieving relatively uniform forage utilization and harvest efficiency is strip grazing, or confining animals to an area of grazing land to be grazed in a relatively short period of time where the paddock size is varied to allow access to specific land area (Ball et al., 2007). A moveable electric fence is used ahead of and behind the animals to ration daily forage. A less labor-intensive strategy for stockpiled forage to reduce waste and preserve quality is the frontal grazing method, which allocates forage within a given land area by means of a sliding fence that allows cows to advance to ungrazed forage with the mineral source and water kept on the grazing side of the fence. This type of management requires periodic measurement to determine the amount of available forage for grazing in a given area (Ball et al., 2007).

Forage Allowance and Utilization

Forage allowance (FA) is the relationship between mass of forage DM per unit area and the total liveweight of animals at any given point in time (Hodgson, 1981). Forage allowance is calculated using the following equation: FA = forage mass (kg DM/ha) ÷ total animal live weight (kg) = kg forage DM/kg animal BW (Sollenberger et al., 2005).

Steps to complete the previous equation begin with determining the paddock size needed to support a given number of animals, which is calculated by the following equation: Ha required/paddock = {(BW, kg) × (DMI, % of BW) × (number of animals) × (d/paddock)} / {(available DM, kg/ha) × (% utilization)}. Note that this equation requires estimates of forage utilization and regrowth period (Sollenberger et al., 2005).

Utilization is defined as the percent of available forage that animals consume. Percentage utilization can vary, depending on the type of grazing management used. Strip grazing, which is recommended for managing stockpiled forage, can improve grazing efficiency to a point where 65 to 75% of available forage will be consumed (Ball et al., 2007). Once the area needed to graze the animals is determined, the number of animals needed to utilize available forage can be calculated: Number of animals required to graze a paddock = {(kg forage DM/ha) × (ha) × (% utilization)}/ {(kg animal weight) × (DMI in % of BW) × (d)}. Finally, the number of animals is used to calculate the number of days the forage is expected to last: {(kg forage DM/ha) × (ha) ×

(% utilization)} / {(kg animal weight) × (DMI in % of BW)} × (number of animals) (Sollenberger et al., 2005).

TIFTON 85 BERMUDAGRASS

Agronomic Characteristics and Nutritive Quality

Bermudagrass is a principal candidate species for stockpiling in the southern United States. The agronomic attributes of bermudagrass that make it such a widely used pasture grass in the South include high biomass production potential, tolerance of intensive grazing, drought tolerance, insect tolerance and its exceptional response to N fertilization (Burton et al., 1993). The nutritive quality of warm-season grasses such as bermudagrass is often perceived as limiting to animal performance (Lalman et al., 2000). However, improved hybrid bermudagrasses provide superior yield potential, persistence, and quality than unselected ecotypes (Hill et al., 2001). ‘Coastal’ is considered the standard for comparison with new bermudagrass selections and hybrids in most of the South. ‘Tifton 68’ has the highest quality and is one of the higher-yielding bermudagrasses released by Dr. Glenn Burton, USDA-ARS, Tifton, GA. Because of its poor cold tolerance, it is not used widely in the United States; however, it is still maintained and used as a parent in crosses to increase yield and quality (Hill et al., 2001).

‘Tifton 85’ an example of a hybrid resulting from crossing ‘Tifton 68’ and a South African bermudagrass accession. It was developed by the USDA-ARS in cooperation with the University of Georgia Coastal Plain Experiment Station in Tifton, GA and was released in 1992 (Burton et al., 1993). It is reported to be highly digestible (Mandebvu et al., 1999), but somewhat cold-sensitive (Hill et al., 1993). Compared with other bermudgrass hybrids, ‘Tifton 85’ has a darker green color, larger stems, broader leaves and larger stolons. ‘Tifton 85’ can be established by planting sprigs with mechanical planters or by broadcasting and disking in tops (Ball et al., 2007). Sprigs can be dug and planted starting in late winter and through the spring and summer.

‘Tifton 85’ has been reported to have greater capacity for forage DM accumulation and improved nutritive value than other varieties such as ‘Coastal’ or ‘Tifton 78’ (Hill et al., 1993). Mandebvu et al. (1999) demonstrated that, compared with ‘Coastal’, ‘Tifton 85’ yielded 26% more DM, 80 g/kg more digestible NDF and 110 g/kg more digestible DM. In a comparison among ‘Tifton 85’, ‘Tifton 44’ and ‘Coastal’, Burns et al. (2007) reported that greatest IVDMD was observed for ‘Tifton 85’, but CP and NDF concentrations were not different between ‘Tifton 85’ and ‘Tifton 44’. Also, ‘Tifton 85’ was found to contain the greatest concentrations of ADF and cellulose, but least concentrations of hemicellulose and lignin compared with ‘Tifton 44’. Mandebvu et al. (1998b) suggested that the chemical nature of ‘Tifton 85’ cell walls had been altered in its development, which is supported by Burns et al. (2007) who reported that ‘Tifton 85’ had the greatest proportion of large particles and the least proportion of small particles in digesta, with ‘Coastal’ having the converse and Tifton 44 the intermediate distributions of particle size. Reduced digestion of fiber fractions in ‘Coastal’ compared with ‘Tifton 85’ has been attributed to ‘Coastal’ having greater concentrations of ethereal ferulic acid linkages with structural carbohydrates in the plant cell wall (Mandebvu et al., 1998b). Jung and Allen (1995) proposed that ferulic acid cross-links between lignin and the cell wall polysaccharides make them less available for microbial breakdown. Whereas ruminal bacteria and fungi possess phenolic acid esterases that ultimately break down ferulate ester linkages, anaerobic cleavage of ether linkages is not known to occur (Jung and Allen, 1995). Therefore, the greater concentration of ether-linked ferulic acid in ‘Coastal’ bermudagrass is thought to be the cause of decreased digestibility of this variety compared with ‘Tifton 85’ bermudagrass. Given its nutritive value, significant opportunity exists for stockpiled ‘Tifton 85’ bermudagrass systems to be utilized by beef cattle producers in order to save on mechanical-harvesting and supplementation costs.

Response to Fertilization

In terms of date and rate of fertilization, N is the nutrient required in greatest quantity and is most frequently deficient in forage production systems (Snyder and Leep, 2007). However, the amount of N a plant can efficiently use is dependent upon many factors, including the yield potential of the plant in question (Burton and DeVane, 1952). Nutritive value increases with increasing N fertilization rate in ‘Tifton 85’ (Vendramini et al., 2008), and ‘Tifton 85’ herbage yields have ranged from 12,000 to 31,600 kg DM·ha^{-1}· yr^{-1} for N fertilization rates between 325 and 616 kg N/ha (Brink et al., 2008). Johnson et al. (2000) reported CP concentration increased from 98 to 181 g/kg as N application rate increased from 0 to 785 kg/ha. Alderman et al. (2011) indicated that herbage yield, CP concentration, and percentage IVDMD were increased by N fertilization, but with greatly diminished effect at high N rates. Increasing N rate beyond 90 kg N/ha did not enhance plant growth; however, the N available for rumen microbes to be utilized for microbial protein synthesis is increased in bermudagrass as fertilization increases. Methodology described by Licitra et al. (1996) divides forage N into fractions of nonprotein N (A), true protein (B) and insoluble N (C), and was used by Johnson et al. (2000) in an experiment to determine N fertilization effects on 3 warm-season perennials. Compared with bahiagrass and stargrass, bermudagrass exhibited a greater percentage of fraction A (NPN) and less of fraction C (undegradable N). Bermudagrass thus had a greater percentage of forage N in a form useable by ruminants. Furthermore, forage DM mass reached a plateau for these forages with application of 78 kg of N/ha.

The success of stockpiling bermudagrass is dependent upon regional variations in temperature, light, and availability of moisture (Henderson and Robinson, 1982). Rate of bermudagrass growth is considerably greater when the temperature is above 24˚C, and very little growth occurs when the temperature is 15 to 18˚C (Burton and Hanna, 1995). Freezing can have negative impacts on bermudagrass forage accumulation, and an adjustment must be made in terms of timing of the stockpiling period to allow time for adequate forage accumulation and quality (Prine and Burton, 1956). The timing of frost varies regionally; for example, the average first frost occurs on approximately December 15 in extreme southern and November 1 in northern bermudgrass-producing areas (Guertzky et al., 2008). The environment in which forage for fall and winter grazing is stockpiled poses major issues concerning the rate and extent of forage deterioration. Hart et al. (1969) reported a decline in nutritive value of stockpiled bermudagrass occurred more rapidly in younger forages (i.e., shorter stockpiling period). When producing stockpiled bermudagrass, it is important to evaluate the probability of climatic events within microclimates to manage for the possibility of reduced forage accumulation.

ANIMAL PERFORMANCE

Physiological Status and Cow Performance

Cow-calf production systems must develop nutritional programs that maintain or enhance reproductive efficiency of the cowherd without negative effects on financial viability (Lusby et al., 1991). Ensuring appropriate nutrition for the beef cow not only affects her body condition, but also promotes proper growth and development of the growing fetus (NRC, 1996). During the early postpartum period, nutritional requirements are often not fulfilled when cows graze low-quality pastures (Johnson et al., 2000). Thus, supplemental energy may be required to maintain body weight and condition of cows. Providing additional supplemental energy beyond that necessary for effective utilization of supplemental degradable intake protein (DIP) is costly and may result in only marginal improvements in cow body condition score (BCS) change, calf weaning weight, and pregnancy rate (Lusby et al., 1991). A study conducted by Taliaferro et al. (1987) indicated that fertilized bermudagrass can maintain elevated concentrations of CP through mid-February, sufficient to maintain a cow without expensive supplement. However, consideration must be given to the risks associated with variable forage production and cow performance.

Adequate body energy reserves at calving are critical for determining reproductive performance of beef cows (Selk et al., 1988). Prepartum and postpartum energy balance are the most important factors affecting duration of the postpartum interval to first estrus in beef cows (Hess et al., 2005). Feeding programs should be designed to keep cows in positive energy balance (i.e., moderate body condition). Lusby et al. (1991) indicated stage of lactation can affect weight change responses of cows grazing dormant, native tallgrass range. Cows thin at calving usually have longer postpartum intervals. Cows in good body condition at calving can tolerate minimal body weight changes before and after calving (Corah et al., 1975).

Body condition score at calving is among the most important factors affecting pregnancy rate (Richards et al., 1986). Body condition is correlated with several reproductive metrics such as postpartum interval, services per conception, calving interval, milk production, weaning weight, calving difficulty and calf survival, and BCS can greatly affect net income of a cow/calf operation (Funston et al., 2010). The body condition score system can be summarized by the following: 1 to 3 reflects thin condition, 4 reflects borderline condition, 5 to 7 reflects moderate condition (optimum), and 8 to 9 reflects fat condition. Extended periods of anestrus are observed in cows that experience prolonged negative energy balance prepartum, which is reflected by reduced BCS at parturition (Hess et al., 2005). It is generally recommended cows be in a BCS 5 or greater for optimal reproductive performance (Lents et al., 2005). However, Mullinix et al. (2012) hypothesized that cows would fit their environment with lower BCS at calving under extensive nutritional management and maintain successful reproductive function. Cows with BCS of 4 to 4.5 were determined to have similar reproductive performance as cows with BCS 5 at calving, which could be associated with cow herds becoming acclimated to performing in extensive range conditions with limited nutrient availability.

Fall-calving cows typically have greater BCS at calving and breeding than do spring-calving cows (Janovick et al., 2002). In a fall-calving system, cows will not be lactating throughout all of the pasture season; therefore, cows' needs during gestation will be met with fair to good quality pasture. However, as calving and lactation begin, available forage is mostly depleted. Thus, the fall-calving cow incurs a 25 to 33% greater expense over the winter compared with a nonlactating, spring-calving cow (Breese and Horner, 2007). In a spring calving system, lactating beef cow needs are met with lush grass, but not during gestation. Most studies have examined nonlactating, spring-calving cows grazing stockpiled bermudagrass, but few studies have examined the performance of lactating beef cows during the winter on stockpiled bermudagrass. Scarbrough et al. (2001) concluded that spring-calving beef cows grazing stockpiled bermudagrass may require supplementation with an energy source during late fall or early winter in order to maintain BW and condition due to decreased forage DM and NDF degradation. Based on this study, stockpiled bermudagrass may be used during a relatively short (60-d) window between October and mid-December in the upper South. However, Wheeler et al. (2002) concluded from the first year of a 2-yr study that forage nutritive value during the first 30 d of grazing was adequate to maintain acceptable animal performance without supplementation. Supplementation was required to minimize weight loss during the final 49 d of the study. In the same study, the authors indicated that cumulative weight and BCS change of cows grazing stockpiled bermudagrass did not respond to increased supplement protein concentration in either experiment, and that the least level of supplementation was adequate. The authors proposed that, because ruminally available N was not limiting, perhaps the addition of rapidly fermentable structural carbohydrates (e.g., soybean hulls) stimulated ruminal fermentation. In another study by Johnson et al. (2000), supplementation was not necessary to maintain spring-calving cows grazing stockpiled bermudagrass pastures during the winter. In this experiment, supplements were formulated using 1) soybean hulls; 2) corn and soybean meal to achieve similar DIP to soybean hulls; 3) corn and soybean meal to achieve twice the DIP of SH; 4) no supplementation (control). Forage CP and DIP concentrations exceeded requirements for a gestating beef cow from November through January. Supplementation with DIP or fermentable carbohydrate (corn or soybean hull) did not influence cow BW change, forage intake or forage utilization, and BCS change was only marginally improved. Beef cows fluctuate in BCS and BW throughout the year without negatively impacting reproductive performance (Freetly and Nienager, 1998). For that reason, implementation of a supplement program must have a measurable positive outcome in order to have biological relevance and justify its continued use.

Dry, pregnant mature cows can be maintained on relatively low-quality forage containing 8% CP and 50% digestible DM (NRC, 1996). Lactating cows require a diet contains approximately 10% CP and about 55% digestibility (NRC, 1996). Matching the nutrient requirements of the cow with the nutrients available in forages has been recommended as a means to efficiently utilize grazed forages (Adams et al., 1996). Two general factors that determine how well the cow and forage complement each other are: 1) genetic potential for milk production by the cow and 2) the synchrony between the cow's nutrient requirements during lactation and the greatest nutrient content of the forage (Adams et al., 1996). Nutrient requirements are much greater for lactation than for gestation, and a cow will mobilize nutrients from her own body stores in order to sustain her inherent capacity to produce a certain amount of milk. Requirements for TDN and CP during the last third of pregnancy are approximately 20 and 14% greater, respectively, than during the middle third of pregnancy. If the cow's requirements and forage nutritive value are well matched, then the need for supplementation will be reduced. Reducing the need for feeding supplemental hay during the winter months has been shown to result in lower production costs and greater net returns (Adams, 1995).

Economic Considerations

Feed costs constitute the greatest portion of annual cow maintenance costs. In most studies, this portion is reported to be between 50 to 70%. Adams et al. (1996) indicated that costs associated with feed was the greatest factor influencing profit of commercial beef cow operations, accounting for over 63% of the variation in total annual cow costs. D'Souza et al. (1990) suggested that more dependence on cows rather than machines to harvest forage is one method to reduce winter feed costs. Minimizing amounts of harvested and purchased feed and maximizing grazed forages is the most economical system in a cow-calf operation. However, the most economical feed resource must be matched to the most appropriate biological type of cow (Adams et al., 1996).

In an Oklahoma study (Lalman et al., 2000), economic simulation and sensitivity analyses were conducted comparing three 100-d systems: stockpiled bermudagrass (SB), tall grass prairie (TGP), and bermudagrass hay (HAY). Sensitivity of input variables for the SB system was determined by changing one variable while holding all other variables constant until the total cost for the 100-d period equaled that of the hay system. Total feed and forage costs/cow for the 100-d period were $39.61, $42.80, and $71.88 for SB, TGP, and HAY, respectively. Percentage of change required for SB system costs to equal HAY systems costs was 46, 51, 51, 179, 261, 354, 355, and 355 for hay, forage production, harvest efficiency, N fertilizer, and pasture rental cost per ha, days of supplemental feeding, amount of supplement fed per day, and supplemental feed price, respectively. The authors concluded that cost per animal for stockpiled bermudagrass systems was affected more by forage accumulation and (or) harvest efficiency than by N fertilizer, pasture rental, or supplementation costs.

A long-term demonstration project was conducted in Arkansas utilizing 90 on-farm stockpiled forage systems including fescue, bermudagrass and bahiagrass across 32 counties over a 4-yr period (Lalman et al., 2000). Savings from stockpiling forages were estimated based on the cost of fertilizer to grow the stockpiled forage compared with the value of hay and supplement required to replace the grazing days and animal performance gained from the stockpiled forage. Average savings per animal unit (AU) for stockpiled bermudagrass (including stockpiled bahiagrass and dallisgrass) were $22.74, $13.93 and $23.76 for 2003, 2004 and 2005, respectively. Average savings per AU for stockpiled fescue were $17.79, $18.85, $12.52 and $29.07 for 2002, 2003, 2004 and 2005, respectively. Surveys given to participants upon completion of the project showed 89% of producers planned to continue the practice, and 100% of county agents planned to continue promoting stockpiling forages.

The strategy of applying financial resources toward feeding and supplementing the cow herd is an enterprise-specific decision. The key is to find the point at which cattle performance and cost outlays are optimized (Hersom et al., 2008), which is affected by many variables including expected cow performance, previous cow condition, forage conditions, supplement type, and environmental conditions.

II. STOCKPILED 'TIFTON 85' BERMUDAGRASS FOR COW-CALF PRODUCTION AS INFLUENCED BY NITROGEN FERTILIZATION

INTRODUCTION

Stockpiled forage is allowed to grow and accumulate for grazing at a later time, for use in winter feeding, or during a period of forage deficit. Bermudagrass (*Cynodon dactylon*), a perennial warm-season forage, is one of the major forage species sustaining beef cattle production systems in the Southeast, and it is ideally suited for autumn stockpiling. Bermudagrass stands often persist and remain productive for more than 35 yr if properly managed, and it is an especially popular forage in the southern US due to its tolerance of acidic and sandy soils, heavy grazing pressure, and variable rainfall distribution (Hill et al., 2001). Improved hybrid bermudagrasses provide superior yield potential, persistence, and quality compared with unselected ecotypes (Hill et al., 2001).

'Tifton 85' is an example of a hybrid resulting from crossing 'Tifton 68' and a South African bermudagrass accession. 'Tifton 85' bermudagrass has been widely grown in the United States, Central and South American, and Southern Africa (Mandebveu et al., 1999). It was developed by the USDA-ARS in cooperation with the University of Georgia Coastal Plain Experiment Station in Tifton, GA, and was released in 1992. It is reported to be highly digestible (Mandebvu et al., 1999) but somewhat cold-susceptible (Hill et al., 1993). Compared with other bermudgrass hybrids, 'Tifton 85' has a darker green color, larger stems, broader leaves and large stolons. Compared with ‘Coastal’ and ‘Tifton 78’ bermudagrass, ‘Tifton 85’ is higher yielding (by 34%), more digestible (Hill et al. 1993), and supports greater milk production (Corriher et al., 2007). Digestibility of NDF is also greater due in part to lesser concentrations of lignin and ethereal linkages between ferulic acid and cell-wall carbohydrates in ‘Tifton 85’. In terms of date and rate of fertilization, nutritive value increases with increasing N rate in ‘Tifton 85’ (Alderman, et al., 2011).

Stockpiling bermudagrass forage for fall and winter grazing has the potential to reduce cow-calf production costs. Much research to date has addressed the effects of variety, management and climate on production, quality and utilization of stockpiled cool-season forages such as tall fescue. However, less attention has been given to stockpiled bermudagrass systems. While the use of stockpiled bermudagrass for fall/winter grazing is not an especially novel practice, nearly all of the published research to date has been conducted in the Lower Great Plains and Upper South with dry, pregnant, spring-calving cows using older, lesser improved varieties of bermudagrass (Lalman et al., 2000). Based on these studies, the conventional wisdom posits that stockpiled bermudagrass would have limited applicability for fall-calving, lactating cows due to their greater nutrient requirements. With use of lactating cows and the goal of increasing stocking capacity, unit cost per animal for stockpiled bermudagrass systems may be affected more by forage management than by fertilizer and feed input variables. For this reason, a late fall/early winter grazing study was conducted to determine effects of rate of N fertilization on productivity, nutritive value and economic feasibility of stockpiled ‘Tifton 85’ bermudagrass for fall-calving, lactating cows as assessed by production and reproductive performance.

MATERIALS AND METHODS

Research Site

All procedures were approved by the Auburn University Institutional Animal Care and Use Committee for the use of live vertebrate animals in experiments (PRN 2013-2204). An existing 'Tifton 85' bermudagrass pasture located at the Wiregrass Research and Extension Center (WREC) in Headland, AL (31.35° N, 85.34° W) was utilized for this experiment. The pasture was utilized for hay production prior to the initiation of the experiment. The soil beneath the pasture was a sandy loam.

Forage treatments and grazing management

Forage in the pasture was clipped to a 10-cm stubble height on August 1 in both 2012 (Yr 1) and 2013 (Yr 2), and the study area was subdivided into 6, 0.76-ha paddocks for stockpiling and deferred grazing. Two adjacent 0.42-ha plots of dormant summer pasture were utilized for the control treatment. On August 17, 2012 and August 28, 2013, the 'Tifton 85' bermudagrass paddocks (2 plots/treatment) were fertilized with 56 (56N), 112 (112N) or 168 (168N) kg N/ha in the form of ammonium nitrate (NH_4NO_3) and stockpiled for deferred grazing until October 31 in Yr 1 and November 11 in Yr 2, respectively. First killing frost occurred on February 18, 2012 and November 10, 2013. The control treatment consisted of *ad libitum* access to round bales of bermudagrass hay and supplementation with 2.7 kg whole cottonseed daily. Bales were weighed prior to placing in paddocks, and hay refusals were weighed before new bales were placed into hay rings.

For each year of the 2-yr grazing study, 16 Angus × Simmental cows and their calves were randomly assigned to 1 of the 4 treatments (4 cow-calf pairs per treatment). A cow with a heifer calf and a cow with a bull calf were randomly assigned to each paddock (2 cow-calf pairs per paddock). Cows and their calves were grouped by initial cow BW, age of dam, calf sex, initial calf age, and initial calf weight. Pairs were placed in their paddocks on October 31, 2012 in Yr 1 of the project and on November 11, 2013 in Yr 2. The same cows were not necessarily used in both yr of the study, but there was some duplication. A total of 26 different cows were used over the course of the experiment. The primary criterion for inclusion in the study was that cows calved early in the calving season. Initially, all cows were to be at least 4 yr old. However, due to the limited number of cows located at the WREC, some 3-yr-old cows had to be utilized in the project. Grazing of stockpiled forage was initiated in both yr when the forage had achieved a mean mass across all paddocks of approximately 4,000 kg DM/ha. A commercial salt-mineral mix (Ca [max.] 16.00%, P [min.] 6.00%, NaCl [max.] 24.00%, Na [max.] 10.50%, Mg [min.] 0.50%, K [min.] .50%, Cu [min.] 650.00 ppm, I [min.] 50.00 ppm, Se [min.] 12.00 ppm, Zn [min.] 750.00 ppm, Vitamin A [min.] 15,000 IU, Producer's Pride®, Tractor Supply Company, Dothan, AL) was provided free choice along with water in each paddock for the duration of the grazing seasons that extended through February 14 in 2013 (116 d) and February 1 in 2014 (82 d). Polytape was moved every 3 to 4 d to provide the equivalent of 1.33 × cows' daily requirement (NRC, 1996) for forage DM (13.6 kg, 10% CP, 55% TDN) and maintain a minimum harvest efficiency of 75% as determined by pre- and post-graze forage mass. Grazing d/ha was calculated as kg forage DM/ha ÷ [1.33 × daily forage DM requirement].

Forage harvesting, sampling and laboratory analyses

Four forage samples were taken randomly from each paddock prior to the initiation of the experiment to estimate forage DM mass and chemical composition. Samples were harvested using a 0.25-m^2 quadrat and hand clippers to cut forage to a 5-cm height. After cows had been turned out for grazing, 4 pre-graze forage samples were taken randomly from each paddock biweekly until cows were removed from paddocks. Following the initiation of the experiment, 4 samples were taken every 21 d from the grazed portion of strips previously grazed. Fresh-cut forage was placed into plastic, zip-closure bags and stored on ice for transportation to the Ruminant Nutrition Laboratory at Auburn University where it was dried at 50° C for 48 h. Dried, air-equilibrated forage samples were weighed, and subsamples were mixed thoroughly for uniformity and ground to pass a 1-mm screen in a Wiley Mill (Thomas Scientific, Philadelphia, PA). Forage concentrations of CP and DM were determined according to procedures of AOAC (1990), and concentrations of NDF, ADF and ADL were determined sequentially according to procedures of Van Soest et al. (1991). Forage IVDMD was determined according to the Van Soest et al. (1991) modification of the Tilley and Terry (1963) procedure using the Daisy II incubator system (Ankom Technology Corporation, Fairport, NY). Ruminal fluid was collected mid-morning from a fistulated Holstein cow that had free access to bermudagrass pasture and was limit-fed a supplement containing cracked corn, distillers dried grains, corn gluten feed, soyhull pellets, soybean meal, cottonseed meal, and cottonseed hulls. Fluid was stored in pre-warmed thermos containers and transported to the Ruminant Nutrition Laboratory where it was then processed for the batch-culture IVDMD procedure.

Cow and calf performance

Cow body condition scores and weights, and calf weights and hip heights were measured every 21 d in both yr. Body condition scores were assigned using visual observations and a scoring system from 1 to 9, with 1 being extremely thin and 9 being extremely fat. Milk production was measured by the weigh-suckle-weigh technique at 31, 45 and 161 d postpartum each year (Totusek et al., 1973). Calves were separated from their dams for 8 h, allowed to suckle until full, and separated again for 12 h. Calves were then weighed, allowed to suckle until full, and reweighed. Milk yield was calculated as the difference between the pre- and post-suckling weights, and milk yield was multiplied by 2 to estimate 24-h milk production. Calf weaning weights were taken when calves averaged 218 d of age in Yr 1 and 204 d of age in Yr 2. Actual calf weaning weights were adjusted to 205-d weights (BIF, 2010) and then to a bull basis. Assessment of body energy status was estimated during lactation by measuring serum urea-N concentrations in whole-blood samples collected via jugular venipuncture on d 31, 45 and 123 postpartum in both years. Immediately after blood collection, 10 ml-samples were placed on ice and, following centrifugation (1500 × g for 20 min), sera were harvested and stored in 1.5-mL microcentrifuge tubes at -20 °C for subsequent analysis of serum urea N. Serum urea N concentration was measured spectrophotometrically (Roche Diagnostics, Indianapolis, IN) at the Pathology Laboratory at the Auburn University Small Animal Veterinary Clinic.

Cow Reproduction

On d 0 (January 7 in both years) of estrous synchronization, cows received GnRH (100 µg, i.m.) with an intravaginal progesterone-releasing insert (CIDR, Zoetis, Florham Park, NJ) for 7 d. On d 7 the CIDR was removed and $PGF_{2\alpha}$ (25 µg, i.m.) was administered. A second GnRH injection was administered 60 h after the $PGF_{2\alpha}$ injection (January 17), and cows were bred using timed artificial insemination (TAI). Twenty-eight d (February 14) after TAI, cows were placed with bulls for 76 d. Cows were pregnancy-checked at weaning on May 28 of both yr, and final pregnancy status was determined using transrectal ultrasonography (Aloka SSD 500 with 7.5-

MHz linear probe, Aloka Co. Ltd., Wallingford, CT) by a licensed veterinarian after bull removal. Days pregnant were determined by ultrasound, and projected calving intervals were calculated for both years.

Economic Evaluation

An economic evaluation of the pasture and hay systems was conducted comparing the stockpiled-forage system at each N fertilization rate with the hay system in terms of savings on a total input cost per cow basis. Costs per cow included variable costs of N fertilizer, grazing costs, labor, hay, supplements, and machinery. The hourly cost of equipment ($25.00/hour) used during the experiment was previously determined by Prevatt et al. (2008) and multiplied by the number of hr actual use time as recorded for each feeding system. Diesel costs were calculated by using the average amount of fuel per piece of equipment used per hr multiplied by the average retail price of fuel during the experiment. A labor rate of $9.00/hr was used and multiplied by the number of actual hr recorded for each treatment. The price of ammonium nitrate, whole cottonseed, and hay was $465, $420, and $132/ton, respectively, during the experiment. The price per ton of ammonium nitrate and whole cottonseed were determined from the Alabama Weekly Feedstuff/Production Cost Report. Nitrogen cost for each treatment was calculated on the basis of the amount of needed N applied per ha. Grazing costs of the ‘Tifton 85’ pastures for stockpiling were obtained from the records of input costs for sprigging, fertilizer application, grazing waste and sprigs. The price of hay per ton was previously calculated by Prevatt et al. (2008) and multiplied by the amount of hay the cows consumed. Formulas and prices used to determine input costs are found in the Appendix.

Statistical analyses

Forage mass, forage nutritive quality parameters and animal performance data were analyzed as a completely randomized design with two replicates per treatment. Because of extreme weather differences between years, forage mass and quality data from each yr were analyzed separately. Data were treated as repeated measures using the PROC MIXED procedures of SAS 9.3 (2003) for forage characteristics. For each yr, the statistical model included treatment, sampling date, and treatment × sampling date interaction as independent variables for forage-mass metrics, grazing d/ha, and forage concentrations of CP, ADF, NDF and ADL, and percentage IVDMD. The experimental unit was considered to be paddock.

Cow and calf data were analyzed as a randomized complete block with 2 replications using PROC MIXED procedures of SAS 9.3 (2003). Cow BW, cow BCS, calf BW, calf hip height, BUN and milk production were treated as repeated measures over time. Independent variables included year, treatment, sampling date and calf sex. Interactions of year × treatment and treatment × time were included in the model. Cow age was used as a covariate. Either cow or calf was treated as a random effect on the model, depending on whether the dependent variable was a cow trait or calf trait. Dependent variables of 205-d weaning weight, 205-d weaning weight adjusted to a bull basis, days pregnant and projected calving date were also analyzed as a completely randomized design with two replicates. Independent variables of year, treatment, and sex of calf were included in the model. The interaction of year × treatment was included in the model along with a covariate for age of dam. These traits were also analyzed using PROC MIXED procedures of SAS 9.3 (2003). Means were separated using least squares means with a Bonferroni adjustment. The significance level was set at $P < 0.05$ for all analyses.

RESULTS AND DISCUSSION

Minimizing amounts of mechanically harvested and purchased feed and maximizing grazed forages is the most economical system for a cow-calf operation (Lalman et al., 2000). However, the most economical feed resource must be matched to the biological type of the cow (Lusby et al., 1991). Advantages of bermudagrass, including high biomass potential, drought tolerance, insect tolerance and exceptionally favorable responses to N fertilization, make it a popular species in the southern US. However, the nutritive quality of certain bermudagrass cultivars can be limiting to animal performance (Ball et al., 2007). Until the present study, the grazing of stockpiled 'Tifton 85' bermudagrass compared with feeding hay and supplement with fall-calving, lactating cows had not been investigated. 'Tifton 85' is one of the improved cultivars that provides superior yield potential, persistence, and quality compared with unselected ecotypes (Hill et al., 2001).

Temperature and precipitation. Rate of bermudagrass growth is considerably greater when the temperature is above 24° C, and very little growth occurs when temperature is 15 to 18° C (Burton and Hanna, 1995). Monthly mean air temperatures (Table 1) in July, August, October and November of Yr 1 were comparable with 30-yr averages for Headland, AL; however, the mean temperature in September was 5° C less than the 30-yr average. In contrast, monthly mean air temperatures in Yr 2 were considerably less than 30-yr average values in the early-to mid-summer and early-fall months. In Yr 1, monthly mean precipitation (Table 2) was 162%, 104%, 71% and 27% of the 30-yr average for the months of August, September, October and November, respectively. In Yr 2, monthly mean precipitation was 43, 7, 97, and 38% less than the 30-yr average for the months of August, September, October and November, respectively. The timing of precipitation and warm weather created optimal conditions in the late summer and early fall of Yr 1 for an exceptionally favorable response to N application, and moderate weather conditions in winter of Yr 1 resulted in a longer grazing season compared with Yr 2 of this study (116 vs. 88 d, respectively). Yr 2 had colder (especially January 2014), drier conditions that greatly reduced forage growth and productivity

Table 1. Monthly mean air temperatures (° C) for Yr 1and Yr 2, and 30-yr averages for Headland, AL

	Avg. High, °C			Avg. Low, °C			Mean, °C		
Month	Yr 1	Yr 2	30-yr	Yr 1	Yr 2	30-yr	Yr 1	Yr 2	30-yr
Jul	35	23	34	23	22	29	29	22	31
Aug	32	23	34	22	26	27	27	25	30
Sep	33	22	31	6	24	20	20	23	25
Oct	26	18	26	14	18	20	20	18	23
Nov	21	19	21	7	8	14	14	13	16
Dec	18	20	17	7	9	13	13	14	15
Jan	20	8	15	8	-1	4	14	4	10
Feb	14	14	18	11	4	11	13	9	15

Table 2. Monthly total precipitation for Yr 1 and Yr 2, and 30-yr averages and differences from 30-yr averages for Headland, AL

	Total Precipitation, mm			Differences, mm	
Month	Yr 1	Yr 2	30-yr	Yr 1	Yr 2
Jul	58	86	154	-96	-68
Aug	172	61	106	66	-45
Sep	110	99	106	4	-7
Oct	57	5	86	-29	-81
Nov	29	66	106	-77	-40
Dec	104	211	111	-7	100
Jan	36	57	133	-97	-76
Feb	445	139	127	318	12

Mean Forage Mass. In Yr 1, there were no differences in pre-grazed forage DM mass among treatments (Table 3). Because weather conditions were wetter and warmer than normal, favorable growing conditions persisted and N rates exceeding 56N kg/ha did not result in increased forage mass or grazing-d/ha (mean across treatments = 314). Given that January was 4˚C warmer than the 30-yr average, weather conditions were supportive of increased growth, even during the winter months. Johnson et al. (2001) reported an increase in forage mass as N application rate increased from 0 to 78 kg/ha; however, a plateau was reached at 78 kg of N/ha. In Yr 2, a treatment × sampling date interaction ($P < 0.05$) was detected such that the 112N treatment was greater ($P < 0.05$) than the 56N treatment throughout the experiment except on January 7 when the 56N treatment was greater ($P < 0.05$) than the 112N treatment. Across all sampling dates, forage mass in the 168N treatment was greater ($P < 0.05$) than the 56N and 112N treatments, equivalent to 201, 218 and 277 grazing-d/ha, respectively. Forage mass reached a peak in early January, and then experienced a sharp decline with temperatures reaching record lows (-1˚C). Given the cooler autumn temperatures in Yr 2, less forage growth was expected compared with Yr 1. Rate of bermudagrass growth may decline in temperatures below 18˚C (Burton and Hanna, 1995).

For both years, herbage accumulation rate in response to N fertilization was comparable to that in a study in Florida where Vendramini et al. (2008) indicated that monthly herbage accumulation rate of 'Tifton 85' increased from 57 to 93 kg/ha/d as N rate increased. However, in mid-January of Yr 2 of the present study, forage DM availability declined considerably. Weather conditions under which forage for fall and winter grazing is stockpiled are major determinants of rate and extent of forage deterioration (Burton and Hanna, 1995). In the present study, record freezing temperatures in early January likely contributed to greater forage deterioration than in Yr 1. Also, the N application and forage accumulation period in Yr 2 did not begin until the end of August compared with mid-August in Yr 1. Hart et al. (1969) concluded that deterioration from weathering was greater for forage that entered the winter dormancy period in a less mature state. Mean forage accumulation across all treatments was 6,190 kg/ha and 4,207 kg/ha for Yr 1 and Yr 2, respectively, which are comparable to values from a previous study in which the average forage accumulation ranged from 2,000 to 8,400 kg/ha for 'Tifton 85' fertilized with 125 kg N/ha (Scarbrough et al., 2001). In Yr 1, forage mass across all sampling dates were not different among N-fertilization treatments, which indicates that application of 56 kg N/ha yielded maximum amounts of DM availability and that fertilization above that rate was not necessary. Factors affecting the accumulation of bermudagrass forage during late summer and fall include variety, the availability of moisture and timing of precipitation, temperature, available soil N, and timing of N application, and the interaction of these factors (Lalman et al., 2000). Average forage accumulation per kg N for 56N, 112N and 168N was 98.9, 58.7 and 36.4 kg, respectively, for Yr 1 and 63.5, 35.3 and 29.9 kg, respectively, for Yr 2. In a 2-yr Georgia study, Hart et al. (1969) used 3 N fertilization rates (0, 56 and 112 kg/ha) and 3 final summer hay harvest dates (July 30, August 15, and September 1) to apply the fall N and begin the stockpiling period. Earlier N application dates combined with greater rates of N fertilization increased biomass yield. For their 112 kg N/ha treatment, DM yield per kg of applied N was 32, 19 and 21 for the July, August and September application dates, respectively, for both years. Wilkinson and Langdale (1974) indicated that standing crop accumulation ranged from 25 to 60 kg DM/kg added N. In a study in northwestern Arkansas, Scarbrough et al. (2001) reported a 45% increase in stockpiled bermudagrass between October 17 and November 14. Maximum mean forage mass was 3,069 kg DM/ha, and the authors concluded that accumulation may continue after mid-October. In a 3-yr trial that averaged 169 days of grazing by stocker cattle (Hill et al., 1993), ‘Tifton 85’ produced 46% more gain per hectare than ‘Tifton 78’ (1,156 vs 789 kg) and 38% more grazing-days per hectare (1,823 vs 1,319).

Table 3. Mean pre-grazed forage mass (kg forage DM/ha) of stockpiled 'Tifton 85' bermudagrass receiving different N fertilization treatments in Yr 1

Sampling Date	Treatment[1]			Mean
	56N	112N	168N	
Oct 24	5,145	6,020	5,550	5,571[x]
Nov 28	5,435	4,700	5,690	5,275[x]
Dec 13	5,900	5,670	6,720	6,096[x,y]
Jan 4	5,800	7,310	6,370	6,493[x,y]
Jan 16	6,600	7,121	7,660	7,127[y]
Mean	5,776	6,164	6,398	

[x,y]Within a column, means without a common superscript differ ($P < 0.05$); SEM = 817; n = 6).
[1]56N = 56 kg N/ha; 112N = 112 kg N/ha; 168N = 168 kg N/ha.

Table 4. Mean pre-grazed forage mass (kg forage DM/ha) of stockpiled 'Tifton 85' bermudagrass receiving different N fertilization treatments in Yr 2

Sampling Date	Treatment[1] 56N	112N	168N	Mean
Nov 11	3,030[a]	3,899[b]	4,380[c]	3,785[x]
Nov 25	2,880[a]	3,082[b]	4,528[c]	3,636[x]
Dec 10	3,560[a]	4,260[b]	5,339[c]	4,386[y]
Jan 7	5,200[a]	4,690[b]	6,260[c]	5,383[y]
Jan 21	3,560[a]	3,810[b]	4,251[c]	3,843[x]
Mean	3,646[j]	3,948[j]	4,952[k]	

[a,b,c]Within a row, means without a common superscript differ ($P < 0.05$; SEM = 162; n = 2).
[x,y]Within a column, means without a common superscript differ ($P < 0.05$; SEM = 228; n = 6).
[j,k]Within a row, means without a common superscript differ ($P < 0.05$; SEM = 228; n = 10).
[1]56N = 56 kg N/ha; 112N = 112 kg N/ha; 168N = 168 kg N/ha.

Crude protein. A treatment × year interaction ($P < 0.05$) was detected for CP forage concentration (Table 5) in Yr 1. Forage CP concentration in the 112N treatment was greater ($P < 0.05$) than the 56N treatment on November 28. However, the 56N treatment was greater ($P < 0.05$) than the 112N treatment on October 24, December 13 and January 4, but it was not different from 112N on January 16. Also, forage CP concentration in the 168N treatment was greater ($P < 0.05$) than the 56N in November, December and mid-January, but it was not different from 56N in October and early January. Across all sampling dates, mean forage CP concentration for the 168N treatment was greater ($P < 0.05$) than the 56N, 112N and HAY treatments, and CP concentration in HAY was less ($P < 0.05$) than in stockpiled forages at all sampling dates. Forage CP concentration in the stockpiled treatments declined considerably in November, but remained relatively unchanged through December to early January. The amount of precipitation in the month of August presumably allowed for favorable plant N uptake response to N fertilization. In Yr 2 (Table 6), mean CP concentration for the 168N treatment was greater ($P < 0.05$) than the 56N at all sampling dates, and greater ($P < 0.05$) than 112N in November and late January. Following a sharp decline in November, CP concentration in the stockpile treatments remained relatively unchanged through December and January. Concentration of CP in HAY was less ($P < 0.05$) than in stockpiled forages at all sampling dates. The greater forage N concentration in late fall in Yr 2 compared with Yr 1 is a result of less DM mass causing a concentration of N, likely because rate of decline in CP is more rapid in forages that experience greater fall and winter precipitation from October through January (Lalman et al., 2000). Forage CP concentrations in the present study are comparable to values from a study in which Johnson (2001) reported late-September CP concentrations of 10.4, 12.1, 14.6, 17.8 and 19.8% of DM for N application rates of 0, 39, 79, 118, and 157 kg/ha. The authors concluded that CP concentrations increased with increasing N fertilization in bermudagrass. The ability of stockpiled bermudagrass to maintain elevated CP concentration after frost and under varying dormant season environments has been studied in only a few experiments (Hart et al., 1969; Taliaferro et al., 1987; Scarbrough et al., 2001; Mislevey and Martin, 2007). Highly soluble N in cured standing forage may be more susceptible to leaching during extended periods of grazing deferral and (or) with high levels of precipitation (Lalman et al., 2000). In Florida, Alexander et al. (1961) applied 56 or 112 kg N/ha to ‘Coastal’ bermudagrass during late August and allowed it to accumulate until October or December. Mean CP concentrations were 6.9 and 8.4% across all harvest dates for 56 and 112 kg N/ha, respectively.

Table 5. Concentration of CP (%, DM basis) in stockpiled 'Tifton 85' bermudagrass receiving different rates of N fertilization, and in 'Tifton 85' bermudagrass hay in Yr 1

Sampling Date	Treatment[1]				Mean
	56N	112N	168N	HAY	
Oct 24	19.1[a]	16.1[b]	19.0[a]	9.7[c]	16.0[x]
Nov 28	10.1[a]	11.2[b]	12.3[c]	9.4[d]	10.8[y]
Dec 13	12.2[a]	10.2[b]	13.2[c]	8.5[d]	11.0[y]
Jan 4	12.3[a]	11.3[b]	12.1[a]	8.9[c]	11.1[y]
Jan 16	10.0[a]	9.7[a]	12.0[b]	8.0[c]	10.0[z]
Mean	12.7[j]	11.8[k]	13.7[l]	8.9[m]	

[a,b,c,d]Within a row, means without a common superscript differ ($P < 0.05$; SEM = 0.31; n = 2).
[x,y,z] Within a column, means without a common superscript differ ($P < 0.05$; SEM = 0.22; n = 8).
[j,k,l,m] Within a row, means without a common superscript differ ($P < 0.05$; SEM = 0.22; n = 10).
[1]56N = 56 kg N/ha; 112N = 112 kg N/ha; 168N = 168 kg N/ha; 'Tifton 85' hay cut in August prior to stockpiling (HAY).

Table 6. Concentration of CP (%, DM basis) in stockpiled 'Tifton 85' bermudagrass receiving different rates of N fertilization, and in 'Tifton 85' bermudagrass hay in Yr 2

Sampling Date	Treatment[1]				Mean
	56N	112N	168N	HAY	
Nov 11	17.7[a]	16.0[b]	22.3[c]	10.2[d]	16.6[x]
Nov 25	11.5[a]	11.0[b]	16.1[c]	9.2[d]	12.0[y]
Dec 10	9.1[a]	11.2[b]	11.4[b]	8.9[c]	10.1[z]
Jan 7	9.1[a]	11.2[b]	11.4[b]	8.6[c]	10.1[z]
Jan 21	9.0[a]	10.1[b]	11.4[c]	8.2[d]	9.7[z]
Mean	11.3[j]	12.0[k]	14.5[l]	9.0[m]	

[a,b,c,d]Within a row, means without a common superscript differ (*P* < 0.05; SEM = 0.04; n = 2).
[x,y,z] Within a column, means without a common superscript differ (*P* < 0.05; SEM = 0.04; n = 8).
[j,k,l,m] Within a row, means without a common superscript differ (*P* < 0.05; SEM = 0.06; n = 10).
[1]56N = 56 kg N/ha; 112N = 112 kg N/ha; 168N = 168 kg N/ha; 'Tifton 85' hay cut in August prior to stockpiling (HAY).

Cell-wall constituents and in vitro dry matter digestibility. In both Yr 1 and 2, NDF concentrations (Tables 7 and 8, respectively) across all sampling dates were greater ($P < 0.05$) for the HAY than stockpile treatments. A sampling date × treatment interaction ($P < 0.05$) in Yr 1 was caused primarily by the HAY treatment having greater ($P < 0.05$) NDF concentration than the stockpiles in late October, but NDF concentrations that were not different from 56N at all other sampling dates, not different from 112N in January, and not different from 168N in early January. There were differences ($P < 0.05$) among the 3 stockpiled treatments, with 56N having the greatest ($P < 0.05$) NDF concentration across all sampling dates followed by the 112N and 168N treatments. Across all treatments, forage NDF concentration was 3.2 percentage units greater ($P < 0.05$) in the month of November than October, but increased ($P < 0.05$) only slightly in early January. In Yr 2, there was a treatment × day interaction ($P < 0.05$) which was due primarily to differences in NDF concentration among the stockpile treatments in early November and January, but lack of differences among them in late November and early December. Forage NDF concentration was less ($P < 0.05$) for the 168N treatment than the 56N, 112N and HAY treatments in January, and the HAY treatment was greater ($P < 0.05$) than the stockpiled treatments prior to January. The HAY treatment was not different from the 112N treatment on January 7. On January 21, the HAY treatment was not different from the 56N treatment, but was less ($P < 0.05$) than the 112N treatment and greater ($P < 0.05$) than the 168N treatment. Forage NDF concentrations were 2.2, 2.5 and 6.0 percentage units greater ($P < 0.05$), respectively, for the 56N, 112N and HAY treatments than the 168N treatment across all sampling dates. Across all treatments, mean NDF concentration increased over time beginning on November 25 and were, on average, 2.6 and 3.1 percentage units greater ($P < 0.05$) in early and late January, respectively, than December. Mean forage NDF concentrations for Yr 1 and Yr 2 were 69.3 and

66.4%, respectively, which are comparable to those from a study in which Mandebvu et al. (1999) reported an average NDF concentration of 69.2% for 'Tifton 85' across all harvest dates. In this study, 'Tifton 85' yielded 80 g/kg more digestible NDF than 'Coastal' bermudagrass. In another study, Burns and Fisher (2007) reported an average NDF concentration of 67.7% for 'Tifton 85' bermudagrass hay in the central Piedmont of North Carolina. 'Tifton 85' is a larger-stemmed plant than 'Coastal', which may account for greater NDF concentrations in these hybrids (Hill et al., 1993).

In Yr 1, there was a treatment × sampling date interaction ($P < 0.05$) for ADF concentration (Table 9), largely because the stockpiled treatments were not different from each other except on December 13 when the 56N treatment was greater ($P < 0.05$) than the 168N treatment, but neither of these were different from the 112N and HAY treatment. Mean ADF concentrations across all sampling dates were greater ($P < 0.05$) for the HAY than the stockpile treatments, but were not different between the 168N and 112N treatments or between the 56N and 112N treatments. There was an increase ($P < 0.05$) in ADF concentration from November 28 to January 4 and, for the months of December and January, ADF concentrations across all treatments were greater ($P < 0.05$) than in the other months. In Yr 2 (Table 10), a treatment × time interaction ($P < 0.05$) resulted largely from the 112N treatment being greater than the 56N and 168N treatment only on January 21, but not at the other sampling dates, and greater ($P < 0.05$) for HAY than stockpiled forages in November and December, but not in January. Forage ADF concentrations across all treatments were less ($P < 0.05$) in late November than at other sampling dates except early December. Stockpiled forage treatments diverged during late January, at which time the 112N treatment had 2.6 and 4.7 percentage units greater ADF concentration than the 56N and 168N treatments, respectively. Forage concentrations of ADF in the present study averaged 32.7 and 29.8% in Yr 1 and Yr 2, respectively, across all treatments and sampling dates.

In Yr 1, concentrations of ADL (Table 11) across all sampling dates were greater ($P < 0.05$) for the HAY treatment than the 56N, 112N and 168N treatments, but were not different among the 56N, 112N and 168N treatments except in late January when 56N was less ($P < 0.05$) than 112N and 168N. In Yr 2, forage concentration of ADL in the HAY treatment was greater ($P < 0.05$) than all 3 stockpile treatments, and the stockpile treatments were different ($P < 0.05$) from each other at all sampling dates. Average lignin concentrations for Yr 1 and Yr 2 were 3.2 and 4.4%, respectively; Yr 2 results are comparable to those from a study where Burns and Fisher (2007) reported an overall mean lignin concentration in bermudagrass of 4.7%. Concentrations of lignin increased considerably more in Yr 2 than in Yr 1 as a result of weathering. For dormant forage, Wheeler et al. (1999) observed no change in concentrations of NDF, ADF, or lignin in esophageal masticate samples collected from cows grazing stockpiled bermudagrass pastures between November and February in Oklahoma. Mean concentrations of NDF, ADF and lignin in masticate samples over 4 sampling dates were 611, 337, and 80 g/kg DM, respectively.

There was a treatment × time interaction for percentage IVDMD in Yr 1 (Table 13) such that there were no differences among treatments on January 4 and January 16, but all 3 stockpiled treatments were greater ($P < 0.05$) than the HAY treatment on October 24. Mean initial IVDMD was 11.7, 16.9 and 16.8 percentage units greater ($P < 0.05$) for the 56N, 112N and 168N treatments than the HAY treatment, respectively, in Yr 1. Mean IVDMD across all treatments declined 6.1, 3.2 and 3.3 percentage units from the preceding sampling date in November, early-January and mid-January, respectively. In Yr 2 (Table 14), there was a treatment × time interaction ($P < 0.05$) largely because the 168N treatment was not different from the other stockpile treatments at any sampling date, except in late November when the 168N treatment was greater ($P < 0.05$) than the other stockpile treatments. There were no differences among treatments in mean IVDMD on January 7, but mean IVDMD was greater ($P < 0.05$) for all three stockpiled treatments than the HAY treatment at all other sampling dates. Mean IVDMD across all treatments declined considerably (14.6%) from early November to December. The stockpiled treatments in Yr 2 remained at values that met cows' requirement for TDN (NRC, 1996) throughout the experiment; however, the HAY treatment declined below that required, warranting supplementation with whole cottonseed. Mandebvu et al. (1999) reported average IVDMD to be between 61.7 (3 weeks harvest) and 56.9% (6 weeks harvest), which is in agreement with values in the present study. Alderman et al. (2011) indicated that percentage IVDMD was increased by N fertilization, but was greatly diminished once N rate was increased beyond 90 kg/ha. Despite relatively high NDF concentrations in 'Tifton 85' in the present study, the observed IVDMD values suggest that its fiber was highly digestible, in agreement with previous research (Hill et al. 1993; Mandebvu et al. 1998a). Mandebvu et al. (1998b) reported declines in the digestibility of DM, OM and NDF with increased NDF concentration in 'Coastal'; however, even though NDF concentration was greater than that of 'Coastal', there was a positive correlation between NDF concentration and digestibilities of DM, OM and NDF in 'Tifton 85'. The authors concluded that this observation may have been related to the greater network of indigestible ethereal linkages between ferulic acid and arabinoxylans in 'Coastal' than in 'Tifton 85'.

In Yr 1, a warmer, wetter late summer and fall combined with a warmer winter caused a favorable response in forage mass, and contributed to greater stability of the stockpiled treatments and less forage deterioration. All 3 rates of N were successful in maintaining acceptable amounts of forage mass throughout the grazing season, and there was a lack of divergence in forage mass among treatments. Colder, drier conditions in Yr 2 contributed to decreased mass and greater forage deterioration. Treatment divergence occurred in Yr 2 with the greatest amount of forage mass resulting from the application of 168 kg N/ha. Considerable declines occurred in CP concentration and percentage IVDMD in both years. Forage CP concentrations in both years were adequate for meeting the CP requirement (10.0% CP) of a 591-kg mature, lactating beef cow during peak lactation. Percentage IVDMD in both years, with the exception of the 168N treatment in Yr 2, was slightly less than the requirement for digestible DM, or TDN (55.0%).

Table 7. Concentration of NDF (%, DM basis) in stockpiled 'Tifton 85' bermudagrass receiving different rates of N fertilization, and in 'Tifton 85' bermudagrass hay in Yr 1

Sampling Date	Treatment[1]				Mean
	56N	112N	168N	HAY	
Oct 24	64.8[a]	65.0[a]	62.0[a]	72.5[b]	66.1[x]
Nov 28	70.5[a,b]	67.0[a]	67.3[a]	72.4[b]	69.3[y]
Dec 13	70.6[a,b]	67.3[a]	65.2[a]	72.6[b]	69.1[y]
Jan 4	73.6	71.2	70.3	72.3	71.8[z]
Jan 16	69.5[a,b]	69.8[a,b]	68.0[a]	72.6[b]	70.0[y]
Mean	69.8[j]	68.2[k]	66.6[l]	72.5[m]	

[a,b,c] Within a row, means without a common superscript differ ($P < 0.05$; SEM = 1.17; n = 2).
[x,y,z] Within a column, means without a common superscript differ ($P < 0.05$; SEM = 1.17; n = 8).
[j,k,l,m] Within a row, means without a common superscript differ ($P < 0.05$; SEM = 1.66; n = 10).
[1]56N = 56 kg N/ha; 112N = 112 kg N/ha; 168N = 168 kg N/ha; 'Tifton 85' hay cut in August prior to stockpiling (HAY).

Table 8. Concentration of NDF (%, DM basis) in stockpiled 'Tifton 85' bermudagrass receiving different rates of N fertilization, and in 'Tifton 85' bermudagrass hay in Yr 2

Sampling Date	Treatment[1]				Mean
	56N	112N	168N	HAY	
Nov 11	65.9[a]	63.5[b,c]	63.3[c]	68.5[d]	65.3[w]
Nov 25	62.8[a]	61.4[a]	60.7[a]	69.4[b]	63.6[x]
Dec 10	65.4[a]	64.6[a]	63.0[a]	70.4[b]	65.9[w]
Jan 7	67.8[a]	69.1[a,c]	66.5[b]	70.6[c]	68.5[y]
Jan 21	67.9[a]	72.7[b]	64.7[c]	70.2[a]	69.0[y]
Mean	66.0[j]	66.3[j]	63.8[k]	69.8[l]	

[a,b,c,d]Within a row, means without a common superscript differ (*P* < 0.05; SEM = 0.77; n = 2).
[w,x,y,z] Within a column, means without a common superscript differ (*P* < 0.05; SEM = 0.77; n = 8).
[j,k,l] Within a row, means without a common superscript differ (*P* < 0.05; SEM = 1.10; n = 10).
[1]56N = 56 kg N/ha; 112N = 112 kg N/ha; 168N = 168 kg N/ha; 'Tifton 85' hay cut in August prior to stockpiling (HAY).

Table 9. Concentration of ADF (%, DM basis) in stockpiled 'Tifton 85' bermudagrass receiving different rates of N fertilization, and in 'Tifton 85' bermudagrass hay in Yr 1

Sampling Date	Treatment[1]				Mean
	56N	112N	168N	HAY	
Oct 24	27.9[a]	27.4[a]	26.9[a]	36.6[b]	30.1[x]
Nov 28	31.2[a]	28.6[a]	29.2[a]	34.7[b]	30.5[x]
Dec 13	34.1[a]	32.7[a,b]	31.3[b]	34.3[a]	33.1[y]
Jan 4	36.1	34.7	34.3	34.0	34.8[z]
Jan 16	34.7	36.5	34.5	34.6	34.7[z]
Mean	32.8[j]	31.9[j,k]	31.2[k]	34.8[l]	

[a,b] Within a row, means without a common superscript differ (*P* < 0.05; SEM = 0.93; n = 2).
[x,y,z] Within a column, means without a common superscript differ (*P* < 0.05; SEM = 0.93; n = 8).
[j,k,l] Within a row, means without a common superscript differ (*P* < 0.05; SEM = 1.31; n = 10).
[1]56N = 56 kg N/ha; 112N = 112 kg N/ha; 168N = 168 kg N/ha; 'Tifton 85' hay cut in August prior to stockpiling (HAY).

Table 10. Concentration of ADF (%, DM basis) in stockpiled 'Tifton 85' bermudagrass receiving different rates of N fertilization, and in 'Tifton 85' bermudagrass hay in Yr 2

Sampling Date	Treatment[1]				Mean
	56N	112N	168N	HAY	
Nov 11	30.8[a]	29.8[a]	29.7[a]	38.0[b]	32.1[x]
Nov 25	28.1[a]	26.7[a]	27.7[a]	33.0[b]	28.9[y]
Dec 10	30.0[a]	28.5[a]	29.6[a]	34.2[b]	30.6[x,y]
Jan 7	31.7[a]	32.1[a,b]	32.1[a,b]	34.1[b]	32.5[x]
Jan 21	31.1[a,c]	33.7[b]	29.0[c]	33.1[a,b]	31.7[x]
Mean	30.3[j]	30.2[j]	29.6[j]	34.5[k]	

[a,b,c] Within a row, means without a common superscript differ (*P* < 0.05; SEM = 0.75; n = 2).
[x,y] Within a column, means without a common superscript differ (*P* < 0.05; SEM = 0.75; n = 8).
[j,k] Within a row, means without a common superscript differ (*P* < 0.05; SEM = 1.06; n = 10).
[1]56N = 56 kg N/ha; 112N = 112 kg N/ha; 168N = 168 kg N/ha; 'Tifton 85' hay cut in August prior to stockpiling (HAY).

Table 11. Concentration of ADL (%, DM basis) in stockpiled 'Tifton 85' bermudagrass receiving different rates of N fertilization, and in 'Tifton 85' bermudagrass hay in Yr 1

Sampling Date	Treatment[1]				Mean
	56N	112N	168N	HAY	
Oct 24	1.6[a]	1.4[a,b]	1.3[b]	2.1[c]	1.6[w]
Nov 28	1.8[a]	1.9[a]	1.9[a]	2.9[b]	2.1[w]
Dec 13	3.1[a]	3.0[a]	3.0[a]	3.5[b]	3.2[x]
Jan 4	4.3[a]	4.2[a]	4.2[a]	4.4[b]	4.3[y]
Jan 16	4.5[a]	4.9[b]	4.9[b]	5.3[c]	4.9[z]
Mean	3.1[j]	3.1[j]	3.1[j]	3.6[k]	

[a,b,c] Within a row, means without a common superscript differ ($P < 0.05$; SEM = 0.05; n = 2).
[w,x,y,z] Within a column, means without a common superscript differ ($P < 0.05$; SEM = 0.05; n = 8).
[j,k] Within a row, means without a common superscript differ ($P < 0.05$; SEM = 0.07; n = 10).
[1]56N = 56 kg N/ha; 112N = 112 kg N/ha; 168N = 168 kg N/ha; 'Tifton 85' hay cut in August prior to stockpiling (HAY).

Table 12. Concentration of ADL (%, DM basis) in stockpiled 'Tifton 85' bermudagrass receiving different rates of N fertilization, and in 'Tifton 85' bermudagrass hay in Yr 2

Sampling Date	Treatment[1]				Mean
	56N	112N	168N	HAY	
Nov 11	1.8[a]	1.7[b]	1.9[c]	3.7[d]	2.3[v]
Nov 25	3.7[a]	3.4[b]	3.9[c]	4.7[d]	3.9[w]
Dec 10	4.1[a]	3.7[b]	4.4[c]	6.5[d]	4.7[x]
Jan 7	4.2[a]	4.3[b]	5.1[c]	6.8[d]	5.1[y]
Jan 21	5.7[a]	5.6[b]	6.7[c]	6.7[c]	6.2[z]
Mean	3.9[j]	3.7[k]	4.3[l]	5.7[m]	

[a,b,c,d] Within a row, means without a common superscript differ ($P < 0.05$; SEM = 0.03; n = 2).
[v,x,y,z] Within a column, means without a common superscript differ ($P < 0.05$; SEM = 0.03; n = 8).
[j,k,l,m] Within a row, means without a common superscript differ ($P < 0.05$; SEM = 0.04; n = 10).
[1]56N = 56 kg N/ha; 112N = 112 kg N/ha; 168N = 168 kg N/ha; 'Tifton 85' hay cut in August prior to stockpiling (HAY).

Table 13. Percentage of IVDMD in stockpiled 'Tifton 85' bermudagrass receiving different rates of N fertilization, and in 'Tifton 85' bermudagrass hay in Yr 1

Sampling Date	Treatment[1]				Mean
	56N	112N	168N	HAY	
Oct 24	69.2[a]	74.4[a]	74.3[a]	57.5[b]	68.1[w]
Nov 28	61.4[a,b]	63.9[b]	65.7[b]	56.9[a]	62.0[x]
Dec 13	56.8[a]	58.3[a,b]	64.4[b]	56.9[a,b]	59.1[x]
Jan 4	56.4	57.1	52.0	57.9	55.9[y]
Jan 16	53.7	52.0	51.0	53.7	52.6[z]
Mean	59.6[j]	61.1[j]	61.4[j]	56.6[k]	

[a,b] Within a row, means without a common superscript differ ($P < 0.05$; SEM = 2.10; n = 2).
[w,x,y,z] Within a column, means without a common superscript differ ($P < 0.05$; SEM = 2.10; n = 8).
[j,k] Within a row, means without a common superscript differ ($P < 0.05$; SEM = 2.97; n = 10).
[1]56N = 56 kg N/ha; 112N = 112 kg N/ha; 168N = 168 kg N/ha; 'Tifton 85' hay cut in August prior to stockpiling (HAY).

Table 14. Percentage of IVDMD in stockpiled 'Tifton 85' bermudagrass receiving different rates of N fertilization, and in 'Tifton 85' bermudagrass hay in Yr 2

Sampling Date	Treatment[1]				Mean
	56N	112N	168N	HAY	
Nov 11	71.8[a]	73.5[a]	74.5[a]	50.0[b]	67.5[x]
Nov 25	62.0[a]	63.0[a]	69.6[b]	46.4[c]	60.1[y]
Dec 10	54.2[a]	58.0[a]	54.5[a]	44.7[b]	52.9[z]
Jan 7	49.5	51.5	51.0	45.2	49.3[z]
Jan 21	51.0[a]	52.5[a]	55.4[a]	45.3[b]	51.1[z]
Mean	57.7[j]	59.7[j]	61.0[j]	46.3[k]	

[a,b,c] Within a row, means without a common superscript differ (P < 0.05; SEM = 1.55; n = 2).
[x,y,z] Within a column, means without a common superscript differ (P < 0.05; SEM = 1.55; n = 8).
[j,k] Within a row, means without a common superscript differ (P < 0.05; SEM = 2.20; n = 10).
[1]56N = 56 kg N/ha; 112N = 112 kg N/ha; 168N = 168 kg N/ha; 'Tifton 85' hay cut in August prior to stockpiling (HAY).

Cow BW and BCS. Simple means of initial cow BW (647 ± 23 kg), BCS (5.8 ± 0.5) and age (5.2 ± 2.1 yrs) are shown in Table 15 for each treatment and year. Cow BW was affected (P < 0.05) by sampling date and cow age. Regardless of year, cow BW declined over the duration of the grazing period. There were linear and cubic ($P < 0.05$) responses over time for least squares means of cow BW. Cow BW was greatest at the initiation of the grazing period (Table 16), but was less ($P < 0.05$) by the next weigh date. However, cow BW was largely unchanged from late November through January. Cow BW then declined ($P < 0.05$) again by the end of the grazing period such that mean cow final BW in February was 78.9 kg less than mean initial BW. The amount of BW loss in the present study is comparable to lactating-cow BW losses in a stockpiled tall fescue grazing experiment where Curtis et al. (2008) reported an average cow BW loss of 105 kg for the grazing treatments and 43 kg for a control hay treatment. Timing of BW loss in the present study is comparable to that from previous reports in the literature. Wheeler et al. (2002) reported greater cow BW loss from d 31 to 79 (November through January) of their study in year 1, and from d 64 to 90 (December and January) in year 2.

Cow BCS (Table 16) was largely unchanged through December ($P > 0.05$), but declined ($P < 0.05$) considerably beginning in January. In the present study, total BCS loss was 0.67 units, with the greatest BCS loss occurring during peak lactation. However, in a similar study, Wheeler et al. (2002) reported slightly greater BCS losses (0.70 and 0.42 for Yr 1 and Yr 2, respectively) over a similar time period. Even though all treatments experienced marginal declines in BW and BCS, fertilized, stockpiled 'Tifton 85' bermudagrass was as effective in minimizing BW and BCS loss as *ad libitum* access to 'Tifton 85' hay plus 2.7 kg of whole cottonseed.

Although there were no differences ($P < 0.05$) in cow BW and BCS between Yr 1 and Yr 2, record low winter temperatures in Yr 2 coupled with peak lactation may have influenced cow

BW and BCS. During the peak lactation period in Yr 2, a mean low temperature of -1 °C was recorded in January, which is only slightly below the critical temperature for cows with dry winter coats; also, during mid-January, sleet and ice resulted in wet winter coats. Loss of insulation results in an increase of critical temperature to 15 °C, at which point energy needs increase by 20% (Young, 1983). Fall-calving cows are expected to lose BCS over winter (Coffey et al., 2005). However, the cows in the present study began the experiment in excellent body condition (5.5 to 6 units) and were able to withstand marginal loss in BW and BCS. In the previously referenced stockpiled tall fescue grazing experiment, Curtis et al. (2008) reported an average BCS loss of 0.79 and 0.42 in Yr 1 and Yr 2, respectively. In the present study, forage CP concentration was not limiting in the stockpiled forage grazed by lactating cows (NRC, 1996). TDN was limiting only in late January, at which point IVDMD declined in all stockpile treatments (NRC, 1996). In other studies under similar conditions where cows consumed stockpiled forage (Lusby et al., 1991; Marston et al., 1998; Steele et al., 2007) or low-quality hay (Banta et al., 2006) and fed a concentrated CP supplement, beef cows continued to experience BCS loss during the winter feeding period.

Table 15. Simple means of age and body measurements of cows and calves wintered on stockpiled 'Tifton 85' bermudagrass receiving different rates of N fertilization, or on 'Tifton 85' bermudagrass hay plus supplement during Yr 1 and Yr 2

	Treatment[1]							
	56N		112N		168N		HAY	
Trait	Yr 1	Yr 2	Yr 1	Yr 2	Yr 1	Yr 2	Yr 1	Yr 2
Cow parameters								
Age, yrs	6.5	5.0	5.0	5.0	5.5	4.8	4.8	5.5
Initial BW, kg	670	641	620	612	705	641	638	634
Initial BCS	6.0	5.8	5.8	5.1	6.0	5.7	6.0	5.8
Calf parameters								
Initial BW, kg	41.3	60.4	47.7	52.4	49.4	53.7	44.4	66.6
Initial height, cm	71.4	66.7	76.5	76.8	74.6	69.2	74.0	73.6
Birth weight, kg	45.5	39.3	41.3	42.0	43.7	38.5	46.9	40.8
Actual weaning weight, kg	269	220	261	241	273	240	291	251
Age at weaning, d	212	202	215	207	213	203	224	203

[1]56N = 56 kg N/ha; 112N = 112 kg N/ha; 168N = 168 kg N/ha; 'Tifton 85' hay cut in August prior to stockpiling (HAY).

Table 16. Body weight and body condition score of cows, and body weight and hip height (hh) of their calves wintered on stockpiled 'Tifton 85' bermudagrass receiving different rates of N fertilization, or on 'Tifton 85' bermudagrass hay plus supplement during Yr 1 and Yr 2

	Month[1]				
Trait	Early-Nov	Late-Nov	Dec	Jan	Feb
Cow BW and BCS[2]					
BW, kg	647.2[a]	610.0[b]	615.4[b]	615.6[b]	568.3[c]
BCS	5.8[a]	5.7[a]	5.5[a,c]	5.3[b,c]	5.2[b]
Calf BW and hh[3]					
BW, kg	52.0[a]	71.0[b]	87.6[c]	104.0[d]	126.0[e]
hh, cm	72.9[a]	81.2[b]	87.4[b]	90.8[b]	95.8[e]

[a,b,c,d,e] Within a row, means without a common superscript differ ($P < 0.05$).

[1]Early-Nov = November 1, 2012 and November 11, 2013; Late-Nov = November 25, 2012 and November 28, 2013; Dec = December 13, 2012 and December 10, 2013; Jan = January 7, 2012 and January 7, 2013; Feb = February 14, 2012 and February 1, 2012.

[2] Cow BW SEM = 11.0 kg; cow BCS SEM = 0.60.

[3] Calf BW SEM = 5.9 kg; calf hh SEM = 0.29 cm.

Milk Production. There were no sources of variation ($P > 0.05$) for milk production in this study, and mean milk production across all treatments and sampling dates was 9.0 kg/d. Also, there were no effects of age of cow or sex of calf on milk production. Several other studies (Reynolds et al., 1978; Chenette and Frahm, 1981; Daley et al., 1987) reported little or no effect of calf sex on dam's milk production. Rutledge et al. (1971) reported an increase of milk production for dams of heifers. However, Pope et al. (1963), McCuskey et al. (1986) and Daley et al. (1987) reported that dams of bull calves produced more milk than dams of heifer calves. For 591-kg mature weight beef cows, peak milk production at 9.1 kg/d requires a diet containing 10.0% CP and 55.0% IVDMD at 3 to 4 months postpartum (NRC, 1996). While cows were losing BW and BCS postpartum in the present study, milk production was expected to increase; however, estimated daily milk production in both years remained largely unchanged. Across all stockpile treatments, mean percentage CP and IVDMD of the forage during peak lactation was 11.0% and 57.5% for Yr 1, respectively, and 10.1% and 51.1% for Yr 2, respectively, which meet the CP and TDN requirements of cows utilized in the present study except for TDN as reflected by IVDMD in Yr 2 at the last forage sampling date.

Blood Urea Nitrogen. Sampling date was the only source of variation ($P < 0.05$) for cow BUN (Table 17). There were linear and quadratic ($P < 0.05$) responses over time for BUN levels. There were no differences ($P > 0.05$) in BUN levels 31 or 45 d postpartum. However, at 116 d postpartum, BUN levels were greater ($P < 0.05$). In terms of N fertilization effects on BUN levels, in the present study, there were no observed effects.

Compared with the first two sampling dates, mean forage CP concentration across all treatments had declined only to 10.0% by the last sampling date. When BUN levels were least, mean forage CP concentration in Yr 1 and Yr 2 were 11.0 and 10.1%, respectively. When BUN levels were greatest, mean CP concentrations were 10.0 and 9.7 in Yr 1 and Yr 2, respectively. Whereas the HAY treatment includes CP from whole cottonseed supplementation, in terms of BUN levels, it was still comparable to the stockpiled treatments. However, when BUN levels were greatest, TDN was lowest for all treatments, which explains why the BUN levels were increased at the end of the study due to the decline in energy to protein ratio (Hammond et al., 1993). Cow BUN levels in the present study are comparable to ranges of values found in other studies. Hammond et al. (1993) summarized data from eight grazing trials in Florida to determine whether BUN could predict the biological response (change in average daily body weight gain, ADG) to protein and/or energy supplementation in steers and heifers grazing warm season grass pastures. In these studies, animals grazed bahiagrass (*Paspalum notatum*) and limpograss (*Hemarthria altissima*), and comparisons between protein supplement treatments and various controls were evaluated. Change in ADG (-.05 to .30 kg/day) due to protein supplementation was linearly related to BUN concentration (6.2 to 15.5 mg/dL) in control cattle (r = .69). Concentrations of BUN between 9 and 12 mg/dL were within a transition range, below which ADG response to protein supplementation was greater, and above which ADG response was less than the response within this range. Other studies in the literature have shown BUN values affected by N fertilization rate, lactation states and cow age. Lima et al. (1994) indicated that increasing N fertilization in common bermudagrass increased BUN in yearling heifers from 4.2 to 9.2 mg/dL and increased ADG from 0.06 to 0.36 kg/d. In the present study, at the end of the grazing season in February, BUN levels increased 2.3 ml/dL. There were no age effects on BUN levels. In dairy cows, BUN increased as cows progressed from the dry stage through early lactation and the lactating pregnant period, and BUN increased with increasing age (Peterson and Waldern, 1981).

Table 17. Least square means of BUN (ml/dL) and milk production (kg/d) of cows wintered on stockpiled 'Tifton 85' bermudagrass receiving different rates of N fertilization, or on 'Tifton 85' bermudagrass hay plus supplement during Yr 1 and Yr 2

	Sampling Period			
Trait	1	2	3	SEM
BUN[1]	10.6[a]	10.2[a]	13.0[b]	0.59
Milk, kg[2]	8.7	9.3	9.0	2.30

[a,b] Within a row, means without a common superscript differ ($P < 0.05$).
[1] BUN measured on 31, 45 and 116 d postpartum.
[2] Milk production on 31, 45 and 161 d postpartum.

Cow reproductive performance. No independent variables were significant sources of variation for pregnancy rate or projected calving interval for this study. Treatment did not influence overall pregnancy rate, and overall mean rebreeding rate was 88%. Adams et al. (1996) reported that BCS and pregnancy rates of cows consuming stockpiled forage in the Nebraska Sandhills and cows consuming hay-based diets were not different, but pre-breeding weights were less for cows grazing stockpiled forage. Even with declines in BW and BCS at the time of breeding, conception rates did not seem to have been affected. In the present study, Yr 2 included 3 open cows which began the study in lower body condition than the other Yr-2 cows, and they were also 3-yr-olds. Houghton et al. (1990) evaluated the BCS of cows at critical junctures and reported that fertility was greater for cows maintaining or approaching a BCS of 5 than cows moving away from moderate BCS, including cows getting thinner or fatter, regardless of the energy intake treatment to which each cow had been assigned. In the present study, the nutritional plane was adequate for cows to maintain their potential for milk production with only modest losses in energy reserves, which should not have impacted rebreeding.

Calf Performance. Simple means of calf birth weight (42.3 ± 9.8 kg), initial BW (52.1 ± 0.5 kg) and initial hip height (72.9 ± 1.8 cm) are shown in Table 15. Independent variables of year, treatment and sampling date were sources of variation ($P < 0.05$) in calf performance measures. There was a year × treatment interaction ($P < 0.05$) for calf BW and a linear effect ($P < 0.05$) of time on calf BW (Table 16). At each time period, calf weight was greater ($P < 0.05$) than the previous weigh date. These results were expected since calves are in a linear ($P < 0.05$) growth curve from birth to weaning.

In Yr 1 of this study, there were no differences in calf BW across treatments. However, for Yr 2, calf BW for the HAY treatment was greater ($P < 0.05$) than the stockpile treatment calves, but there were no differences ($P > 0.05$) for calf BW among the 3 stockpile treatments. Also, Yr-2 calf BW was 31 kg greater ($P < 0.05$) than Yr 1 calf BW at the end of the grazing period. In Yr 2, all calves utilized in the study were sired by low-birth-weight, high-growth-EPD bulls. In Yr 1, all calves were sired by a natural-service sire. The AI bull did possess higher growth potential than the natural service bull.

Differences in calf BW are not due to differences in milk production of cows (Table 17). Rutledge et al. (1971) showed that a dam's milking ability describes 66% of the variation in calf weaning weight. Adams et al. (1996) observed that calves from cows grazing stockpiled forage in the sandhills of Nebraska were lighter at birth than calves from cows fed a hay-based diet, but there were no differences in calf weight at weaning.

For calf hip height (Table 16), sources of variation ($P < 0.05$) included year and time. A linear and quadratic effect ($P < 0.05$) of time was detected. Calf hip height was greater ($P < 0.05$) at each subsequent weigh period, as expected. In Yr 2, calves were 3.4 cm shorter ($P > 0.05$) than calves in Yr 1.

Simple means of calf age at weaning (209.9 ± 9.7 d) and actual weaning weight (563.5 ± 71.5 kg) for each treatment in both years are shown in Table 15. Year was the only source of variation ($P < 0.05$) for 205-d weight or 205-d weight adjusted to a bull basis (Table 18). Calves were 20 kg heavier ($P < 0.05$) in Yr 1 for 205-d weight and 21 kg heavier in Yr 1 for 205-d weight adjusted to a bull basis. While it is expected to have yearly fluctuation in weaning weight, it was unexpected that Yr-1 calves would weigh more ($P < 0.05$) than Yr-2 calves. In Yr 2, calf BW was greater ($P < 0.05$) at the end of the stockpile period; however, they grew poorly from February through May. Milk production does not provide a satisfactory explanation for the differences found in weaning weights, because no differences were detected among treatments or between years. However, Yr-1 calves were placed on ryegrass pasture with their dams at the end of the grazing period, whereas Yr 2 calves had to remain on the test pastures with hay due to lack of available ryegrass pasture in Yr 2. Weaning weights in the present study were greater than those from a similar study in which Curtis et al. (2008) reported average weaning weight from calves nursing cows grazing stockpiled fescue to be 195 ±8 kg when cows were given access to strips of forage to meet 2.25% of BW/d per cow.

Table 18. Weaning weight (ww) of calves nursing cows wintered on stockpiled 'Tifton 85' bermudagrass receiving different rates of N fertilization, and in 'Tifton 85' bermudagrass hay plus supplement during Yr 1and Yr 2

	Sampling Date		
Trait	Yr 1	Yr 2	SEM
205-d ww, kg	268[a]	248[b]	5.7
Adj. ww	279[a]	257[b]	5.9

[a,b] Within a row, means without a common superscript differ ($P < 0.05$).

Economics of winter feeding systems. Economic evaluation of the stockpiled treatments compared with the HAY treatment (Table 19), and an additional comparison of feeding hay without supplement was made. Variables included were cost of N (ammonium nitrate), forage establishment, herbicide, labor, harvest, supplement, and machinery. Hay-feeding wastage was calculated throughout the study and averaged 20%. It was revealed that input costs/cow were 66.0, 61.0 and 56.0% greater for HAY than 56N, 112N and 168N, respectively. In addition, hay alone was 11% lower in cost than hay plus supplement. In an Oklahoma study (Lalman et al., 2000), economic simulation and sensitivity analyses were conducted comparing three 100-d systems: Stockpiled bermudagrass, tall grass prairie, and bermudagrass hay (HAY). Sensitivity of input variables for the SB system was determined by changing one variable while holding all other variables constant until the total cost for the 100-d period equaled that of the hay system. Total feed and forage costs/cow for the 100-d period were $39.61, $42.80, and $71.88 for SB, TGP, and HAY, respectively.

The strategy of applying financial resources toward feeding and supplementing the cow herd is an enterprise-specific decision. The key is to find the point at which cattle performance and cost outlays are optimized (Hersom et al., 2008). This will be affected by many variables including expected cow performance, previous cow condition, forage conditions, supplement type, and environmental conditions.

Table 19. Estimated costs ($/cow/ha) associated with stockpiled 'Tifton 85' bermudagrass pasture or hay plus supplement.

	Treatment[1]			
Item	56N	112N	168N	Hay + suppl.
Nitrogen, kg	$23.91	$47.81	$71.72	0
Grazing cost	$108.80	$108.80	$108.80	0
Hay	0	0	0	$237.27
Labor	$16.97	$16.97	$16.97	$32.50
Supplement	0	0	0	$146.16
Fixed costs of machinery	$24.50	$24.50	$24.50	$90.63
Cost per cow	$174.18	$198.08	$221.99	$506.53

[1]56N = 56 kg N/ha; 112N = 112 kg N/ha; 168N = 168 kg N/ha; 'Tifton 85' hay cut in August prior to stockpiling (HAY).

Implications

Results of this study are interpreted to mean that fertilized stockpiled 'Tifton 85' bermudagrass was sufficient in its productivity and nutritive value to support lactating beef cows and reproductive performance without supplementation. Whether to supplement cows during the grazing season must be a strategic management decision and implementation of a supplement program must have a measurable positive outcome in order to have biological relevance and justify its continued use. Cow weight and body condition were fairly consistent from year to year. Calf weights showed dramatic changes, which could have been due to the considerable variation that occurred from year to year in precipitation profiles and in quantity and quality of forage available, which were associated with the variation in response from year to year.

Literature Cited

Adams, N.R. 1995. Detection of the effects of phytoestrogens on sheep and cattle. J. Anim. Sci. 73:1509-1515.

Adams, Don, R. Clark, T. Klopfenstein, and J. Volesky. 1996. Nutritional value of grazed forages and how it fits the cow's requirement. Range Beef Cow Symposium. Paper 192.

Alderman, P.D., K. J. Boote, and L. E. Sollenberger. 2011. Regrowth dynamics of 'Tifton 85' bermudagrass as affected by nitrogen fertilization. Crop. Sci. 51: 1716-1726.

Alexander, R. A., J. F. Hentges, Jr., J. T. McCall, H. W. Lundy, N. Gammon, Jr., and W. G. Blue. 1961. The nutritive value of fall-harvested coastal bermudagrass hay as affected by rate of nitrogen fertilization and state of maturity. J. Anim. Sci. 20: 93-98.

AOAC. 1990. Official Methods of Analysis. 15th ed. Assoc. Offic. Anal. Chem., Arlington, VA.

Ball, D. M., C. S. Hoveland, G. D. Lacefield. 2007. Southern Forages. 4th ed. Williams Printing Company, Atlanta, GA.

Banta, J.P., Lalman D.L., Krehbiel C.R., Wettemann R.P. 2006. Whole soybean supplementation and cowage class: effects on intake, digestion, performance, and reproduction of beef cows. JAnim Sci. 86:1868-78.

Barnhart, S. 2013. Evaluate forage stands for winter injury. PM 1362. Iowa State University Extension Publications.

BIF. 2010. Guidelines for Uniform Beef Improvement Programs 9th Edition. Cundiff, L. V., L. D. VanVleck and W.D. Hohenbohen. Editors.

Bolton, J. K. and R. H. Brown. 1980. Photosynthesis of grass species differing in carbon dioxide fixation pathways. V. response of *Panicum maximum*, *Panicum miliodes*, and tall fescue (*Festuca arundinacea*) to nitrogen nutrition. Plant Physiol 66: 97-100.

Breese, M. and J. Horner. 2007. Projected beef cow/calf annual budget for calves sold in 2007. http://www.agebb.missouri.edu/mgt/budget/annlbeef.pdf.

Brink, G., M. Hall, P. Mertens and M. Caster. 2008. Grass yield and quality affect potential stocking rate and milk production. Forage and Grazinglands 6(1): 1313-1320.

Brown, R.H. 1978. A difference in N use efficiency in C3 and C4 plants and its implications in adaptation and evolution. Crop Sci 18: 93-98

Burns, J.C., and D.S. Fisher. 2006. Intake and digestion of 'Jesup' tall fescue hays with a nove endophyte, without an endophyte, or with a wild-type endophyte. Crop Sci. 46: 216 -223.

Burns, J. and D.S. Fisher. 2007. Dry matter intake and digestibility of 'Coastal', 'Tifton 44', and 'Tifton 85' Bermudagrass Hays Grown in the U.S. Upper South. Crop Sci. 47: 795 -810.

Burton, G. W. and E. H. De Vane. 1952. Effect of rate and method of applying different sources of nitrogen upon the yield and chemical composition of bermudagrass, *Cynodon dactylon* (L) Pers., and hay. Agron. J. 44: 128-132.

Burton, G.W., R. Gates, and G. Hill. 1993. Registration of 'Tifton 85' bermudagrass. Crop Sci. 33: 644-645.

Burton, G. W., and W. W. Hanna. 1995. Bermudagrass. In: R. F. Barnes, D. A. Miller, and C. J. Nelson (ed.) Forages – An introduction to grassland agriculture. 1:421. Iowa State University Press, Ames.

Chenette, C. G., and R. R. Frahm. 1981. Yield and composition of milk from various two-breed cross cows. J. Anim. Sci. 52: 483-492.

Coffey, K. P., W. K. Coblentz, D. A. Scarbrough, J. B. Humphry, B. C. McGinley, J. E. Turner, T. F. Smith, D. S. Hubbell III, Z. B. Johnson, D. H. Hellwig, M. P. Popp, and C. F. Rosenkrans Jr. 2005. Effect of rotation frequency and weaning date on forage measurements and growth performance by cows and calves grazing endophyte-infected tall fescue pastures overseeded with crabgrass and legumes. J. Anim. Sci. 83:2684–2695.

Corah, L..R., T..G. Dunn and C.C. Kaltenbach. 1975. Influence of prepartum nutrition on the reproductive performance of beef females and the performance of their progeny. J. Anim. Sci. 41:819-824.

Corriher, V.A., G.M. Hill, J.G. Andrae, M.A. Froetschel, and B.G. Mullinix. 2007. Cow and calf performance on Coastal or Tifton 85 Bermudgrass pastures with aeschynomene creep grazing paddocks. J. Anim. Sci. 85: 2762-2771.

Curtis, L.E., R.L. Kallenbach, and C.A. Roberts. 2008. Allocating forage to fall-calving cow-calf pairs strip-grazing tall fescue. J. Anim. Sci. 86: 780-789.

Daley, D. R., A. McCuskey, and C. M. Bailey. 1987. Composition and yield of milk from beef type Bos taurus and Bos indicus × Bos taurus dams. J. Anim. Sci. 64:373-384.

D'Souza, G. E., E. W. Maxwell, W. B. Bryan, and E. C. Prigge. 1990. Economics of extended grazing systems. Am. J. Alternative Agric. 5:120-125.

Freetly, H. C., and J. A. Nienaber. 1998. Efficiency of energy and nitrogen loss and gain in mature cows. J. Anim. Sci. 76: 896-905.

Funston, R.N., D.M. Larson, and K.A. Vonnahme. 2010. Effects of maternal nutrition on conceptus growth and offspring performance: Implications for beef cattle production. J. Anim. Sci. 88: 4094-4101.

Guretzky, John A., J. Ball, and B.J. Cook. 2008. Nitrogen fertilizer rate and weather dictate nutritive value of fall stockpiled bermudagrass. Forage and Grazinglands 10(1): 118-125.

Hammond, A. C., Kunkle, W.E., Bates, D.B. and Sollenberger, L.E. 1993. Use of blood urea nitrogen concentration to predict response to protein or energy supplementation in grazing cattle. In: Proc. of the XVll International Grassland Congress, pp. 1989-1991. Rockhampton, Australia.

Hart, R., W. Monson, and R. Lowrey. 1969. Lowrey. Autumn-saved coastal bermudagrass (Cynodon dactylon (L.) Pers.): Effects of age and fertilization on quality. J. Anim. Sci. 61: 940-941.

Henderson, M. S., and D. L. Robinson. 1982. Environmental influences on yield and in vitro true digestibility of warm-season perennial grasses and the relationships to fiber components. Agron. J. 74:943–946.

Hersom, M., E. 2008. Opportunities to enhance performance and efficiency through nutrient synchrony in forage fed ruminants. J. Anim. Sci. 86 (E. Suppl.): E306-17.

Hess, B.W., S. L. Lake, E. J. Scholljegerdes, T. R. Weston, V. Nayigihugu, J. D. C. Molle, and G. E. Moss. 2005. Nutritional controls of beef cow reproduction. J. Anim. Sci. 83(E. Suppl.):E90–E106.

Hill, G.M., R.N. Gates, and G.W. Burton. 1993. Forage quality and grazing steer performance from Tifton 85 and Tifton 78 bermudagrass pastures. J. Anim. Sci. 71:3219–3225.

Hill, G. M., R. N. Gates and J. W. West. 2001. Advances in bermudagrass research involving new cultivars for beef and dairy production. Invited Paper. J. Anim. Sci.79 (E. Suppl.): E48-E58.

Hodgson, J. 1981. Variations in the surface characteristics of the sward and the short-term rate of herbage intake by calves and lambs. Grass and Forage Science 36: 49–57.

Houghton, P.L., R.P. Lemenager, L.A. Horstman, K.S. Hendrix, and G.E. Moss. 1990. Effects of body composition, pre- and postpartum energy level and early weaning on reproductive performance of beef cows and preweaning calf gain. J. Anim. Sci. 68:1438-1446.

Hudson, W., D. Hancock, and K. Flanders. 2013. Biology and management of bermudagrass stem maggot. Alabama Cooperative Extension Systems. ANR- 1462.

Janovick, N. A., J. Russell, D. R. Strohbehn and D. G. Morris. 2002. Productivity and hay requirements of beef cattle in a Midwestern year-round grazing system. J. Anim. Sci. 82: 2503-2515.

Johnson, C. R., D. L. Lalman, A. D. O'Neil, and J. Steele. 2000. Effect of supplemental energy source and degradable intake protein amount on performance of spring-calving cows winter grazing stockpiled bermudagrass. J. Anim. Sci. 78 (Suppl. 1):115 (Abstr.).

Johnson, C. R., B. Reiling, P. Mislevy, and M. Hall. 2001. Effects of nitrogen fertilization and harvest date on forage yield, in-vitro organic matter digestibility, and protein fractions of tropical grasses. J. Anim. Sci. 79: 2439-2448.

Jung, H.G., and M. S. Allen. 1995. Characterisitics of plant cell walls affecting intake and digestibility of forages by ruminants. J. Anim. Sci. 73: 2774-2790.

Lalman, D. L., C. M. Taliaferro, F.M. Epplin, C. R. Johnson, and J. S. Wheeler. 2000. Review: Grazing stockpiled bermudagrass as an alternative to feeding harvested forage. J. Anim. Sci. 79: 1-8.

Lents, C. A., R. P. Wettemann, F. J. White, I. Rubio, N. H. Ciccioli, L. J. Spicer, D. H. Keisler, and M. E. Payton. 2005. Influence of nutrient intake and body fat on concentrations of insulinlike growth factor-I, insulin, thyroxine, and leptin in plasma of gestating beef cows. J. Anim. Sci. 83:586–596.

Licitra, G., T. M. Hernandez, and P. J. Van Soest. 1996. Standardization of procedures for nitrogen fractionation of ruminant feeds. Anim. Feed Sci. Technol. 57:347-358.

Lima, G. F. da C., L. E. Sollenberger, W. E. Kunkle, J. E. Moore, and A. C. Hammond. 1994. Improving limpograss forage quality and utilization using nitrogen fertilization and supplementation. In: National Conference on Forage Quality, Evaluation, and Utilization. p 90. Univ. Nebraska, Lincoln.

Lusby, K. S., R. P. Wettemann, K. H. Ovenell, and D. A. Cox. 1991. The value of wheat middlings in winter supplements for beef cows. Prof. Anim. Sci. 7:24-29.

Mandebvu, P., J. W. West, and G. M. Hill. 1998a. Effect of hay maturity, forage source, or neutral detergent fiber content on digestion of diets containing Tifton 85 bermudagrass and corn silage. Anim. Feed Sci. Technol. 73: 281-290.

Mandebvu, P., J. W. West, and G. M. Hill. 1998b. In vitro digestion kinetics of neutral detergent extracted from Tifton 85 bermudagrass and Coastal bermudagrass. Anim. Feed Sci. Technol. 73: 263-269.

Mandebvu, P., J. W. West, G. M. Hill, R. N. Gates, R. D. Hatfield, B. G. Mullinix, A. H. Parks, and A. B. Caudle. 1999. Comparison of Tifton 85 and Coastal bermudagrasses for yield, nutrient traits, intake, and digestion by growing beef steers. J. Anim. Sci. 77: 1572-1586.

Marston, T. T., Blasi, D. A., Brazle, F. K. and Kuhl, G. L. 1998. Beef Cow Nutrition Guide. Kansas State University Agricultural Experiment Station and Cooperative Extension Service Publication C-735.

McCuskey, A., D. R. Daley, and C. M. Bailey. 1986. Milk yield of beef-type Bos indicus × Bos taurus dams. J. Anim. Sci. 63:177 (Abstr.).

Mislevey, P. and Martin, F. 2007. Yield and nutritive value of stockpiled grasses as influenced by cultural practices and a freeze. Forage and Grazinglands. FG-2007-0206-01-RS.

Mullinix, J. T., S. H. Cox, M. E. Kemp, R. L. Endecott, R. C. Waterman, D.M. VanLeeuwen, and M.K. Peterson. 2012. Relationship between body condition score at calving and reproductive performance in young postpartum cows grazing native range. J. Anim. Sci. 90: 2811-2817.

Newman, S., A. Reverter, and D. J. Johnston. 2002. Purebred crossbred performance and genetic evaluation of postweaning growth and carcass traits in *Bos indicus* × *Bos taurus* crosses in Australia. J. Anim. Sci. 80:1801–1808.

NRC. 1996. Nutrient Requirements of Beef Cattle. 7th rev. ed. Natl. Acad. Press, Washington, DC.

Peterson, R.G. and Waldern, D. E. 1981. Repeatabilities of serum constituents in Holstein Friesians affected by feeding, age, lactation, and pregnancy. J. Dairy Sci. 64:822-837.

Pope, L. S., L. Smithson, D. F. Stephens, D. Pinney, and M. Velasco. 1963. Factors affecting milk production of range beef cows. Oklahoma Agric. Exp. Sta. Misc. Publ. 70:69. Oklahoma State Univ., Stillwater.

Prevatt, W., M. Runge, D. Ball, M. Davis, and C. Prevatt. 2008. Budgets for major forage crop enterprises in Alabama. Alabama Cooperative Extension. BUM 1-2.

Prine, G. M., and G. W. Burton. 1956. The effect of nitrogen rate and clipping frequency upon the yield, protein content and certain morphological characteristics of Coastal bermudagrass (*Cynodon dactylon,* (L) Pers.). Agron. J. 48:296-301.

Reynolds, W. L., T. M. DeRouen, and R. A. Bellows. 1978. Relationships of milk yield of dam to early growth rate of straightbred and crossbred calves. J. Anim. Sci. 47:584-594.

Richards, M. W., J. C. Spitzer, and M. B. Warner. 1986. Effect of varying levels of postpartum nutrition and body condition at calving on subsequent reproductive performance in beef cattle. J. Anim. Sci. 62:300–306.

Rutledge, J. J., W. Robison, W. T. Ahlschwede, and J. E. Legates. 1971. Milk yield and its influence on 205-day weight of beef calves. J. Anim. Sci. 335-363.

Scarbrough, D. A, W. K. Colbentz, K. P. Coffey, J. E. Turner, G. V. Davis, D. W. Kellogg, and D. H. Hellwig. 2001. Effects of calendar date and summer management on the in situ dry matter and fiber degradation of stockpiled forage from bermudagrass pastures. J. Anim. Sci. 79: 3158-3169.

Scarbrough, D. A., W. K. Coblentz, K. P. Coffey, D. S. Hubbell III, T.F. Smith, J.B. Humphry, J.A. Jennings, R. K. Ogden, and J. E. Turner. 2006. Effects of forage management on nutritive value of stockpiled bermudagrass. Agron. J. 98: 1280-1289.

Selk, G. E., R. P.Wettemann, K. S. Lusby, J. W. Oltjen, S. L. Mobley, R. J. Rasby, and J. C. Garmendia. 1988. Relationships among weight change, body condition and reproductive performance of range beef cows. J. Anim. Sci. 66:3153–3159.

Snyder, C.S., and R.H. Leep. 2007. Fertilization. In: Barnes, R.F., editors, Forages: the science of grassland agriculture. Vol. II. 6th ed. Blackwell Publ., Ames, IA. p. 355–377.

Sollenberger, Lynn E., John E. Moore, Vivien G. Allen, and Carlos G. S. Pedreira. 2005. Reporting forage allowance in grazing experiments. Crop Sci. 45: 896-900.

Steele J.D., Banta J.P., Wettemann R.P., Krehbiel C.R., Lalman D.L. 2007. Drought-stressed soybean supplementation for beef cows. Prof. Anim. Sci. 23:358–365.

Taliaferro, C. M., S. W. Coleman, and P. L. Claypool. 1987. Relative winter forage quality of selected bermudagrass cultivars. Crop Sci. 27:1285-1290.

Tilley, J. M. A., and R. A. Terry. 1963. A two-stage technique for the *in vitro* digestion of forage crops. J. Br. Grassl. Soc. 18:104–111.

Totusek, R., D. W. Arnett, G. L. Holland, and J. V. Whiteman. 1973. Relation of estimation method, sampling interval and milk composition to milk yield of beef cows and calf gain. J. Anim. Sci. 37:153–158.

Tucker, H. A., J. A. Koprowski and W.D. Oxender. 1973. Relationships among mammary nucleic acids, milk yield, serum prolactin, and growth hormone in heifers from 3 months of age to lactation. J. Dairy Sci. 56: 184-188.

USDA AL Dept of Ag Market News. Alabama Weekly Feedstuff/Production Cost Report, MG GR210. 2013.

Van Soest, P. J., J.B. Robertson, and B. A. Lewis. 1991. Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal production. J. Dairy Sci. 74: 3583-3597.

Vendramini, J. M. B., L. E. Sollenberger, A. T. Adesogan, J. C. B. Dubeux, Jr., S. M. Interrante, R. L. Stewart, Jr., and J. D. Arthington. 2008. Protein fractions of Tifton 85 and rye ryegrass due to sward management practices. Agron. J. 100: 463-469.

Wheeler, J., D.L. Lalman, C.A. Lents, and L.A. Redmon. 1999. Supplemental degradable protein requirement of spring calving beef cows grazing stockpiled bermudagrass. Okla. Agr. Exp. Sta. Res. Rep. p. 973:92.

Wheeler, J. S., D. L. Lalman, G. W. Horn, L. A. Redmon, and C. A. Lents. 2002. Effects of supplementation on intake, digestion, and performance of beef cattle consuming fertilized, stockpiled bermudagrass forage. J. Anim. Sci. 80: 780-789.

Wilkinson, S. R. and G. W. Langdale. 1974. Fertility needs of the warm-season grasses. In DA Mays, ed, Forage Fertilization. Ed 1, Chap 6, Am. Soc. Agron., Madison, Wise., pp. 119-145.

Young, B.A. 1983. Ruminant cold stress: Eff ect on production. J. Am. Soc. Anim. Sci. 57:1601 -1607.

APPENDIX

Calculation of cost per cow for the stockpile system and the hay plus supplement system

Nitrogen

The 56N treatment was used as an example for calculation of cost of nitrogen and cost of NH_4NO_3 = $465/ton.

Total amount of NH_4NO_3 = [total amount of N used ÷ percent N in NH_4NO_3]
= 255 kg N ÷ 0.34 N/kg NH_4NO_3
= 750 kg NH_4NO_3

Total cost of NH_4NO_3 = [total amount of NH_4NO_3 × cost/kg of NH_4NO_3]
= 750 kg × $0.51/kg
= $382.50

Cost per cow = [total cost of NH_4NO_3 ÷ number of cows wintered over the grazing season]
= $382.50 ÷ 16 cows
= $23.91

Grazing cost

Cost of sprigs = [total bushels (bu) of sprigs needed × cost/bu of sprigs]
= 336.60 bu × $4.50/bu
= $1,514.70

Cost of herbicide = [total gal of herbicide used × cost/gal]
= 3.36 gal herbicide × $7.00/gal
= $23.52

Fuel cost to disk, plow, spread fertilizer and sprig = [gallons (gal) of fuel to disk, plow and sprig × cost of fuel]
= [34.62 gal × $3.25]
= $112.52

Temporary fencing repair cost = [total cost of temporary polytape fencing × number of replacements]

= \$60 × 1.5 replacements
= \$90

Cost per cow = (\$1,514.70 + \$23.52 + \$112.52 + \$90) ÷ 16 cows
= \$108.80

Hay

The cost of hay had been previously determined by Prevatt et al. (2008) and is \$132/ton.

Total cost of hay = [cost of hay/kg × kg of hay consumed]
= \$0.15/kg × 25,309 kg
= \$3,796.35

Cost per cow = \$3,796.35 ÷ 16 cows
= \$237.30

Labor

Cost of labor for harvesting and establishing hay is included in the previous hay cost. Labor cost for hay and supplement is associated with feeding only.

Stockpile grazing labor = [(hrs to establish pasture + hrs to move fencing) × labor rate]
= ((15.68 hrs + 14.50 hrs) × \$9.00)
= \$271.62

Cost per cow = \$271.62 ÷ 16 cows
= \$16.97

Hay and supplement labor = [(hrs to feed hay and supplement) × labor rate]
= 58 × \$9.00
= \$522

Cost per cow = \$522 ÷ 16 cows
= \$32.63

Supplement

Total cost of supplement = [cost of supplement/kg × kg supplement fed]

= $0.46/kg × 5,062 kg supplement
= 2,328.43

Cost per cow = $2,328.43 ÷ 16 cows
= 145.53

<u>Fixed cost of machinery</u>

A rate of $25/hr (Prevatt et al., 2008) is used for each calculation and machinery cost associated with harvesting and establishment is included in the previously determined hay cost.

Machinery cost of stockpile pasture = [establishment hrs × $25/hr]
= 15.68 hrs × $25/hr
= $392

Cost per cow = $392 ÷ 16 cows
= $24.50

Machinery cost of feeding hay and supplement = [hrs of feeding × $25/hr]
= 58 hrs × $25/hr
= $1,450

Cost per cow = $1,450 ÷ 16 cows
= $90.63