HARVEST MANAGEMENT OF TIFTON 85 BERMUDAGRASS

By

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To Claret, Pepe Padre, Tati (my role model) and JP

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Harvest management is critical in hay or greenchop systems to sustain high yields of superior nutritive value. Tifton 85 bermudagrass (*Cynodon spp*.) is a high-quality, high-yielding warm-season perennial grass that has stimulated interest among dairy producers for use as hay, silage, and pasture. Despite the increasing adoption of this grass and the potential for utilization in rations of lactating cows, harvest management practices and the economic implications of Tifton 85 as a component of rations have not been studied widely. Morphological features of this plant compared to other grasses used in the region suggest the adoption of a more conservative harvest stubble may be needed. During 2007 and 2008, a field study was conducted with the objective of determining the effects of harvest management of Tifton 85 on forage yields, nutritive value, and nutrient removal. A second objective was to examine the feasibility of incorporating Tifton 85 greenchop into lactating dairy cow diets. To meet the first objective, different harvest intervals (21, 24, 27, and 35 d) and stubble heights (8 and 16 cm) were compared using established Tifton 85 bermudagrass fields. Dry matter (DM) yield, nitrogen (N) and phosphorus (P) removal by the grass, and herbage concentrations of crude protein (CP), P, neutral detergent fiber (NDF) and in vitro

digestible organic matter (IVDOM) were measured. To meet the second objective, a least-cost ration formulation linear program was developed using data from the field study.

Results from the harvest management trial and least-cost ration formulation indicate that Tifton 85 can be included in diets of milking herds when appropriate management is used. The field trials suggest that highest yields occur with lower harvest intervals (35 d) when adequate moisture is present, and when shorter stubble heights (8 cm) are used. Nevertheless, shorter stubble heights (8 cm) were associated with greater weed encroachment and are generally not recommended. Also, management for greater nutritive value and stand persistence can be met generally with more frequent defoliation at 24- to 27-d intervals. When Tifton 85 greenchop was included in the ration formulation model and compared to other widely used forage options in the state, such as alfalfa (*Medicago sativa* L.) hay, Tifton 85 hay, and corn (*Zea mays* L.) silage, ration costs were reduced for a range of production levels of lactating dairy cows. Future research should use animal trials to estimate the impacts of incorporating greenchop on milk production, and the assessment of the economic impact of using Tifton 85 greenchop at the whole-farm level. Also, forage management trials incorporating the different harvest management treatments under different N fertilization rates and sources, and the impact on the environment should be considered.

CHAPTER 1
INTRODUCTION

Recent estimates indicate that over 68% of all agricultural lands in the USA are used for forage production, as rangeland, planted pasture, or for mechanical harvest (USDA-NASS, 2009). Grasslands sustain the livestock industry and are one of the most important land uses in the country. Forage production is pivotal for Florida's agriculture and economy. For example, in 2007 alone, beef and dairy farming generated more than $900 million in cash receipts (USDA-NASS, 2009b). These industries rely heavily on the 2.1 million ha of pastureland in the state, of which more than 300,000 ha are planted forages for mechanical harvest (USDA-NASS, 2009b). The prominence of grassland agriculture emphasizes the importance of developing forages and management practices adapted to Florida farming conditions.

Of the forage species grown in the state, warm-season perennial grasses provide the basis for livestock production (Pitman, 2007). Among the species planted, hybrid bermudagrasses have a prominent role because of their adaptability to grazing and mechanical harvest, high yields, and quality (Chambliss et al., 2006). Among the bermudagrasses developed, Tifton 85 bermudagrass has gained acceptance since its release in 1993 throughout the southern USA and particularly in Florida as harvested forage and in grazing systems (Hill et al., 2001). Additionally, it has shown potential in excess nutrient removal from effluent sprayfields (Newton et al., 2003; Woodard et al., 2003, 2007), becoming a preferred option for soil nutrient management in intensive animal-feeding operations.

Forage research results suggest that Tifton 85 can be used as a source of digestible fiber to supplement high energy diets for lactating dairy cows when harvested at early growth stages (West et al., 1998). Because of the lower costs associated with using local or on-farm grown forage (Hill et al., 2001), use of Tifton 85 may be a viable alternative to using alfalfa (West et al., 1997) or corn silage (Mandebvu et al., 1998) in dairy animal rations. Although its benefits in grazing, silage, and hay production are known, further research is needed to assess its potential use as greenchop in confined dairy systems. Greenchop is a management practice where the above-ground biomass of the forage is mechanically harvested and fed fresh to livestock; an approach that avoids the problems of hay-making in humid environments.

In order for producers to take advantage of the potential of bermudagrasses for use as harvested forage or in nutrient extraction from soil, management practices must be tailored to specific environmental and farming conditions. Among these practices, management of defoliation is perhaps one of the most important aspects that producers control, because of its marked effects on yield, nutritive value, and stand persistence. In general for bermudagrasses, longer harvest intervals tend to maximize dry matter yields but decrease herbage nutritive value (Monson and Burton, 1982; Holt and Conrad, 1986; Johnson et al., 2001; Burns and Fisher, 2007), whereas more intensive defoliation increases yields but can compromise persistence over multiple seasons (Mislevy and Everett, 1981). Thus, it is important to understand the effects of harvest interval and stubble height on yields and nutritive value of bermudagrasses, and to evaluate the economic feasibility of different forage utilization alternatives in order to generate specific management guidelines for producers in the Southeast USA.

The objectives of this study were to quantify the effects of varying harvest interval and stubble height on dry matter yield, nutritive value, and N and P removal of Tifton 85 bermudagrass, and to estimate the impact of incorporating Tifton 85 greenchop on cost of lactating dairy cow rations. The research can provide valuable information to producers about harvest management of Tifton 85 under Florida conditions, as well as provide insight into its potential use as greenchop for milking herd rations.

CHAPTER 2
LITERATURE REVIEW

‘Tifton 85’ Bermudagrass

Bermudagrass [*Cynodon dactylon* (L.) Pers.] is a tropical, stoloniferous forage plant native to tropical east Africa that has naturalized throughout the tropics and subtropics and is one of the most widespread and widely used genera of grasses in the world (Hanna and Sollenberger, 2007). This warm-season perennial grass is used for hay production and grazing in the southern USA because of its high biomass production, rapid establishment, and tolerance to defoliation and drought (Hill et al., 2001; Redfearn and Nelson, 2003). Currently, it is planted on approximately 15 million hectares in the USA (Taliaferro et al., 2004).

There are several cultivars of bermudagrass. They range from the low producing common to the high yielding and high quality hybrids (Hill et al., 2001). Among the many hybrid bermudagrasses developed and released in the southeastern USA, Tifton 85 is one of the most recent (Burton et al., 1993). Others include ‘Coastal’ bermudagrass, the first released for use in southern forage programs (Burton, 1986), ‘Tifton 44’, one of the most cold-tolerant hybrids (Monson and Burton, 1982), and several others such as ‘Callie’, ‘Tifton 78’, ‘Florakirk’, ‘Coast Cross I’, and ‘Coast Cross II’.

The high nutritive value and upright growth habit characteristic of Tifton 85 can be attributed to its lineage. This grass is the result of a cross between a tall, highly-digestible African stargrass (‘Tifton 68’; *C. nlemfuensis* hybrid), and an armyworm-resistant bermudagrass accession from South Africa (PI 290884; *C. dactylon*) (Burton, 2001). Morphologically, Tifton 85 is taller, has a more erect growth habit, thicker stems and stolons, and wider leaves than previous bermudagrass releases. It also produces larger but fewer rhizomes than Coastal bermudagrass (Burton et al., 1993). Together with the robust growth, these morphological traits have important implications in determining the defoliation management for long-term persistence of Tifton 85. In addition, it has shown greater drought tolerance (Marsalis et al., 2007) and late-season dry matter (DM) production (Evers et al., 2004) than other hybrid or seeded bermudagrasses; and while it is less cold-tolerant than Tifton 44 bermudagrass, successful stands have been maintained as far north as North Carolina (Burns and Fisher, 2007). Sexual seed production is minimal, and like most hybrids, propagation is through vegetative material as stolons or rhizomes (Hill et al., 2001).

Since its release in 1993, Tifton 85 has gained acceptance throughout the southern USA as harvested forage (Hill et al., 2001). This plant showed promise in its initial small plot trials, producing 20, 19, and 22% more DM ha^{-1} than Coastal, Tifton 44 and Tifton 68, respectively (Burton et al., 1993). More recently DM yields of Tifton 85 have been reported in the 16 to 26 Mg ha^{-1} yr^{-1} range (Woodard et al., 2007; Marsalis et al., 2007).Yields of this magnitude have been associated with removal of large quantities of nutrients from effluent sprayfields (Newton et al., 2003; Woodard et al., 2003, 2007), and Tifton 85 is considered an attractive option for good soil nutrient management in animal-feeding operations in the Southeast.

The high nutritive value of Tifton 85 has been demonstrated in multiple studies throughout the Southeast USA (Hill et al., 2001; Mandebvu et al., 1999; Mislevy and Martin, 2006). The crude protein (CP) concentrations of this grass are greater than most tropical grasses grown in the region (Mislevy and Martin, 2006; Johnson et al., 2001; Marsalis et al., 2007), frequently exceeding 160 g kg^{-1}. Likewise, the digestibility is considered better when compared to other warm- or cool-season forages used throughout Florida. Although Tifton 85 has a high fiber concentration like most tropical grasses, neutral detergent fiber (NDF) digestibility is greater than most of the warm-season grasses grown in the region. It is this attribute that makes Tifton 85 a viable option for lactating dairy cow rations (Mandebvu et al., 1999; Mandebvu et al., 1998; West et al., 1997).

Forage Responses to Defoliation

Defoliation has marked effects on the physiological and morphological processes that occur in plants. In the short term, forages rely on mechanisms such as increased photosynthate allocation to shoots over roots (Nelson, 2000) and remobilization of stored C and N to sites of active photosynthesis and growth in order to rapidly reestablish the photosynthetic area of the plant (Thornton et al., 2000). Some forage species also can increase the photosynthetic ability of the leaves that remain on the plant after defoliation, a process known as compensatory photosynthesis (Richards, 1993). Plants also can modify their morphology in order to both reduce the probability of future defoliation events and to better withstand them as they occur. This is accomplished in certain species by altering leaf growth, rate of tillering, and orientation of tillers and leaves in positions that are less likely to be harvested, i.e. favoring horizontal and lower growth (Nelson, 2000).

Effects on dry matter yields

Early studies on Coastal bermudagrass (Ethredge et al., 1973) suggest that both harvest interval and stubble height are important criteria to consider in hybrid bermudagrass management. These studies point to effects not only in terms of biomass production and leaf to stem ratios, but also to their effects on stand persistence throughout subsequent growing seasons.

One of the early studies that looked at the effects of harvest interval is that of Prine and Burton (1956). The authors reported that increasing harvest interval increased cumulative DM yield over 70%, from 5.1 Mg ha^{-1} at 14 d to 8.7 Mg ha^{-1} at 42 d, but this reduced leaf percentage from 86 to 63%. A study conducted in Puerto Rico by Caro-Costas et al. (1972) on stargrass (*Cynodon nlemfuensis* Vanderyst) also reported that increasing harvest interval from 30 to 90 d increased DM yield, but no reduction in the leaf to stem ratio was detected.

In another study Holt and Lancaster (1968), focused on the effects of stubble height on N-fertilized Coastal bermudagrass. They found that defoliating to a 5-cm stubble height and harvesting when the canopy was 35- to 40-cm tall produced DM yields of 15.3 Mg ha^{-1}; the highest observed in the trial. The authors noted that grass managed under tall stubble heights (13 cm) had greater root mass accumulation than those under the short stubble (5 cm) regime. They also found that more infrequent harvest treatments resulted in lower stand densities compared to those under more frequent cutting. Holt and Conrad (1986) evaluating various clipping treatments reported that total annual forage yield of Coastal increased 0.15 Mg ha^{-1} for each day that harvest was delayed after 14 d of regrowth. Forage yield was 58% greater when harvested every 56 d than when harvested every 14 d. Ethredge et al. (1973) found that both harvest interval and stubble height had a major influence on Coastal DM yields, noting that shorter cutting heights (0 cm) resulted in greater DM yield than taller stubble (14 cm) (9.6 vs. 6.5 Mg ha^{-1} for 0 and 14 cm, respectively). Likewise, they found that longer harvest intervals resulted in the highest annual DM yields (6.9 vs. 8.2 Mg ha^{-1} for 21- and 35-d intervals, respectively).

More recent findings confirm the trends observed in earlier research. Studies in the southern Piedmont on vegetatively propagated ‘Midland 99’ and ‘Tifton 44’ bermudagrasses showed that under adequate moisture, harvest intervals of 4 and 6 wk maximized DM yields on clay loam and sandy soils, respectively (Fike et al., 2005). Similar results also were obtained by Mandebvu et al. (1999), who found that longer harvest intervals (49 and 56 d) maximized Tifton 85 and Coastal bermudagrass yields, producing on average 6 and 6.4 Mg ha^{-1}, respectively.

In summary, these studies found that harvest interval and stubble height are important parameters to consider in perennial hybrid bermudagrass management. In general, both short stubble heights and fewer harvests tend to increase DM yield.

Effects on nutritive value

Broadly defined, digestibility is a measure within forage nutritive value that represents the proportion of a feed’s DM or of one of its constituents that is broken down and absorbed within the digestive tract of an animal (Barnes et al., 2007). In general, its value is tightly linked to the chemical composition of the plant material (Smith et al., 1972), to the structure of the forage in terms of plant architecture and leaf to stem ratios, the proportion of tissues (e.g., vascular bundles, mesophyll, and epidermis), and fiber fractions (Van Soest, 1967). Tropical grass canopies are generally vertically heterogeneous in terms of DM distribution and nutritive value, with nutrient concentrations and digestibility typically declining from the top of the canopy to soil level (Stobbs, 1975; Newman et al., 2002). Because of the strong relationship between digestibility and the morphological and physiological characteristics of forage plants, the effects of defoliation practices on digestibility have been an important area of study within bermudagrass management. In the following, several studies are described that looked at the effect of harvest interval and stubble height on nutritive value.

Early studies on Coastal bermudagrass found that increasing harvest interval negatively affected DM digestibility percentages, with values decreasing from 65.2 to 56.6% as interval between defoliation increased from 21 to 42 d (Burton et al., 1963). This change was associated in part with a decrease in leaf percentage from 85.2 to 67.2% during the same interval. Holt and Conrad (1986) compared five bermudagrass cultivars (‘Coastal’, ‘Callie’, ‘Tifton 68’, ‘S-16’, and ‘S-83’) harvested at 14-, 28-, 42-, and 56-d intervals and cut to a 5-cm stubble. They found that digestibility declined as harvest interval increased, but that differences existed among the rates at which this occurred among the species studied. Overall, the rate of decline in forage in vitro digestible dry matter (IVDDM), averaged across species, was 2 g kg^{-1} of DM for each day of increasing age between 14 and 56 d. During this period, leafiness also declined by 180 g kg^{-1}, suggesting that the leaf to stem ratio can be an important factor that affects forage digestibility. Caro-Costas et al. (1972) found that increasing harvest interval of stargrass after 30 days at 15-day intervals reduced forage digestibility; increasing lignin concentration from 7.8 to 10%. The researchers also reported a drop in herbage CP concentration from 146 to 77 g kg^{-1} when interval between harvests increased from 30 to 90 d (Caro-Costas et al., 1972). Another study on Coastal bermudagrass harvest interval also found that CP concentration decreased with longer intervals between harvests, averaging 18.25% at 14 d and decreasing to 12.03% at 42 d across different N-fertilization rates (Prine and Burton, 1956).

Research focusing on comparing harvesting intervals of Tifton 85 hays also found that CP concentration declined markedly from 20.8% at 14 d of regrowth to 11.1% at 49 d, reflecting the lower leaf to stem ratios (Mandebvu et al., 1999). Mandebvu et al. (1998) also showed that delaying harvest by 25 d, from 24 to 49 d, produced a 43% decline in CP concentration in Tifton 85 hay. More recent work focused on shorter harvest intervals (2 and 4 wk) at each of three N fertilization levels (0, 40, and 80 kg ha^{-1} in each 4-wk period) (Vendramini et al., 2008). They concluded that management practices, such as shorter regrowth periods between harvests of 'Tifton 85' bermudagrass can be effective in increasing herbage CP concentration. In their study, CP was always greater for herbage harvested at 2-wk intervals, obtaining an average of ~17% compared to ~12% at 4-wk intervals.

Specifically for Tifton 85, reports from Mandebvu et al (1998) showed that when harvested at 7 wk of regrowth the grass had a marked reduction in digestibility of DM (IVDMD) and NDF at 48 h of fermentation when compared to forage harvested at 3.5 wk (from 58.5 to 50.9% and 53.5 to 38%, respectively). In the study, the authors also found that the 3.5-wk treatment had similar IVDMD and greater NDF digestibility coefficients at 48 h than corn silage, a high quality forage component of cattle rations. Similar results were obtained by Mandebvu et al. (1999), who found that Tifton 85 harvested as hay at 3-wk intervals had greater IVDMD, NDF digestibility, and ADF digestibility than hays harvested at 5- or 7-wk intervals. In this study, Tifton 85 was compared to Coastal bermudagrass harvested at similar ages. Tifton 85 had greater NDF concentrations but showed greater overall IVDMD (63.2 vs. 59.4%) and NDF digestibility (65.5 vs. 57.8%). The reasons for this high digestibility in spite of high NDF concentrations has been related to the lower ether-linked ferulic acid concentrations in Tifton 85 when compared to other forages, a factor which appears to facilitate digestion by rumen microorganisms (Mandebvu et al., 1998b). Given that longer intervals between harvests have negative effects on CP and IVDOM, management should target shorter intervals, as nutritive value appears to decrease markedly after 30 to 35 d of regrowth. This management should be considered particularly when feeding forages to ruminants such as lactating cows, which require greater amounts of degradable nutrients.

Relative to the effect of stubble height on nutritive value, early studies conducted in Puerto Rico focused on the effects of stubble height on nutritive value for different warm-season perennials. Comparisons of low (0-8 cm) or high (18-25 cm) cutting heights for elephantgrass (*Pennisetum purpureum*), guineagrass (*Panicum maximum*), 'Pangola' digitgrass (*Digitaria eriantha*), molassesgrass (*Melinis minutiflora*) or Caribgrass (*Eriochloa polystachya*) found no differences in forage CP concentration (Caro-Costas and Vicente Chandler, 1961). Similar results were obtained for stargrass under similar tropical conditions, where no differences in CP concentration were detected between 5- and 15-cm stubble heights (Caro-Costas et al., 1972).

Tifton 85 Bermudagrass Use as Harvested Forage

The use of Tifton 85 bermudagrass as hay or silage has been documented widely for different livestock systems throughout the USA, but its use as greenchop has not been studied widely. Greenchop or fresh-cut forage is a management practice where the above-ground biomass of the forage is harvested mechanically and supplied directly to livestock. This approach avoids trampling and fouling (Marten and Donker, 1964), potential uprooting and spatial selectivity associated with grazing (Weir and Torell, 1959), and provides an alternative to haying, particularly in environments where rain distribution in the summer is an important factor associated with nutrient loss (Scarbrough et al., 2005). Early studies in the southern USA compared milk production and forage and land utilization of fresh cut and grazing systems. Stone (1959) concluded that cows fed greenchop produced at least as much milk as cows under either strip or rotational grazing, while gaining more weight than cows under either pasture system. Additionally, this system appeared to reduce forage losses associated with trampling and uneven grazing pressure in pastures. Also, this practice allowed producers to use lands that were farther away within their farms that would be unfeasible under grazing. While this work was done over 50 years ago under less intensive farming systems than the ones currently used in Florida, the benefits of using greenchop appear relevant today when producers are forced to find alternative forage management strategies to produce high quality forages to meet the requirements of the herds.

Bermudagrasses in general are well suited for mechanical harvest, given their high yield, rapid regrowth, and high nutritive value under frequent harvest (Taliaferro et al., 2004). Studies have shown that Tifton 85 hay or silage can be used as a source of digestible fiber in high energy diets for lactating cows (West et al., 1998; Mandebvu et al., 1999), and that its high nutritive value and yields make it a viable alternative to other harvested forages. Early studies that used Tifton 85 bermudagrass as silage found that material harvested at 5-wk could be an economically feasible substitute to using corn silage, given its lower costs of incorporation to the dairy cow rations and its high NDF digestibility (Ruiz et al., 1995). Additionally, in a study comparing dairy rations with

Tifton 85 (harvested at 3.5-wk) or alfalfa hays, CP concentrations were similar (16.6 vs. 17.3%, respectively), but the NDF digestibility was considerably greater for diets containing Tifton 85 (ranging from 58.4 vs. 39.1%, respectively), resulting in equal dry matter intake (DMI) of lactating Holstein cows (West et al., 1997). When compared with Coastal bermudagrass at different harvest ages (3, 4, 5, 6, 7, and 8 wk), Tifton 85 produced 7.1% more DM (4,500 vs. 4,200 kg ha^{-1}), had significantly greater IVDMD (58.7 vs. 54.8%), and had greater NDF digestibility (55.7 vs. 48%) and ADF digestibility (41.4 vs. 32.5%). These values show 9% greater DM digestion and 13.3% greater NDF digestibility for Tifton 85 than Coastal (Mandebvu et al., 1999).

Similar results were obtained when comparing 'Alicia' bermudagrass with Tifton 85, where hays harvested at 5 and 7 wk from fields receiving poultry litter (18 t ha^{-1}) and commercial fertilizer (269 kg ha^{-1} of N and 56 kg K_2O ha^{-1}) (Hill et al., 2001). The authors reported that CP, ADF and NDF were similar among species, but IVDMD was greater for Tifton 85 samples at both growth stages (Hill et al., 2001). When compared to stargrass in South Florida, Tifton 85 forage had similar CP (10.2 vs. 10%) and 11.9% greater IVDOM when both were harvested at 4 wk, without receiving fertilization throughout the experiment (Arthington and Brown, 2005). These results suggest that Tifton 85 bermudagrass is a premium forage relative to other C_4 grasses, and that it can be adopted for high-quality hay production.

Removal of Nutrients

The use of forage production in effluent sprayfields can help reduce potential nutrient leaching (Rotz et al., 2002; Pant et al., 2004). Under Florida conditions, C_4 grasses managed intensively can be effective options for removal of soil nutrients, particularly N (Woodard et al., 2002) and P (Newman et al., 2009; Newman et al., 2009b). Among the forages available, Tifton 85 has shown promise for use in soil nutrient remediation from impacted sites throughout the Southeast USA. Multi-forage cropping systems that contained Tifton 85 extracted 86% of applied N during the cropping season, which was greater than those based on warm-season annuals (Woodard et al., 2002). Studies in northern Florida suggest that systems based on this forage are appropriate for dairy sprayfields since they extract large amounts of N from the soils, in addition to producing high-yields of forage with high CP concentration (Macoon et al., 2002). Modeling of North Florida farms, where crop models were run for 43 years of daily weather data, also suggest that forage systems containing bermudagrass were among the best options for reducing N leaching (Cabrera et al., 2006). Woodard et al. (2003) studied corn-bermudagrass-rye (*Secale cereale* L.) and corn-rhizoma peanut (*Arachis glabrata* Benth.)-rye forage rotations, and determined that for N removal, the system containing Tifton 85 bermudagrass had the lowest NO_3-N levels and highest N harvest (191 kg ha^{-1}), despite a sustained decline in production after the first of three cycles.

Woodard et al. (2007) determined that Tifton 85 was the best warm-season component of year-round forage systems in North Florida dairies for P extraction, with high P removal (67 kg ha^{-1}) associated with high yields (3,800 kg ha^{-1}). However, previous work (Woodard et al., 2003) found that stand persistence can decline considerably in intensive year-round forage systems, possibly because of water, nutrient, and light competition issues with the other components of the rotation (i.e., corn and rye).

After reviewing the literature, an important conclusion from these studies is that DM yield, nutritive value, and nutrient removal cannot be maximized simultaneously by manipulating harvest interval, requiring a compromise between them under any management situation. Given that the responses of forages to defoliation are expressed differently at different time periods and affect various physiological and morphological processes, it is important to study how warm-season grass species perform under different defoliation regimes, and how defoliation affects yield, herbage nutritive value, and soil nutrient removal. Understanding these processes can guide the development of forage management practices that fit the ecological and farming conditions of producers in the region, and allow for alternative forage uses to be evaluated for their economic feasibility.

Forage Budgets

Budgets are the financial layout for a given enterprise, with which the feasibility of alternative production technologies and management practices can be evaluated, aiding the decision-making process for resource-use optimization (Olson, 2004). Budgeting options exist that allow producers to analyze different components and aspects of their businesses, from the whole-farm scale to specific farming activities. Enterprise or unit budgets are projections of income and expenses that specify the quantities, prices, and relationships for a given meaningful unit of production, such as a hectare of pasture (James and Eberle, 2000); allowing farmers to plan ahead and gain insight into the potential economic outcomes of specific activities. Also, by conducting the analysis on a unit (i.e., per hectare) basis, the input-use efficiency can be estimated more accurately than if total farm budgets are used (Olson, 2004).

The use of forage budgets is a practice that managers and university extension specialists use throughout the country, providing a framework to estimate the costs and profitability of a given forage production system, and greatly enhancing the decision-making process of choosing the best cropping alternative or farm management practices (Schuler, 2005; Pflueger, 2005; Miller et al., 2003; Landblom et al., 2005).

As with other financial instruments, budgeting strongly depends on using accurate and adequately classified information about the proposed enterprise (Kay et al., 2004). The data used to create these budgets can be placed into two broadly defined categories, those relating to the physical relationships of transforming materials into products, or input-output relationships, and those that refer to the prices of these inputs and outputs (James and Eberle, 2000). When arranging a cost structure, operational (variable) and ownership (fixed) costs need to be considered. Operational costs are those that occur only if production takes place, and vary with the volume of production during the time period for which the budget is developed. Most forage budgets include fertilizer, agrochemicals (herbicide, insecticide), costs of vegetative establishment (propagating material and incorporation), machinery and labor costs, as well as the price of land rent. In turn, ownership costs refer to those that do not vary during the given time period of the study, even if no production takes place (Simpson, 1989; Kay et al., 2004), and would typically include depreciation, insurance, interests and housing costs of machinery and equipment, as well as taxes and other administrative costs (Olson, 2004; AAAE, 2000). Because of the large amounts of manure that are generated in confined-housing dairy farms, it is also important to consider its potential use as a nutrient source for forage crops, and thus, analyze the economic impact of its management.

Dairy Manure Costs

Traditionally, manure has been considered a valuable resource in agricultural systems as a byproduct that has use as fertilizer for crops (Keplinger and Hauck, 2006). On the other hand, the rapid decline in overall farm numbers in recent decades, accompanied by an increase in operation specialization and size, and the advent of relatively inexpensive synthetic fertilizers and stricter environmental regulations has led to the increasing view of manure as an undesired waste product (Ribaudo et al., 2003; Keplinger and Hauck, 2006). This situation has forced farmers to pay close attention to all aspects of manure management, from animal nutrition and feeding strategies to handling, application, and cost estimation.

Although the value of manure has decreased with time, particularly in relation to commercial fertilizers, it is still widely considered an important source of crop nutrients in many livestock-centered farms, including dairy enterprises. Utilization of dairy manures generated on-farm for forage production is one such example where producers, particularly in the Southeast, have taken advantage of the availability of this by-product in fertilization regimes. This approach reduces the potential leaching of excess N and P (MEQB, 2002; Rotz et al., 2002), and can provide significant amounts of forage that can help reduce feeding costs and nutrient imports into the system (Pant et al., 2004).

Although the application of manures for forage production is viewed frequently simply as taking advantage of a waste product (Keplinger and Hauck, 2006), the incurred costs must be incorporated into farm budgets in order to adequately estimate the economic impact of their utilization in milk production systems (Ribaudo and Agapoff, 2005). Intrinsic characteristics of dairy excreta make their usage for crops more difficult and in some aspects more costly than traditional fertilizers. The low mass:value ratios of manure markedly increases its handling, transportation, and application costs when compared to typical purchased fertilizer (Keplinger and Hauck, 2006). Additionally, use of manure at agronomic rates is complicated by the fact that the manure nutrients occur in proportions that do not match crop requirements (Feinerman et al., 2004). Applications based on plant N requirements typically result in a buildup of P (Toth et al., 2006), given the difference in N:P ratios between those found in plant tissue (generally in the 5-6:1 range) and those supplied by livestock manure (typically approaching 2:1) (Toth et al. 2006; Dou et al., 2002; Elliot et al., 2002). Thus, applications based on plant N requirements may have negative environmental impacts, while those done based on P requirements typically require larger amounts of land for disposal of all farm-generated wastes (particularly in operations with high animal densities) and frequently result in insufficient N being applied.

Overall, any analysis of the fertilizer value of manure depends critically on assumptions about the concentration of N, P, and K in manure, crop requirements, commercial fertilizer prices, and application costs (Koehler and Lazarus, 2007). The two most important factors that determine the net value of manure are its nutrient content and the distance it needs to be hauled before it is used, with greater nutrient content enhancing manure value and longer transportation distance reducing it (Ribaudo and Agapoff, 2005). Given the number of factors that affect the calculation of manure-use costs, best estimates are obtained utilizing producer-specific values, that can capture the differences in manure production and nutrient content, land available, and crop demands, as well as manure handling equipment available, among others (Koehler and Lazarus, 2007).

Least-Cost Ration Linear Programming Models for Dairy Cattle

Linear programming is a quantitative method that deals with the analysis of optimization problems where the relationships between production factors are lineal (McCarl and Spreen, 1996; Simpson, 1989). Since its development in 1958, its use in agricultural economics has been widespread (Simpson, 1989; Pesti and Seila, 1999), serving as a complement to budgeting and as an analytical tool to analyze the feasibility of livestock enterprises (Simpson et al., 1989). In general, linear programming is considered an optimization procedure where a given response variable (e.g., ration cost) is maximized or minimized under a set of constraints or restrictions (e.g., amount of DM intake, CP, energy required in ration).

Use of this approach in determining least-cost rations has been widespread in dairy production systems throughout the USA (Eastridge, 2006). One of the most important challenges in feeding dairy cows is finding the optimum balance between starch and fiber to meet their nutritional requirements and maintain rumen health. With the shift towards the use of total mixed rations (TMR) in the past 25 yr, producers increasingly have opted to use computerized systems to control diet composition and cost (VandeHaar and St.-Pierre, 2006), many of which are least-cost and ration evaluation programs such as the Spartan ration evaluator/balancer from Michigan State University, Cornell University’s CPM Dairy Program, or the PCDairy2 software from the University of California, Davis.

Initial studies have found that this type of software constitutes a user-friendly and accurate means of formulating rations for lactating dairy cows (Howard et al, 1968; Chandler and Walker, 1972; Black and Hlubik, 1980). An additional benefit is that these tools are adaptable to multiple research and producer management questions, such as the feasibility of incorporation of certain concentrates or forages in the ration. Recent studies also have used this application for the evaluation of dairy farm management activities, such as manure disposal costs (Hadrich et al., 2008), adjustment of CP levels in dairy heifer rations (Tozer, 2000), or dairy grazing management (Duru et al., 2007).

In the following chapters, harvest management strategies for Tifton 85 bermudagrass will be evaluated. The effects of stubble height and harvest interval will be examined in detail. Responses measured and reported include DM production and nutrient removal (Chapter 3) and herbage nutritive value (Chapter 4). In addition, an assessment of the impact on ration cost of incorporating Tifton 85 bermudagrass greenchop as a forage source for lactating dairy cows is presented (Chapter 5).

CHAPTER 3
HARVEST MANAGEMENT EFFECTS ON FORAGE DRY MATTER PRODUCTION AND NUTRIENT REMOVAL OF TIFTON 85 BERMUDAGRASS

Introduction

‘Tifton 85’ bermudagrass (*Cynodon spp*.) is an important warm-season forage grass for use in the southeastern USA. The greater yields and quality of this grass compared to other *Cynodon* hybrids make it an ideal forage for livestock farming in the region, particularly for dairy and beef production (West et al., 1998; Hill et al., 2001).

Tifton 85 has consistently produced dry matter (DM) yields that have been in the upper tier when evaluated against a number of other grasses under diverse management and environmental conditions (Sistani et al., 2004; Woodard et al., 2007; Marsalis et al., 2007). Also, the above average nutritive value makes it an increasingly accepted subtropical forage option for dairies in the southern USA (Hill et al., 2001). While it has shown greater DM yields than other bermudagrass hybrids such as ‘Coastal’ (Mandebvu et al., 1999; Marsalis et al., 2007), ‘Tifton 78’ (Hill et al., 1993), and ‘Tifton 44’ (Hill et al., 2001), as well as seeded bermudagrass varieties including ‘Wrangler’, ‘Cheyenne’, ‘Sahara’, and ‘Giant’ (Marsalis et al., 2007), the effects of mechanical defoliation on DM yields under sandy soil conditions in Florida have not been documented widely.

Harvest interval and stubble height affect DM production and stand persistence (Mislevy and Everett, 1981). In general, infrequent cuttings of hybrid bermudagrasses have been shown to maximize DM yield (Holt and Lancaster, 1968; Holt and Conrad, 1986; Mandebvu et al., 1999) and lower leaf to stem ratios (Prine and Burton, 1956). The literature indicates that low stubble heights are associated with maximization of yield (Ethredge et al., 1973), but it also shows how lower stubbles can affect negatively the persistence of some species (Mislevy and Everett, 1981).

The morphological characteristics of Tifton 85, particularly a more upright growth habit than Coastal bermudagrass (Burton et al., 1993), may require a different defoliation management approach than the close defoliation widely established for Coastal bermudagrass and other warm-season perennial grasses (Holt and Lancaster, 1968).

Additionally, DM yields of warm-season perennial grasses and particularly *Cynodon* species have shown a high potential for removal of N and P (Newman et al., 2009). Newton et al. (2003) and Woodard et al. (2003) found that Tifton 85 removed 86 and 73% of N applied, respectively. Woodard et al. (2007) concluded that Tifton 85 would be the best warm-season option for P removal from dairy effluent sprayfields in Florida after analyzing the P-extraction potential of forage systems that included corn plants (*Zea mays* L.), perennial peanut (*Arachis glabrata* Benth.), and forage sorghum [*Sorghum bicolor* (L.) Moench.] as warm-season components. Thus, understanding the effects of harvest interval and stubble height on DM yields is needed to determine the potential for excess soil nutrient removal by Tifton 85, and for establishing management guidelines for long-term persistence. Based on the literature, the hypothesis of the study is that longer harvests and shorter stubble heights of Tifton 85 bermudagrass should produce greater DM yields.

Specific objectives of this study were to i) quantify the DM production of Tifton 85 bermudagrass in response to harvest intervals and stubble heights and ii) determine the

N and P removal under different harvest interval by stubble height treatment combinations.

Materials and Methods

Study site description

This study was conducted during 2007 and 2008 on established hayfields of Tifton 85 bermudagrass in North Central Florida. In 2007, the study was located on a commercial dairy farm near Bell in Gilchrist County, within the Suwannee River basin (29°43'N and 82°51'W). The soils are excessively drained Kershaw fine sands (thermic, uncoated Typic Quartzipsamment), characterized by a very rapid permeability, slow surface runoff, water table below a depth of 10 m, and gently rolling topography (Soil Service Staff, 2006). Soil pH was 7.4. Mehlich I extractable P, K, Ca, and Mg at the site were classified as either high or very high (Table 3-1), with values of 597, 175, 1993, and 220 mg kg^{-1}, respectively. Organic matter was 22.5 g kg^{-1}. During the period of the study (May to October), the experimental area received applications of solid manure and manure water at rates of 47.2 Mg DM ha^{-1} and 1.7 ML ha^{-1}, respectively. These applications totaled to 144 kg ha^{-1} of P and 148 kg ha^{-1} of N.

In 2008, the study was conducted approximately 16 miles south of the first location, also within the Suwannee River basin in North Central Florida (29°30'37.38"N, 82°48'49.04"W). The soils were also moderately to excessively well drained Otella-Candler fine sands (loamy, siliceous, semiactive, thermic Grossarenic Paleudalfs) characterized by a rapid permeability, slow surface runoff, water table below a depth of 1.4 m, and gently rolling topography (Soil Service Staff, 2006). Soil pH was 6.0. Mehlich I extractable P, K, Ca, and Mg at the site were 83, 44, 424, and 66 mg kg^{-1}, respectively. Organic matter was 15.4 g kg^{-1}. Whereas no fertilizer was applied during the experiment, the field served as a feed lot for feeder calves during the fall and spring prior to initiation of this experiment.

Table 3-1. Current interpretation for Mehlich-1 soil test results for agronomic and vegetable crops.

	Very Low	Low	Medium	High	Very High
	-----------------------------ppm-----------------------------				
P	<10	10-15	16-30	31-60	>60
K	<20	20-35	36-60	61-125	>125
Mg	--	<15	15-30	>30	

Harvest management and sampling

At both locations, the experimental area was a 35- × 30-m (1050 m^2) section of an established Tifton 85 bermudagrass hay field. The staging cut to initiate the experiment occurred on 26 June in both years. Experimental units were 6- × 2.5-m (14.9 m^2), with 2.5 m borders on each side. Sampling units consisted of a 6- × 1.25-m (7.6 m^2) strip from the center of the plot. Plots were harvested according to treatment (Table 3-2) during afternoon hours using a flail-type mower. Stubble heights were achieved by adjusting the harvester to the desired height for each experimental unit. Fresh weight was measured, and subsamples of approximately 400- to 500-g were taken from the harvested material for dry weight determination by oven drying for 48 h at 55°C. Samples were ground to pass a 1-mm screen in a Wiley mill, and tissue N and P concentrations were determined by semiautomated colorimetry (Hambleton, 1977). Nitrogen and P removal (kg ha^{-1}) was calculated as the product of DM yield (kg ha^{-1}) by herbage tissue concentration (g kg^{-1} herbage). Additionally a weed assessment was conducted, where summer weeds present in the plots at the time of harvest were removed manually, counted and classified as either grass, broadleaf or *Amaranthus sp*.

Table 3-2. Harvest schedule for Tifton 85 harvest intervals in 2007 and 2008.

Harvest Number†	21 d		24 d		27 d		35 d	
	2007	2008	2007	2008	2007	2008	2007	2008
1	17 July (198)‡	17 July (199)	20 July (201)	21 July (203)	23 July (204)	23 July (205)	31 July (212)	31 July (213)
2	7 Aug. (219)	7 Aug. (220)	13 Aug. (225)	13 Aug. (226)	20 Aug. (232)	19 Aug. (232)	4 Sept. (247)	4 Sept. (248)
3	28 Aug. (240)	28 Aug. (241)	6 Sept. (249)	5 Sept. (249)	17 Sept. (260)	15 Sept. (259)	9 Oct. (282)	9 Oct. (283)
4	17 Sept. (260)	18 Sept. (262)	1 Oct. (274)	30 Sept. (274)	15 Oct. (288)	13 Oct. (287)		
5	9 Oct. (282)	9 Oct. (283)	24 Oct. (297)					
6	30 Oct. (303)							

† Staging cut was on 26 June in both years.
‡ Day of year.

Experimental design

The experiment was analyzed as a randomized complete block design with a split-plot arrangement of treatments with three replicates. Stubble heights were 8 and 16 cm and were assigned to main plots. Harvest interval levels were 21, 24, 27, and 35 d and were assigned to sub-plots, generating a total of eight treatments of stubble height by harvest interval level, and a total of 24 experimental units (Figure 3-1). Stubble heights were selected with the goal of simulating those used by producers (8 cm), and a taller one (16 cm), that may be more appropriate for the growth habit of this grass. The 21-, 24-, and 27-d harvest interval levels were selected to evaluate the effect on DM yield of harvesting before 28-d of regrowth, which is likely the interval to be used for greenchop on dairies. The 35-d level was selected to represent the longest interval within the recommended range for bermudagrass in Florida (Staples, 2003).

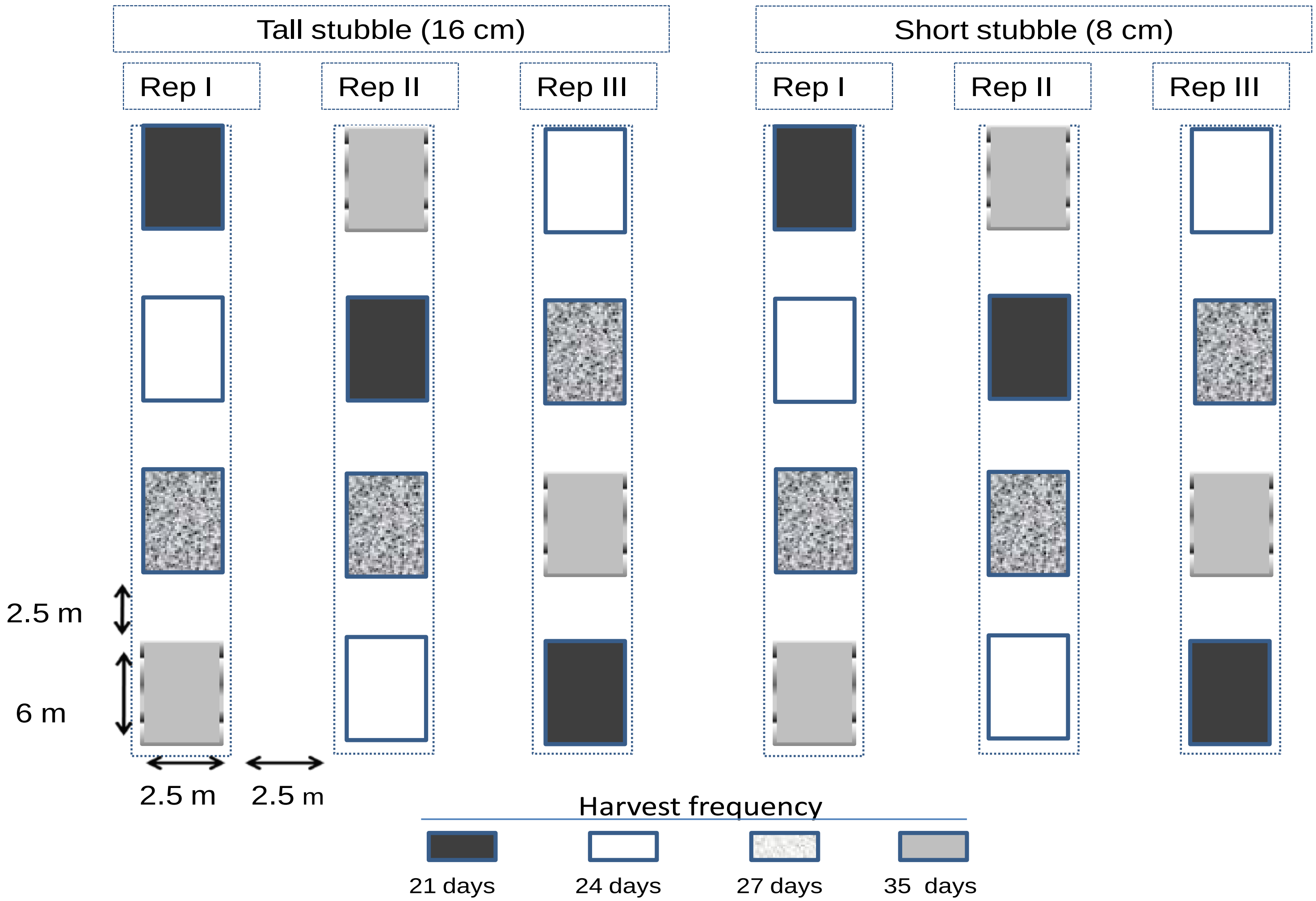


Figure 3-1. Experimental layout of defoliation management trial during 2007 and 2008.

Data analysis

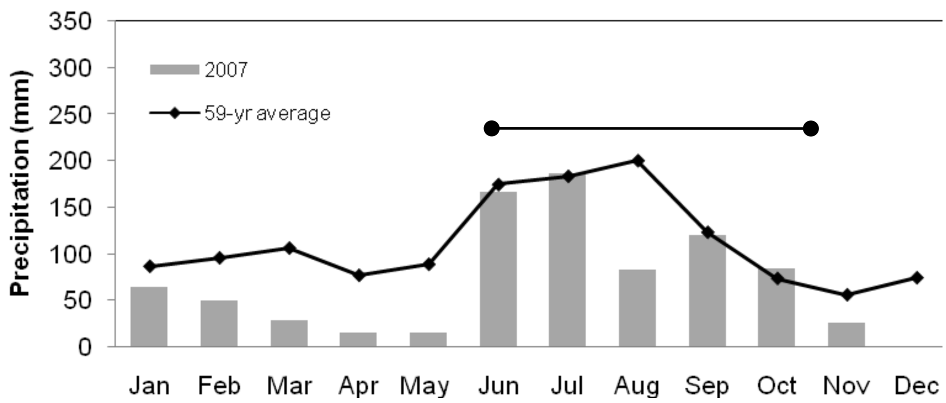
Data were analyzed using PROC MIXED procedures of SAS (SAS Institute Inc., 2004). In all models, year, stubble height, and harvest interval were considered fixed effects; replicates and their interactions were modeled as random effects. Total DM yields were calculated as the sum of DM from each harvest during the growing season. In order to study the seasonal trends in DM yields within each harvest interval, data was analyzed using the repeated measures statement in PROC GLIMMIX. The nature of the harvest interval effect was assessed using orthogonal polynomial contrasts. Because of the unequally spaced harvest interval levels, coefficients were obtained using the ORPOLY macro procedure in SAS (SAS Institute, 2004). Mean separation was further accomplished using least-square means and the PDIFF option in SAS. All test differences were considered significant at $P \leq 0.05$, while values at $P \leq 0.10$ were further discussed as trends.

Results and Discussion

Weather conditions

During both years of the study unusually dry conditions were present (Figure 3-2). In 2007, total rainfall was considerably lower than the 59-yr average (835 vs. 1331 mm, respectively), and reached 790 mm for the May through October period. The distribution reflected markedly drier January through May and August periods that received less than 50% of the expected rainfall. In 2008, total rainfall was also considerably lower than the long term (51 yr) average (1031 vs. 1525 mm, respectively), and was only 571 mm for the May through October growing season. The distribution throughout the year also showed considerably drier April through July and September through December periods. The months of April, June and July received less than 55% of the expected rain, while the

A



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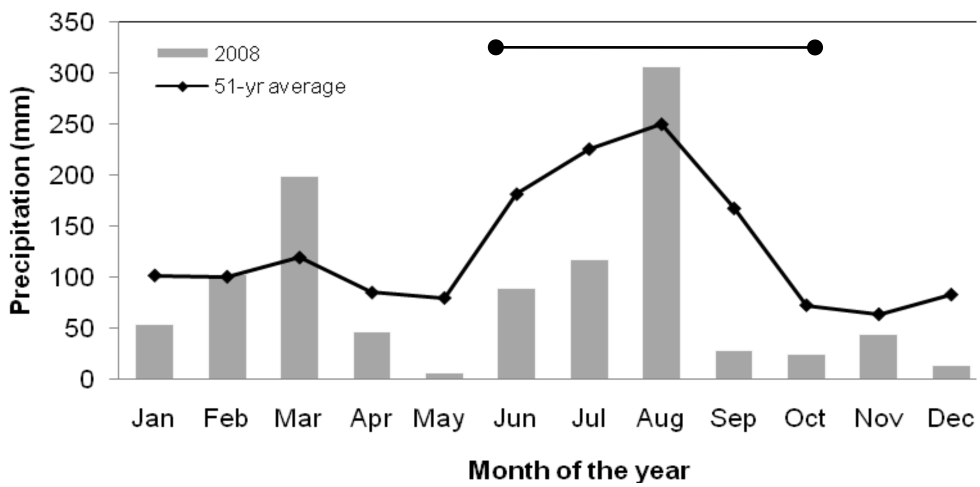

Figure 3-2. Monthly rainfall for the study site in 2007 near Bell, Florida and the 59-yr average (A) (SERCC, 2008); and for the study site in 2008 near Chiefland, FL and the 51-yr average (B) (SERCC, 2009). Bar indicates data collection period.

month of May received only 7% of the typical rainfall. Additionally, whereas the month of August received greater than average rain, 45% occurred in a three day span (24-27 August). Implications of these rainfall patterns will be discussed for the response variables below.

Total DM yields

Although no year x HARVEST x STUBBLE interaction was detected (P = 0.42), a significant ($P \leq 0.01$) year × HARVEST interaction and a year × STUBBLE interaction trend (P = 0.10) were observed for total DM yield (Table 3-3). Because there were interactions with year, data were further analyzed by year. In both instances, main effects for HARVEST and STUBBLE were found (Table 3-3).

Table 3-3. Observed significance level (P value) from mixed models for the effects of harvest interval (HARVEST), stubble height (STUBBLE) and year on total DM yields (Mg DM ha^{-1}).

	Year		
Source of variation	2007-2008	2007	2008
HARVEST	<0.0001	<0.0001	0.0008
STUBBLE	0.0005	0.0474	0.0084
HARVEST *STUBBLE	0.6521	0.3907	0.7080
Year	<0.0001		
Year* HARVEST	<0.0001		
Year*STUBBLE	0.0945		
Year* HARVEST*STUBBLE	0.4200		

In 2007, harvest interval had a significant effect on total DM yield ($P \leq 0.01$); increasing linearly from 7.3 Mg ha^{-1} under 21- and 24-d harvests to 10.8 Mg ha^{-1} for the 35-d interval (Table 3-4). Stubble height also had a significant effect on DM yield during this year (P = 0.05), with the 8-cm height producing ~9% more DM ha^{-1} than the 16-cm stubble, at 8.8 and 8.1 Mg DM ha^{-1}, respectively. In 2008, harvest interval had a significant effect on total DM yield ($P \leq 0.01$), increasing from 6.4 to 7.4 Mg ha^{-1} for 21- to 27-d harvests, while 35-d harvests presented the lowest values at 5.6 Mg ha^{-1}. As in 2007, stubble height had a strong effect on DM yield (P = 0.01); with the short stubble height producing 27% greater yield than the tall stubble, at 7.3 and 5.8 Mg ha^{-1}, respectively.

Table 3-4. Comparison of DM yield means as affected by harvest interval (HARVEST) and stubble height (STUBBLE) in 2007 and 2008.

	Year†		Number of Harvests	
HARVEST (d)	2007	2008	2007	2008
	----- Mg ha^{-1} -----			
21	7.3 c	6.4 b	6	5
24	7.3 c	6.6 b	5	4
27	8.4 b	7.4 a	4	4
35	10.8 a	5.6 c	3	3
SE	0.39	0.24		
PC‡	L**	L**, Q**, C*		
STUBBLE (cm)				
8	8.8 a	7.3 a		
16	8.1 b	5.8 b		
SE	0.19	0.31		

† Means within a treatment variable and year are different if not followed by the same letter, $P \leq 0.05$.
‡PC, Polynomial contrast for the effect of harvest interval (L = linear, Q = quadratic, C = cubic); * Indicates significant differences at $P \leq 0.05$; ** Indicates significant differences at $P \leq 0.01$.

Dry matter yield in 2007 showed the general trends reported by Ethredge et al. (1973), Pedreira et al. (1999), and Mandebvu et al. (1999) for hybrid bermudagrasses, where longer periods between defoliation events maximized DM yield. The causes of the unexpectedly low yield observed in 2008 at 35-d intervals are unclear and rather seem to contradict most tropical forage research. The low levels of residual N associated with the lack of fertilization were likely involved in the lower DM yields observed for all harvest intervals in 2008.

The greater yields obtained in both years with intervals up to 27 d could generally be associated with the greater light interception by the stand during the growing season (Morgan and Brown, 1983; Pedreira et al., 2000), which would allow more DM accumulation despite fewer harvests. Additionally, the typically greater DM concentration of older herbage compared to younger material could have contributed to the yield increase (Danley and Vetter, 1973). The differences in yields between stubble heights also follow the trends described in studies across different hybrid bermudagrasses, which suggest that leaving shorter residual stubble heights after defoliation results in greater yields throughout the year (Holt and Lancaster, 1968; Ethredge et al., 1973).

Seasonal (by harvest) DM yields

Analysis of the data by harvest by year shows that there were differences in DM yield between harvest events for all harvest interval treatments in the study (Table 3-5; Fig. 3-3 and 3-4). For each harvest interval in 2007, yields were greater initially and lower at the last harvest event each year. In this year there was also a significant harvest event × STUBBLE interaction for all harvest interval treatments except 27 d [21 d ($P \leq 0.01$); 24 d ($P \leq 0.01$); and 35 d ($P \leq 0.03$)]. Yields were less variable under tall stubble height than those from short stubble (Table 3-6). Furthermore, if we take into consideration that total yields under short stubble were only ~9 % greater than those under tall stubble (Table 3-3), producers could benefit from obtaining more stable yields throughout the season leaving taller stubble heights. In 2008, significant harvest event by stubble height interactions were observed only for 27- and 35-d harvests ($P \leq 0.01$) (Table 3-7). While the reasons for the trends observed for 27-d are not clear, the proportionally greater decrease of 8-cm stubble yields in the last harvest of the 35-d treatment appeared to have produced the interaction.

Table 3-5. Observed significance level (*P* value) from mixed models of the effects of stubble height (STUBBLE) and harvest event (HE) on total DM yield analyzed by harvest interval (HARVEST) in 2007 and 2008.

	Harvest interval (d)							
	------ 21 ------		------ 24 ------		------ 27 ------		------ 35 ------	
Source of variation	2007	2008	2007	2008	2007	2008	2007	2008
STUBBLE	0.9591	0.0571	0.2075	0.1068	0.0426	0.0180	0.3545	<0.0001
HE	<0.0001	<0.0001	<0.0001	0.0004	<0.0001	<0.0001	<0.0001	<0.0001
STUBBLE x HE	<0.0001	0.2713	0.0029	0.4035	0.3764	<0.0001	0.0286	0.0012

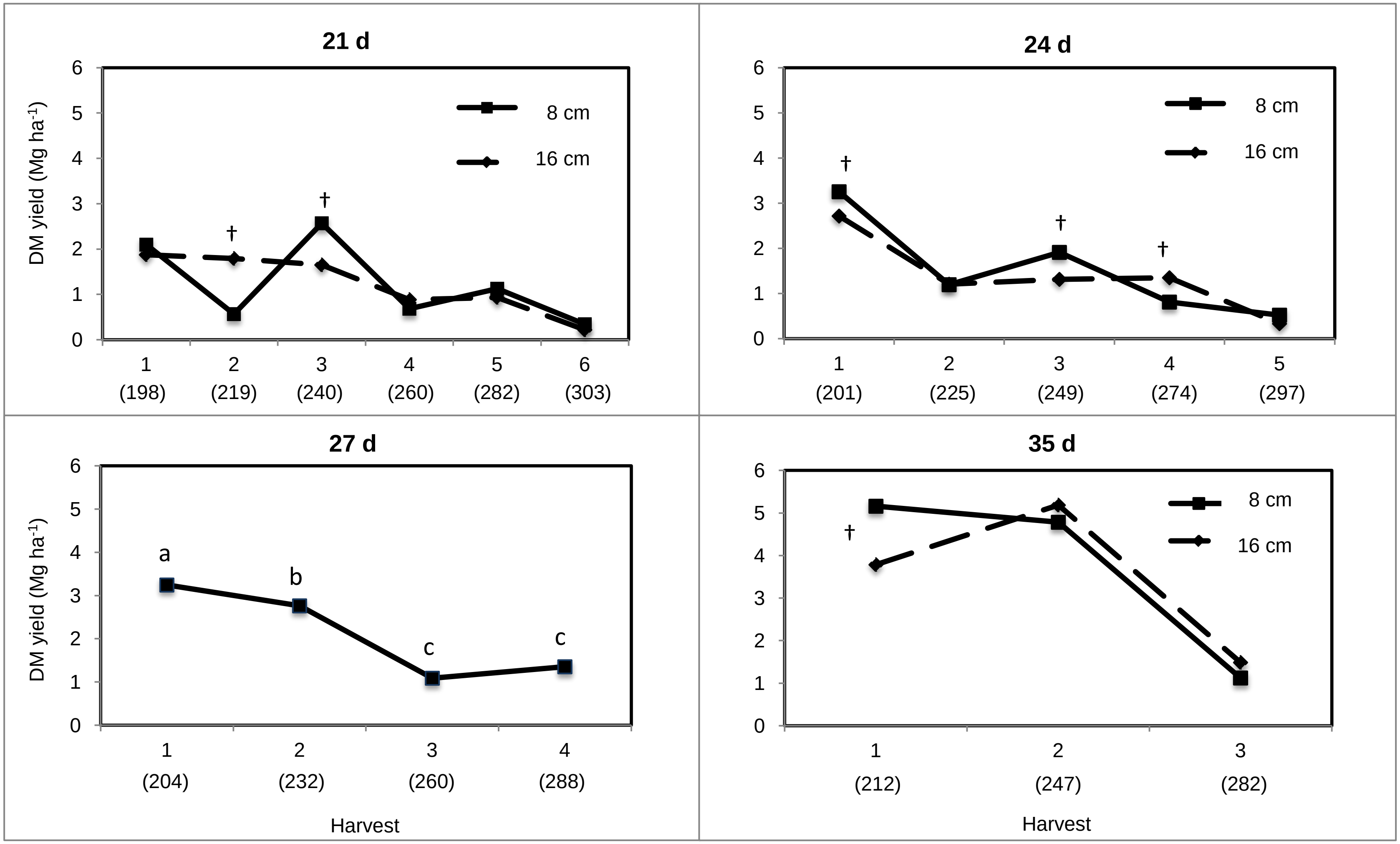

Figure 3-3. Dry matter yield response of Tifton 85 bermudagrass to harvest event by harvest interval (HARVEST) in 2007. † represents LSM significant differences ($P \leq 0.05$) between stubble heights for a given harvest when stubble height × harvest interaction was detected ($P \leq 0.05$). When no interaction was present, harvests with different letters are different ($P \leq 0.05$). Day of year is presented for each harvest in parenthesis. Standard errors (SE) were 0.11 (21 d), 0.13 (24 d), 0.15 (27 d), and 0.28 (35 d).

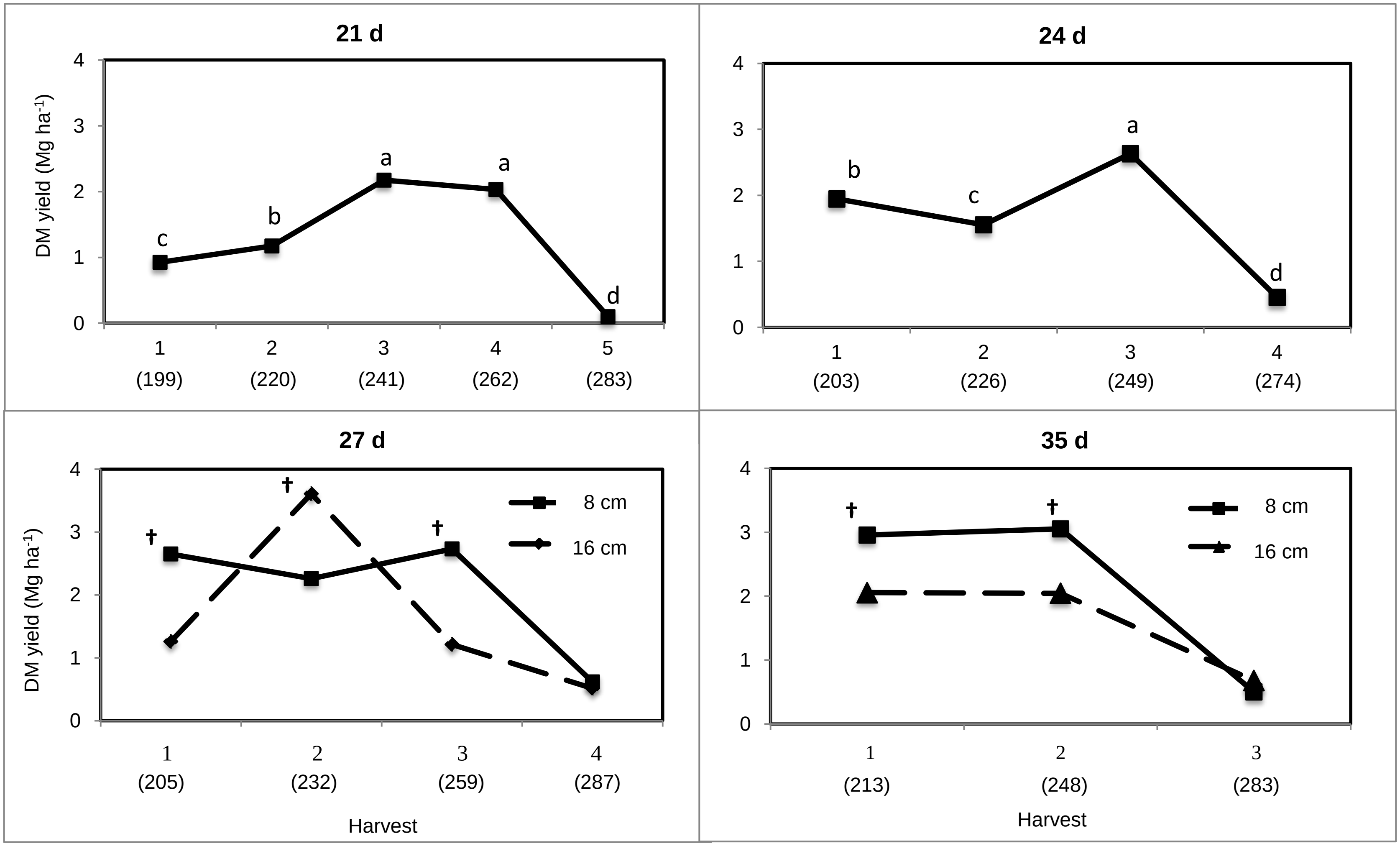

Figure 3-4. Dry matter yield response of Tifton 85 bermudagrass to harvest event by harvest interval (HARVEST) interaction in 2008. † represents LSM significant differences ($P \leq 0.05$) between stubble heights for a given harvest when stubble height × harvest interaction was detected ($P \leq 0.05$). When no interaction was present, harvests with different letters are different ($P \leq 0.05$). Day of year is presented for each harvest in parenthesis. Standard errors (SE) were 0.18 (21 d), 0.32 (24 d), 0.14 (27 d), and 0.09 (35 d).

Table 3-6. Stubble height (STUBBLE) × harvest event effects on DM yield analyzed by harvest interval (HARVEST) in 2007.

HARVEST (d)	STUBBLE (cm)	Harvest event† 1	2	3	4	5	6	SE
		------------------------		Mg ha^{-1}	------------------------			
21								
	8	2.10 a†	0.56 b	2.57 a	0.68 a	1.13 a	0.34 a	0.90
	16	1.87 a	1.79 a	1.65 b	0.88 a	0.93 a	0.22 a	0.65
24								
	8	3.25 a	1.20 a	1.91 a	0.81 b	0.52 a		1.09
	16	2.72 b	1.21 a	1.32 b	1.35 a	0.33 a		0.85
27								
	8	3.58 A‡	2.94 B	1.14 C	1.54 C			1.15
	16	2.91	2.59	1.04	1.16			0.96
35								
	8	5.16 a	4.78 a	1.12 a				2.23
	16	3.78 b	5.19 a	1.49 a				1.87

† Stubble height means within each harvest interval and harvest event not followed by the same lower case letter are different at $P \leq 0.05$

‡ Harvest event means across stubble heights within a row not followed by the same upper case letter are different at $P \leq 0.05$.

Table 3-7. Stubble height (STUBBLE) × harvest event effects on DM yield, analyzed by harvest interval (HARVEST) in 2008.

HARVEST (d)	STUBBLE (cm)	Harvest event 1	2	3	4	5	SE
		------------------------		Mg ha^{-1}	-------------------		
21							
	8	1.28 C†	1.29 B	2.47 A	2.04 A	0.17 C	0.9
	16	0.57	1.06	1.87	2.02	0.03	0.8
24							
	8	2.32 B	1.34 C	2.92 A	0.56 D		1.0
	16	1.57	1.77	2.34	0.34		0.8
27							
	8	2.65 a‡	2.26 b	2.73 a	0.62		1.0
	16	1.26 b	3.61 a	1.21 b	0.51		1.4
35							
	8	2.96 a	3.05 a	0.50			1.4
	16	2.06 b	2.04 b	0.68			0.8

† Harvest event means across stubble heights within a row not followed by the same upper case letter are different at $P \leq 0.05$.

‡ Stubble height means within each harvest interval and harvest event not followed by the same lower case letter are different at $P \leq 0.05$.

It would also seem that under these conditions, 35-d harvests do not take full advantage of the forage's regrowth capacity, suggesting that more frequent harvests would produce more DM on a yearly basis. Nonetheless, this would seem to contradict most research dealing with defoliation management of hybrid bermudagrasses, and the results obtained in 2007. The low yield observed for 21- and 24-d intervals in the first two harvests compared to the following two harvests were likely due to the unusually dry conditions present at the start of the growing season; where the months of June and July received less than 55% of the average rainfall.

In general, the harvest event trends observed are to be expected, since environmental conditions, such as water and temperature, or daylength, and plant phenological stages vary throughout the year. In both years, harvests occurring during times of adequate moisture from mid-June to August tended to have greater yields than those performed later in the year when the days were shorter (Sinclair et al., 2001; Newman et al., 2007). Periods of lower rainfall and temperature that occur in North Central Florida are can reduce DM yields, while a stronger partitioning of photosynthate to storage organs during the fall period can also reduce herbage DM accumulation (Sinclair et al., 2003).

Tifton 85 bermudagrass nutrient removal

Averaged across years, main effects for STUBBLE were detected for N and P removal ($P \leq 0.016$ and $P \leq 0.02$, respectively; Table 3-8). For both nutrients, stubble heights resulting in the greatest yields also resulted in the highest removal (Table 3-9), with the 8-cm stubble management removing 29.5 and 3.5 kg ha^{-1} more N and P, respectively, than the 16-cm stubble management.

Table 3-8. Observed significance level (*P* value) from mixed models of the effects of harvest interval (HARVEST) and stubble height (STUBBLE) on total N and P removal, analyzed by year.

	N			P		
Effect	2007-2008	2007	2008	2007-2008	2007	2008
HARVEST	0.0002	<0.001	<0.001	0.0001	<0.0010	<0.0010
STUBBLE	0.0016	0.0768	0.0055	0.0175	0.2008	0.0092
HARVEST*STUBBLE	0.7894	0.5070	0.2494	0.6616	0.5322	0.3594
Year	<0.0010			0.0004		
Year* HARVEST	<0.0010			<0.0010		
Year*STUBBLE	0.1545			0.2039		
Year* HARVEST *STUBBLE	0.2686			0.2601		

Table 3-9. Yield, nutrient concentration, and nutrient removal of Tifton 85 bermudagrass in response to increasing harvest interval (HARVEST) and two stubble heights (STUBBLE) in 2007 and 2008.

Harvest (d)	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008
	DM yield		N		P		N removal		P removal	
	--- kg ha^{-1} ---		---- % ----		---- % ----		-- kg ha^{-1} --		--- kg ha^{-1} ---	
21	7300 c	6400 b	3.2 a	2.6 a	0.31 a	0.30 a	231 c	167 a	23 b	19 b
24	7300 c	6600 b	3.1 a	2.4 b	0.30 ab	0.29 b	222 c	156 b	22 b	19 b
27	8400 b	7400 a	3.1 a	2.3 bc	0.29 b	0.30 a	262 b	170 a	24 b	22 a
35	10800 a	5700 c	2.9 b	2.2 b	0.29 b	0.27 c	310 a	125 c	31 a	15 c
STUBBLE (cm)										
8	8800 a	7300 a	3.0	2.4	0.29	0.29	221.5 a		23.5 a	
16	8100 b	5800 b	3.0	2.3	0.29	0.28	192.0 b		20.0 b	

† Columns with different lower case letters are different at P ≤ 0.05.

A year × HARVEST interval interaction was detected for both N and P removal (*P* ≤ 0.01; Table 3-8); consequently the data were analyzed by year. In both years of the study, main effects for harvest interval were significant (*P* ≤ 0.01) for N and P removal. In 2007, 21-d harvests removed 231 and 23 kg^{-1} ha^{-1} yr^{-1} of N and P, respectively, while 35-d harvests removed 310 and 31 kg^{-1} ha^{-1} yr^{-1} (Table 3-9). Thus, harvest at 35-d removed 35% more N and P than harvesting at 21-d intervals.

Overall, these findings coincide with previous research involving Tifton 85. Woodard et al. (2003) studied forage systems on dairy sprayfields in North Florida and found that Tifton 85 as a component of a corn-bermudagrass-rye forage system removed on average 191 kg ha^{-1} of N in two cuttings at a 3-cm stubble. In a similar study, Woodard et al. (2007) reported that Tifton 85 harvested four to five times as a part of a bermudagrass-rye forage system removed 33 kg ha^{-1} of P from dairy manure sprayfields receiving an average of 120 kg P ha^{-1} yr^{-1}. These authors also reported that Tifton 85 removed only an average of 8 kg P ha^{-1} when a component of a corn-bermudagrass-rye system that was harvested twice during the warm season under the same effluent rate. Brink et al. (2004) reported annual removal rates of 220 and 33 kg ha^{-1} $yr^{-1}$of N and P, respectively, for Tifton 85 receiving swine effluent at average rates of 39 and 202 kg ha^{-1} yr^{-1} of P and N, respectively. A common conclusion from these studies is that forages with greater DM yields typically removed the most nutrients from sprayfields.

An important consideration when studying the phytoremediation potential of forage grasses is the proportion of nutrients applied that were removed in the herbage. When the amounts of solid manure and manure irrigation water applied during the 2007 growing season are taken into consideration, 35-d harvests extracted 22% of P and approximately 2.1 times as much N as was applied. Although the nutrient application data does not take into consideration the amounts already available in the soil from previous applications, the results highlight the potentially benefits of using Tifton 85 bermudagrass for excess nutrient extraction.

Weed assessment

Summer weed count data taken on each plot during the 2008 season proved insufficient for further statistical analysis, since very little weed presence was detected. The few observations recorded did not follow any discernible harvest interval or stubble height pattern. Nevertheless, a plot weed coverage estimation conducted in winter (5 Mar. 2009) revealed that experimental units under the short stubble height had on average 48 ± 16% weed cover, compared to plots with a taller stubble which had 17± 6.9% weed cover. Main species present included cudweed (*Gnaphalium sp.*), golden rod (*Solidago sp.*) and an unidentified broadleaf in the *Brassica* genus. These results suggests that the lower residual leaf coverage in plots of shorter stubble height likely allowed more light penetration, increasing the number of weeds germinating from seed. This highlights another potential benefit of harvesting Tifton 85 at higher stubble, since less weed coverage could lead to fewer herbicide applications, as well as overall greater yields and nutritive value.

Summary and Conclusions

Tifton 85 bermudagrass is considered a high quality warm-season grass for livestock production in the Southeast USA. It has been known to produce greater DM yield than other widely grown hybrid bermudagrasses under various environmental and management conditions. Results from the defoliation management trial that tested the effects of harvest interval (21, 24, 27, and 35 d) and stubble height (8 and 16 cm) on herbage DM yield lead to the following conclusions:

Under 2007 conditions, total yields were consistently greater as the interval increased from 21 and 24 d to 35 d, suggesting that longer periods between harvests maximize total DM yields. In 2008, overall yields were probably affected by water stress and lack of N fertilization, and presented unusually low yields for the 35-d harvest interval. Across years, the short stubble height produced more DM than the tall level, although this difference was considerably more pronounced under the water and N-restricted conditions in 2008.

In terms of seasonality of DM production, in both years greater yields were typically present when environmental conditions were most conducive to vegetative growth, particularly in terms of water availability. In 2007, harvest event × stubble height interactions were present for all but the 27-d level, and while significant differences were found between stubble heights for a given harvest, these were usually not of great magnitude. In addition, tall stubble management tended to result in more consistent yields throughout the season, possibly suggesting a management that may be more beneficial for producers, because of the dependability of yields. In addition, the lower stubble management could hinder persistence through multiple growing seasons due to the high incidence of weeds observed during winter. In 2008, interactions between harvest interval and stubble height were observed only for 27- and 35-d harvests. While the causes of the unusual fluctuations in yields during the initial harvests under 27 d are not clear, they are likely due to the differential effects of water stress and low soil N levels on the treatments.

Patterns of removal N and P followed that of DM yield patterns in both years. While no significant harvest interval × stubble height interactions were detected, harvest interval by year interactions were detected for N and P removal. The 35- and 27-d harvests removed the most N and P in 2007 and 2008, respectively. Stubble height main effects were found for both N and P removal, with the short stubble removing 29.5

and 3.5 kg ha^{-1} more N and P, respectively, than the taller stubble. In addition, 35-d harvests in 2007 removed 22% of applied P and 2.1 times as much N as was applied in either manure or manure irrigation water, suggesting that Tifton 85 can be a an important tool for phytoremediation in dairy sprayfields.

Overall, the results suggest that both harvest interval and stubble affect DM yields and soil nutrient removal of Tifton 85 bermudagrass. While longer intervals and shorter stubble heights seem to increase DM production and excess soil nutrient removal, using taller stubble heights in North Central Florida conditions may be necessary in order to guarantee stand persistence.

CHAPTER 4
HARVEST MANAGEMENT EFFECTS OF TIFTON 85 BERMUDAGRASS ON HERBAGE NUTRITIVE VALUE

Introduction

One of the main goals in forage production for livestock is to maximize nutritive value. Nutritive value of forages is strongly affected by maturity, season, and management (Moore, 1994). Forage nutritive value declines with time because of the lower leaf to stem ratio and lower protein and energy associated with fiber deposition in mature forage (Jung and Allen, 1995).The challenge remains to maintain high forage nutritive value that meets the nutritional requirements of livestock without compromising yield or stand persistence (Holt and Conrad, 1986). Harvest interval is critical in determining herbage nutritive value of bermudagrasses (Mislevy and Everett, 1981), and, in general, longer harvest intervals of warm-season grasses tend to decrease leaf to stem ratios and herbage nutritive value (Monson and Burton, 1982), while stubble height effects tend to be less critical.

Research on Tifton 85 bermudagrass management has shown that nutritive value varies with harvest interval and season. Fiber fractions have been found to increase with age at harvest, causing a reduction in herbage crude protein concentration and digestibility (Mandebvu et al., 1999). Several studies in Florida (Mislevy and Martin, 2006; Johnson et al., 2001) have found strong seasonality effects on herbage crude protein concentrations, with greater values in these studies occurring early and late in the growing season.

In terms of the effects of stubble height on nutritive value of Tifton 85, there is a limited amount of research currently available. While the potential benefits of using Tifton 85 in dairy production have been studied they have been limited to long harvest intervals (Ruiz et al., 1995). Further research on Tifton 85 is needed that evaluates stubble height under a range of shorter harvest intervals in order to determine the effects on herbage nutritive value. The objective of this study was to quantify the effects of harvest interval and stubble height on Tifton 85 herbage crude protein (CP), P, in vitro digestible organic matter (IVDOM) and neutral detergent fiber (NDF).

Materials and Methods

Study site description

This study was conducted during 2007 and 2008 on established hayfields of Tifton 85 bermudagrass in North Central Florida. In 2007, the study was located in a commercial dairy farm near Bell, Gilchrist County, within the Suwannee River basin (29°43'N and 82°51'W). In 2008, the study was conducted approximately 16 miles south of the first location, also within the Suwannee River basin in North Central Florida (29°30'37.38"N, 82°48'49.04"W). Soils at these locations, the soil chemical analysis, and weather descriptions were detailed in Chapter 3. The experimental area was a 35× 30-m (1050 m^2) section of an established Tifton 85 bermudagrass hay field at each site. Experimental units were 14.9 m^2 (6.1 × 2.5 m), with 2.5-m borders on each side.

Treatments

Treatments were arranged as a split-plot experiment in a randomized complete block design with three replicates. Stubble height levels were 8 and 16 cm and were assigned to main plots, while harvest interval levels were 21, 24, 27, and 35 d and were assigned to sub-plots, resulting in a total of eight stubble height by harvest interval combinations and a total of 24 experimental units (Figure 2-1). Stubble heights were selected with the goal of representing those used by producers (8 cm), and a taller one (16 cm), that may be more appropriate considering the growth habit of Tifton 85. The

21-, 24-, and 27-d harvest interval levels were selected in order to evaluate the effects on nutritive value of harvesting before 28 d of regrowth, which is the likely range of intervals to be used for greenchop on dairies, while the 35-d level was selected to represent the longest interval within the recommended range for bermudagrass in Florida (Staples, 2003).

Herbage sampling and processing

Sampling units consisted of a 6.1 × 1.25 m (7.6 m^2) strip, harvested with a flail-type mower for DM yield calculation. A 400-500 g subsample was taken from the fresh harvested material for nutritive value analysis. Samples were dried for 48 to 72 h at 55°C in a forced air dryer to constant dry weight. Subsequently, samples were ground using a Willey mill to pass a 1-mm screen.

Laboratory analysis

Herbage samples were analyzed for CP, P, IVDOM, and NDF. Samples for N and P analysis were digested using a modification of the aluminum block digestion procedure of Gallaher et al. (1975). Nitrogen and P in the digestate were determined by semiautomated colorimetry (Hambleton, 1977). Crude protein was calculated as N multiplied by 6.25. A modification of the two-stage procedure of Moore and Mott (1974) was used to determine IVDOM. Neutral detergent fiber was analyzed using the method described by Van Soest et al. (1991), utilizing the ANKOM filter bag technique (ANKOM Technology, Macedon, NY, USA).

Statistical analysis

Data were analyzed using PROC MIXED procedures of SAS (SAS Institute Inc., 2004). In all models, year, stubble height and harvest interval were considered fixed effects, and blocks considered random. Total (yearly) nutritive value data were calculated as means weighted by DM yields. In order to study the seasonal trends in nutritive value within each harvest interval; data was analyzed using the repeated measures statement in PROC GLIMMIX. The nature of the harvest interval effect was assessed using orthogonal polynomial contrasts. Because of the unequally spaced harvest interval levels, coefficients were obtained using the ORPOLY macro procedure in SAS (SAS Institute, 2004). Mean separation was done using the LS MEAN statement of PROC MIXED, and the PDIFF option (SAS Institute Inc., 2004). Responses were analyzed by year and by harvest in order to quantify the effect of harvest event in nutritive value as affected by the treatments. All test differences were considered significant at $P \leq 0.05$, while values at $P \leq 0.10$ were further discussed as trends.

Results and Discussion

Crude protein

There were only main effects ($P \leq 0.01$) of harvest interval and year on herbage CP concentration (Table 4-1), however, a trend toward a harvest interval × year interaction was found (P = 0.08), and results are further described by year. During the 2007 season no differences were found across stubble heights, and crude protein values averaged 191 g kg^{-1}. Similar results were found by Pedreira et al. (1999) in a study using ‘Florakirk’ bermudagrass in North Florida. For three postgraze stubble heights (8, 16, and 24 cm), no stubble height effects were detected for herbage CP. Although the study was under grazing conditions, the lack of differences between the stubble heights suggests that total CP concentrations are fairly similar when defoliating above an 8-cm stubble height.

Table 4-1. Observed significance level (*P* value) from mixed models of the effects of stubble height (STUBBLE) and harvest interval (HARVEST) on Tifton 85 herbage CP, P, IVDOM and NDF concentrations in 2007and 2008.

		Year		
Nutrient	Source of variation	2007-2008	2007	2008
CP				
	HARVEST	<0.001	0.0007	0.0006
	STUBBLE	0.6257	0.6820	0.2475
	HARVEST*STUBBLE	0.2556	0.1344	0.7373
	Year	<0.001		
	Year* HARVEST	0.0756		
	Year*STUBBLE	0.2495		
	Year* HARVEST*STUBBLE	0.7542		
P				
	HARVEST	0.0005	0.0459	0.0006
	STUBBLE	0.9055	0.8805	0.2475
	HARVEST *STUBBLE	0.1327	0.3803	0.7373
	Year	0.2342		
	Year* HARVEST	0.0318		
	Year*STUBBLE	0.4374		
	Year* HARVEST*STUBBLE	0.4425		
IVDOM				
	HARVEST	<0.001	<0.001	0.0014
	STUBBLE	0.2474	0.9581	0.1367
	HARVEST*STUBBLE	0.0852	0.1163	0.2441
	Year	<0.001		
	Year* HARVEST	0.2018		
	Year*STUBBLE	0.2161		
	Year* HARVEST*STUBBLE	0.3205		
NDF				
	HARVEST	<0.001	0.0003	0.0002
	STUBBLE	0.2905	0.8781	0.1840
	HARVEST*STUBBLE	0.0266	0.0237	0.3332
	Year	<0.001		
	Year* HARVEST	0.0992		
	Year*STUBBLE	0.2044		
	Year* HARVEST *STUBBLE	0.8959		

Crude protein, however, varied with harvest interval. Shorter intervals (21- to 27-d harvests) showed no differences in total CP concentration in 2007, averaging 194 g kg^{-1}; while at longer harvest intervals (35 d), a drop of 7% to 180 g kg^{-1} was observed (Table 4-2). During 2008, CP was 148 g kg^{-1} averaged across stubble heights. A 15% decline in CP concentration after 21d was observed, falling from 163 to 137 g kg^{-1} at 35 d (Table 4-2). The overall lower values observed when compared to 2007 are likely associated with the lack of N fertilization.

When the analysis was performed by harvest within years (Figure 4-1), CP was at or above 170 g kg^{-1} during the first 240 d in 2007 for each of the harvest intervals. In 2008, trends were similar to those in 2007, but CP was overall lower, averaging 148 g kg^{-1} across stubble heights and harvests. Recent findings by Alderman (2008) studying the regrowth dynamics of Tifton 85 as affected by N fertilization shows differences that exceeded 100 g kg^{-1} in CP concentration between treatments receiving no N fertilizer and those with 135 kg ha^{-1} of N per harvest. These findings are similar to those obtained by Vendramini et al. (2008) and Silveira et al. (2007). Also, a stubble height × harvest interaction was detected for 27-d harvests in 2008 (Figure 4-2). While the exact reason for this pattern is unclear, tall stubble (16 cm) harvests were noticeably more homogenous in CP concentration than short stubble (8 cm) harvests.

Phosphorus

Year by HARVEST effects were found for herbage P concentration ($P \leq 0.03$), but there were no year or stubble height main effects (Table 4-2). In 2007, highest values were obtained for 21- and 24-d harvests, averaging 3.0 g kg^{-1}, while lowest values were for 27- and 35-d harvests, with 2.9 g kg^{-1}. The differences observed could be due to the dilution of P and other plant nutrients when more DM is accumulated with the onset of

Table 4-2. Comparison of total (year) herbage crude protein (CP) and phosphorous (P) means as affected by harvest interval (HARVEST) for 2007 and 2008.

HARVEST (d)	Stubble height (cm)	Year† 2007	2008
		---- CP (g kg^{-1} DM) ----	
21		197 a	163 a
24		191 a	148 b
27		194 a	144 bc
35		180 b	137 c
PC		L**	L**, Q*
SE		2.8	3.2
	8	190	150
	16	192	146
SE		2.9	2.2
		----- P (g kg^{-1} DM) ----	
21		3.1 a	3.0 a
24		3.0 ab	2.9 b
27		2.9 b	3.0 a
35		2.9 b	2.7 c
PC		L**, C**	L**, Q**, C**
SE		0.09	0.02

† Means with a column not followed by the same lower case letter are different at $P \leq 0.05$;
PC= polynomial orthogonal contrast; L, Q and C represent linear, quadratic and cubic effects, respectively.
* and ** represent significant differences at the $P \leq 0.05$ and $P \leq 0.01$ levels, respectively.

maturity. In 2008 the results show no clear trend in herbage P concentration, with 21- and 27-d harvests obtaining the highest values at 3.0 g kg^{-1}. In terms of harvest interval, it should be noted that while statistical differences were found, the values obtained suggest that in biological terms the differences are not important. Herbage P concentrations found were similar or higher than those reported for other bermudagrasses (McLaughlin et al., 2004) and Tifton 85 specifically (Woodard et al., 2007; Brink et al., 2004). In both years, soils presented very high Mehlich I extractable P levels (Chapter 3), and consequently it can be considered that P deficiency was not present. Thus, the small differences found indicate that Tifton 85 tends to keep fairly stable herbage P concentration across defoliation regimes.

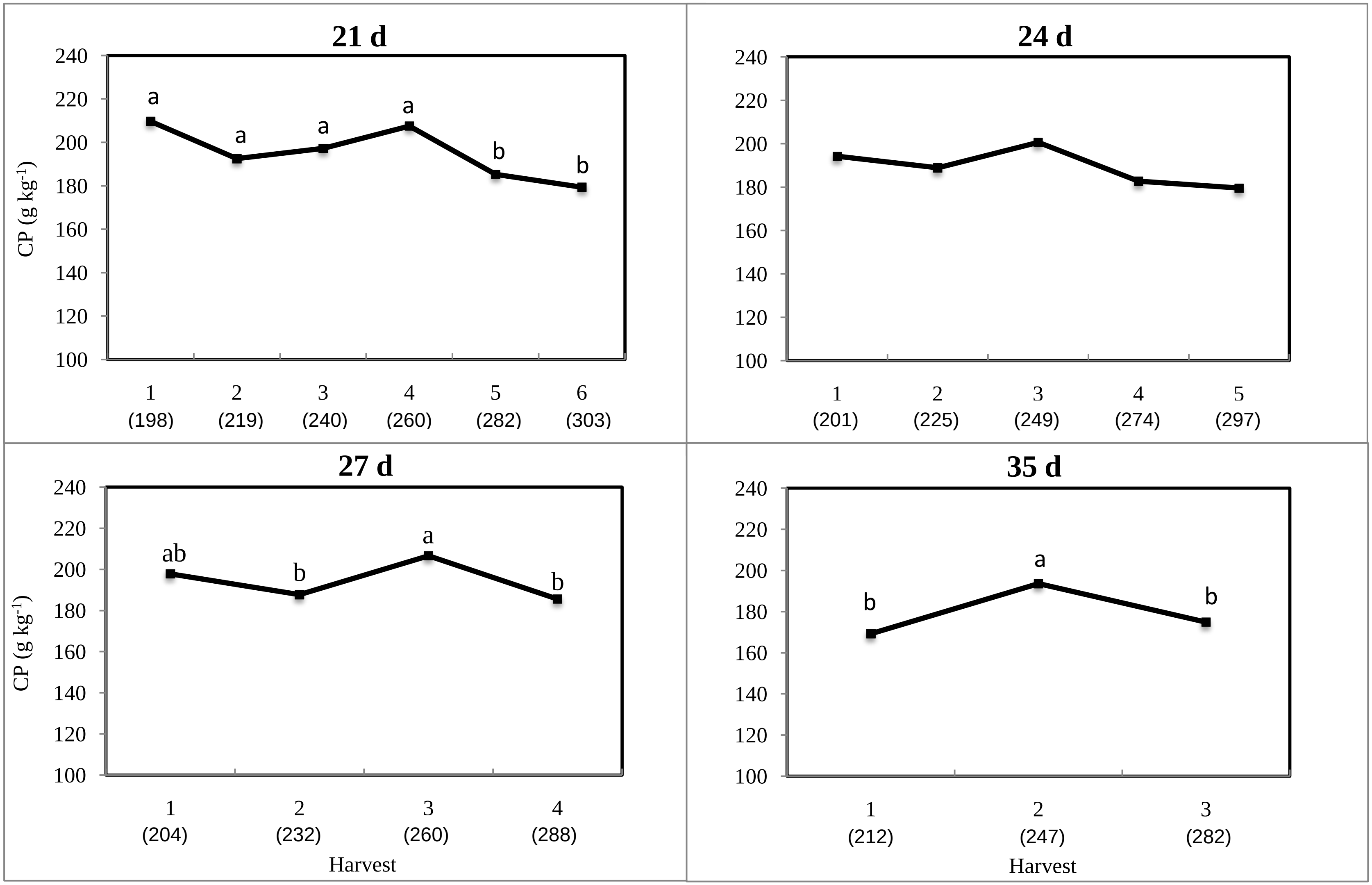

Figure 4-1. Crude protein (CP) response of Tifton 85 bermudagrass to harvest event by harvest interval levels in 2007. Harvests with different lower case letters are different at $P \leq 0.05$. Day of year is presented for each harvest in parenthesis. Standard errors (SE) were 6.8 (21 d), 6.2 (24 d), 4.7 (27 d), and 4.4 (35 d).

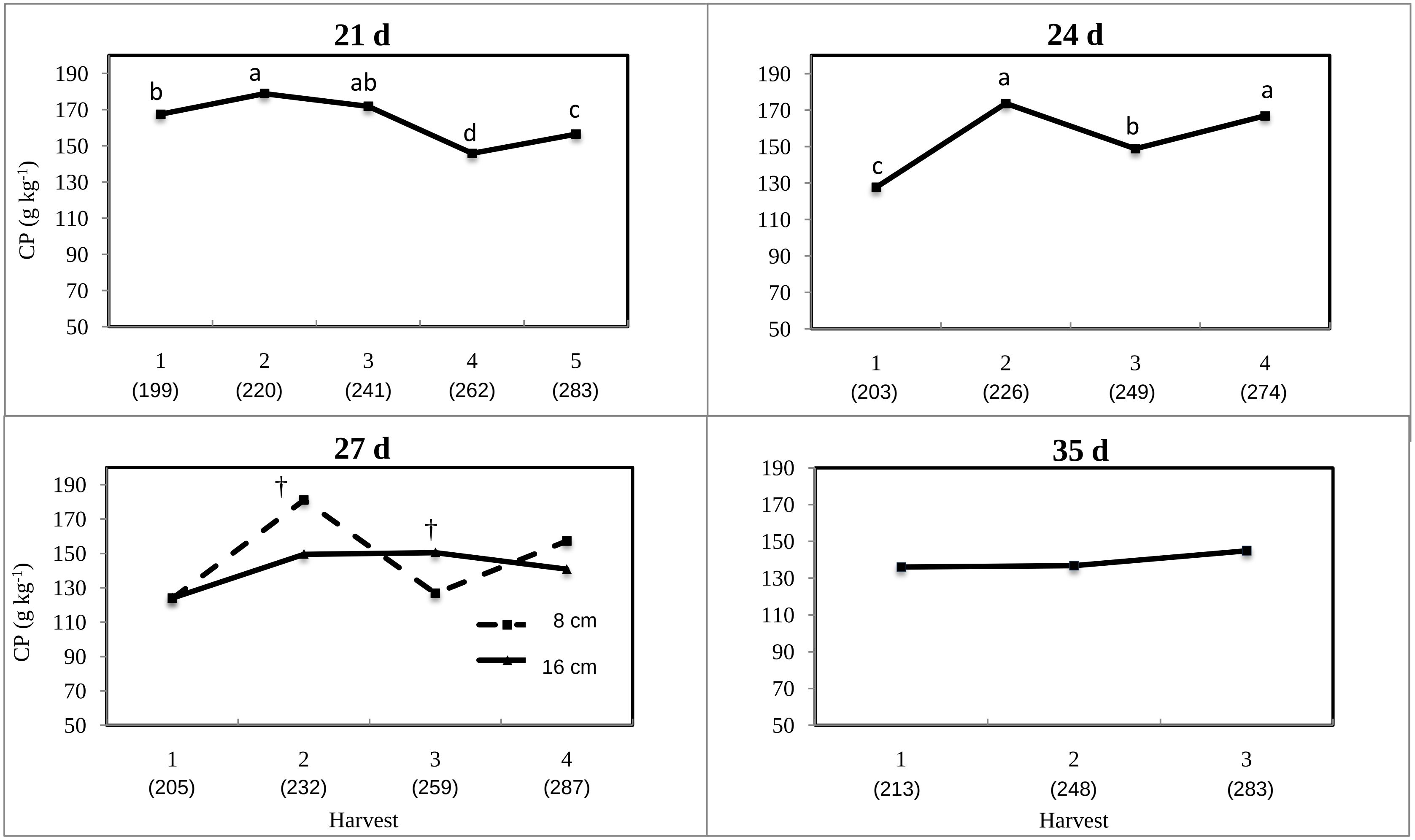

Figure 4-2. Crude protein (CP) response of Tifton 85 bermudagrass to harvest event by harvest interval levels in 2008. † represents significant differences ($P \leq 0.05$) between stubble heights for a given harvest when stubble height × harvest event interaction was detected ($P \leq 0.05$). When no interaction was present, harvests with different lower case letters are different at $P \leq 0.05$. Day of year is presented for each harvest in parentheses. Standard errors (SE) were 5.1 (21 d), 6.4 (24 d), 5.8 (27 d), and 4.3 (35 d).

In vitro digestible organic matter

There were significant harvest interval main effects for IVDOM ($P \leq 0.01$) as well as year main effects ($P \leq 0.01$) (Table 4-1). Since there were also trends indicating a stubble height × harvest interval effect ($P = 0.09$), the interaction is further discussed. These trends show that there were only differences between stubble heights under 21-d intervals, where the 8-cm height produced 588 g $kg^{-1}$of IVDOM compared to 565 g kg^{-1} under the 16-cm stubble (Table 4-3). The reason for this difference is unclear. Polynomial contrasts indicate that IVDOM declined linearly with increasing harvest interval across stubble heights, from an average of 577 g kg^{-1} at 21 d to 513 g kg^{-1} at 35 d, a reduction of approximately 11% (Table 4-3). These data support the literature indicating that forage digestibility declines with maturity. Reductions in leaf to stem ratio and the accumulation of secondary cell wall are associated with maturity in tropical grasses (Buxton and Redfearn, 1997).

When the analyses were conducted by harvest in 2007 for 21-d harvest interval, IVDOM varied less for taller stubbles than short (Figure 4-3). For 21 d, tall stubble had significantly lower IVDOM (average of 593 g kg^{-1}) during the first two harvests of the season, while the short stubble height had the lowest value in the last harvest, at 355 g kg^{1}. On the other hand, the trend for 24 d was reversed; tall stubble had the highest digestibility during the start of the season (average of 671 g kg^{-1}) and the lowest (520 g kg^{-1}) at the end. It should be noted that the majority of the differences observed were in the 5 to 10% range, suggesting that Tifton 85 maintained a relatively consistent digestibility over time for this harvest interval. The exception would be the final harvest of the 21-d interval, where the tall stubble had 38% more digestibility than the shorter stubble. Both 27- and 35-d intervals showed no differences among harvests, suggesting

Table 4-3. Comparison of total (year) in vitro digestible organic matter (IVDOM) means as affected by the stubble height × harvest interval interaction.

	Stubble height (cm)	
HARVEST (d)	8	16
	--- IVDOM (g kg^{-1} DM)[†] ---	
21	588 a	565 b
24	558 a	571 a
27	549 a	549 a
35	520 a	505 a
PC[‡]	L**	L**
SE	7.2	
	--- NDF (g kg^{-1} DM)[†] ---	
21	670 b	686 a
24	685 a	680 a
27	696 a	698 a
35	702 a	702 a
PC[¶]	L**	L**, C*
SE	3.3	

[†] Means within a row followed by different lower case letters are different at $P \leq 0.05$
[‡]PC= polynomial orthogonal contrast for harvest effect across stubble. L represents linear effects.
*, ** represents significant differences at the $P \leq 0.05$ and $P \leq 0.01$ levels, respectively.

that IVDOM for longer regrowth intervals varies little throughout the season. In 2008, when analyses were conducted by harvest (Figure 4-4), lowest IVDOM was observed in harvests at the beginning and the end of the growing season, except for 21-d harvests that had greater IVDOM in the first three harvests. Although the 35-d harvest interval showed a stubble height × harvest event interaction, the differences were in the 5 to 8% range, and also exhibited declining trends in IVDOM towards the end of the season. During this time, less favorable growing conditions, more dead material, and possibly lower leaf to stem ratios in plants could lower digestibility.

These results also support those from several studies with bermudagrasses (Monson and Burton, 1982; Mislevy and Martin, 2006; Marsalis et al., 2007) and with Tifton 85 bermudagrass (Mandebvu et al., 1999; Johnson et al., 2001) in the Southeast USA.

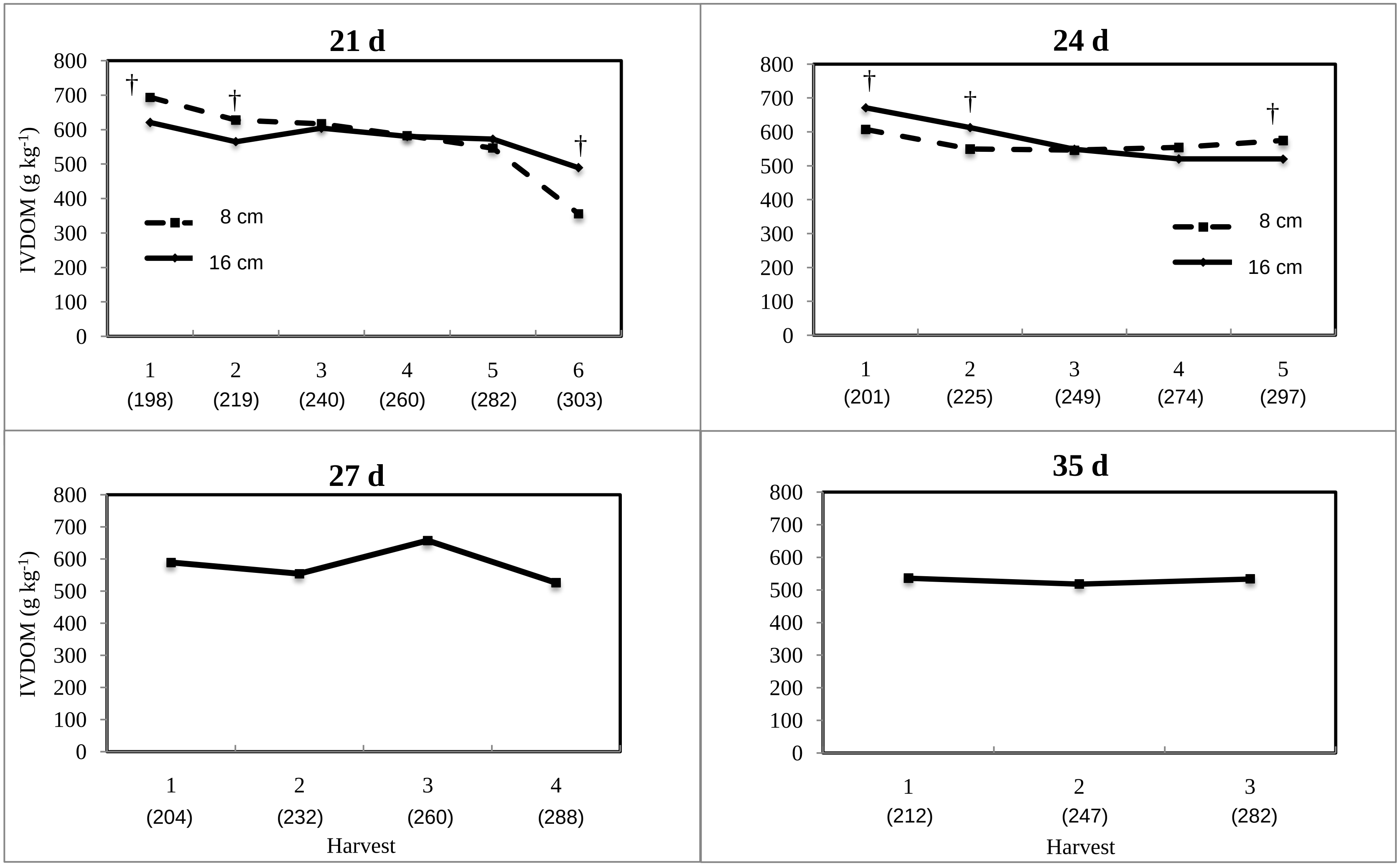

Figure 4-3. In vitro digestible organic matter (IVDOM) response of Tifton 85 bermudagrass to harvest event by harvest interval levels in 2007. † represents significant differences ($P \leq 0.05$) between stubble heights for a given harvest when stubble height × harvest event interaction was detected ($P \leq 0.05$). When no interaction was present, harvests with different lower-case letters are different ($P \leq 0.05$). Day of year is presented for each harvest in parenthesis. Standard errors (SE) were 16.8 (21 d), 20.1 (24 d), 36.1 (27 d), and 18.5 (35 d).

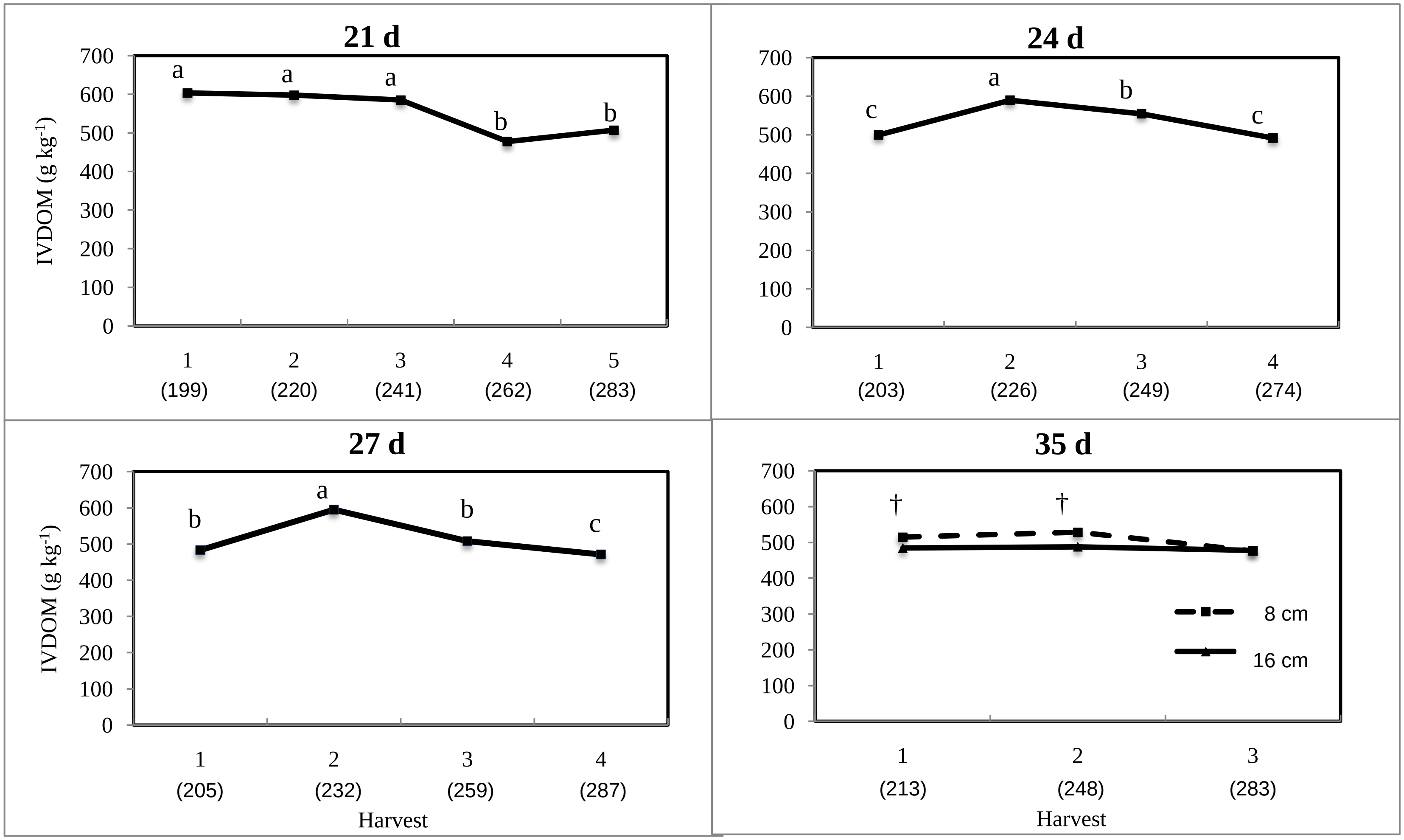

Figure 4-4. In vitro digestible organic matter (IVDOM) response of Tifton 85 bermudagrass to harvest event by harvest interval levels in 2008. † represents significant differences ($P \leq 0.05$) between stubble heights for a given harvest when stubble height × harvest event interaction was detected ($P \leq 0.05$). When no interaction was present, harvests with different lower-case letters are different at $P \leq 0.05$. Day of year is presented for each harvest in parenthesis. Standard errors (SE) were 12.3 (21 d), 10.1 (24 d), 11.5 (27 d), and 9.2 (35 d).

Neutral detergent fiber

Fiber concentration measured by NDF presented stubble height × harvest interval interaction effects ($P \leq 0.03$). Neutral detergent fiber was 16 units greater for the 16 cm than the 8 cm stubble height at 21 d (Table 4-3). No differences were observed among stubble heights for all other harvest intervals in the study. Polynomial contrasts across stubble heights suggest that NDF concentration increases with increasing harvest interval and maturity. Harvests at 21 d had an average NDF concentration of 678 g kg^{-1}, while those done at 35-d intervals were 3.4% greater, averaging 718 g kg^{-1}. Although the reasons for greater NDF concentrations under 16 cm vs. 8 cm stubble heights for 21-d harvests are unclear, the greater NDF values observed under longer harvest intervals coincides with research in forage management. Overall, longer regrowth periods are associated with greater secondary plant cell wall deposition and reduced digestibility (Buxton and Redfearn, 1997). Additionally, with longer intervals between harvests we can typically expect leaf to stem ratios to lower, since more DM is accumulated in stems than in leaves with increasing maturity, raising the proportion of lignified tissue in herbage (Buxton and Redfearn, 1997). These results are also consistent with previous findings for Tifton 85 by Mandebvu et al. (1999), which also found an increase in NDF concentration from 21- to 35-d harvests, while Johnson et al. (2001) reported values that were in the 745 to 788 g kg^{-1} range, and that only showed differences between 7- and 35-d harvest intervals.

Summary and Conclusions

Results from the defoliation management trial that tested the effects of harvest interval (21, 24, 27, and 35 d) and stubble height (8- and 16-cm stubble) on herbage nutritive value lead to the following conclusions:

Across years, total CP concentration was highest at 21 d but lowest at 35 d intervals. In 2008, CP declined as interval between harvests increased beyond 21 d, while a decline was only detected at 35-d harvests in 2007. No differences were detected due to stubble height in either year. Seasonally, more variability in CP levels was detected in 2008 than in 2007, likely a consequence of the lower soil nutrient levels and more marked water stress conditions in 2008. It should be noted that overall, CP levels were highest in 2007 and decreased only for the longest harvest interval (35 d), further highlighting the benefits of supplying fertilization and irrigation.

Phosphorus concentration was affected by harvest intervals in both years. Nonetheless, levels remained fairly stable and corresponded to values reported in other bermudagrass studies (Pierzynski and Logan, 1993; Woodard et al., 2007) suggesting a narrow variation of P concentration in herbage tissue.

Concerning digestibility, a stubble height × harvest interval interaction trend was present due to differences between stubble heights at the 21-d harvest interval. In addition, IVDOM decreased gradually and at similar rates from 21- to 35-d intervals across years. No significant differences were found between stubble heights in either year. In general, the relatively low variability of IVDOM values observed across harvest intervals and stubble heights suggests that under contrasting growing conditions, Tifton 85 bermudagrass can produce dependably high digestible herbage for lactating dairy cow use.

In terms of fiber analysis, trends suggest that increasing harvest interval from 21 to 35 d increases NDF concentrations, which can be expected since with increased maturity more secondary cell wall accumulates. As with IVDOM, no stubble height main effects were found in either year. Overall, it should also be noted that the magnitude of the increase in NDF concentration across harvest intervals, when present, never surpassed 4%, indicating that even when significant differences were found, these were relatively small. This homogeneity throughout the season is an important advantage for producers utilizing Tifton 85 in dairy cow rations; no major adjustments in formulation would need to be made in order to maintain optimum NDF diet levels.

CHAPTER 5
ECONOMIC ANALYSIS OF TIFTON 85 GREENCHOP INCORPORATION INTO DAIRY RATIONS

Introduction

Dairy production in Florida is centered around confined housing systems, which depend on purchased concentrate feeds and forages to meet the nutritional demands of the herds (Pitman, 2007). Currently, feeding represents approximately 75% of the operational expenditures of dairies in the state, with an estimated 80% of these costs going into purchased feedstuffs (USDA-NASS, 2009). Because of the importance of feeding on dairy profitability, producers are seeking alternative feedstuffs, as well as management and cropping options that can help reduce costs.

Hay production in Florida during the warm-season months is strongly influenced by the high temperatures and humidity that can negatively affect drying and baling activities, increase dry matter (DM) losses and negatively impact forage nutritive value (Scarborough et al., 2005). Thus, livestock systems that depend on mechanically harvested forages produced on-farm are generally interested in developing alternative forage utilization methods. Harvesting for hay, silage, and haylage allows producers to store forages for feeding at times when herbage availability can be limiting. Conserving forage however can be challenging to implement effectively because of forage drying issues under frequent precipitation and the costs involved in establishing and maintaining the infrastructure necessary for silage or haylage production. A possible alternative is using forages as greenchop, which is a management practice where the herbage is mechanically harvested and fed fresh to livestock. This approach can avoid the dry matter and nutritive value losses inherent in hay or ensiled forages. Additionally, production costs under this management can be lower, not only because of reduced field losses, but also due to the reduced costs incurred as less machinery, infrastructure, and their related activities (i.e., baling, storing) are required.

To determine the feasibility of using greenchop in the rations for milking herds, the cost of producing greenchop and the feeding requirements of different lactating dairy cows must be considered. While budgets project the income and expenses for a unit of production, such as a hectare of forage for greenchop, least-cost ration formulation programs can estimate the combination of forages and other feedstuffs that can minimize feed costs while meeting the requirements of the dairy animals. These programs can be adapted to different feedstuffs, prices and nutrient profiles, as well as different animal requirements, making them a powerful and dynamic tool for feeding management (Tozer, 2000).

The main objective of this analysis was to assess the economic impact of incorporating Tifton 85 bermudagrass greenchop in lactating dairy cow rations. Specific objectives were i) to determine the establishment and production costs of Tifton 85 under different harvest interval practices, and ii) to determine the least expensive combination of forages, including Tifton 85 greenchop harvest interval scenarios, and concentrate feeds available to producers in the state.

The hypothesis of the study is that Florida dairy farmers can reduce the cost of lactating dairy cow rations by utilizing locally harvested, warm-season perennial grasses such as Tifton 85 greenchop.

Materials and Methods

Tifton 85 bermudagrass greenchop production cost

In order to develop the production cost of Tifton 85 greenchop, establishment and production budgets were developed. Greenchop management activities differ from those of hay production, since the herbage is simply harvested and transported fresh to livestock, and no field drying, baling, or storing activities are required. This reduces machinery operating and ownership costs, as well as labor requirements. One difference with this management strategy is that a forage wagon is included in greenchop operations to collect the material that is harvested by the rotary mower. This implement is usually pulled behind the harvesting equipment, or is operated by a truck that runs parallel to the harvester.

Within the establishment budget developed, costs of vegetative planting of bermudagrass using above ground stems were obtained from custom operators in North Florida and South Georgia, given that this is an activity that is not frequently done directly by producers. The cost of this activity also is considered in the production budgets, included as a 10-yr prorated cost of establishment. Thus, the cost of establishing the stand is divided by the expected life of the stand (years) and allocated to the production budgets as fixed costs. This value serves as a base estimate for stand survival of vegetatively propagated bermudagrasses, although well-maintained stands could last considerably longer.

Because of the interest in determining the effects of producing Tifton 85 greenchop under different harvest management options, production budgets were calculated with three, four, and five harvests per season, corresponding to 35-, 27-, 24-, and 21-d harvest intervals, as suggested by the agronomic trial results (Chapters 3 and 4). The differences in costs between these different harvest intervals reflect the increased machinery and labor use when more harvests are done.

Determination of machinery costs

Operating and ownership costs for the machinery were estimated using spreadsheet-based machinery cost calculator developed by researchers at the University of Minnesota (Lazarus, 2009). The spreadsheet uses American Society of Agricultural and Biological Engineer (ASABE) formulas and coefficients to calculate depreciation, maintenance and repair, fuel, insurance, interest and housing costs for the required operations and machines. One important consideration that Lazarus (2009) utilizes in calculating costs is that depreciation is classified as an operating expense, with the justification that to some extent, these costs are use-related since increased usage decreases years of life and potential salvage value. Although this approach is somewhat contrasting to traditional cost allocation schemes that considered depreciation to be an exclusively fixed cost (AAAE, 2000), it has been adopted widely by extension economists in calculating farming budgets in the United States, such as those of the University of Wisconsin (Schuler, 2005), South Dakota State University (Pflueger, 2005) Iowa State University (Miller et al., 2003) and North Dakota State University (Landblom et al., 2005), among others.

Input, land and labor costs used in the spreadsheet are those that best reflect conditions in North Central Florida. These included diesel prices at $0.66 per liter (average price for Levy County gas stations in October 2009), and utilizing the average price for unskilled agricultural field workers in Florida at $9.18 per hour (USDA-NASS, 2009c). While dairy farm size in Florida is variable (DeVries et al., 2006), area was adjusted to 202 ha (~500 acres), a value that approaches the average pasture and crop area reported. Assumptions on time of year and number of passes over each unit area of land varied depending on activity requirement and harvest schedule, and are specified in each budget. Land rent values were set at \$44.46 ha^{-1}(~\$18 $acre^{-1}$), corresponding to those reported for Florida in 2009 (USDA-NASS, 2009). Additionally, insurance and housing were calculated at 1.5% of average machinery or equipment investment, lubrication costs were estimated at 10% of fuel costs, while no sales tax or inflation rate was included.

Developing budgets based on results from agronomic trials

Fertilization costs used in the study reflect the fertilization management applied during each year of the agronomic trials (Chapters 3 and 4). Thus, 2007 greenchop production budgets included manure application costs to match the 144 kg ha^{-1} of P and 148 kg ha^{-1} of N applied via solid manure and manure irrigation water during the length of the growing season (May to October). In 2008, greenchop production budgets were calculated with no fertilization. While prior applications of manure or commercial fertilizer may have contributed to plant nutrition during the study in both years, they were not included in the fertilization costs because of a lack of adequate data on the amounts applied and their availability to plants. Establishment fertilization rates were those in the UF-IFAS recommendations for bermudagrass (Mylavarapu et al., 2009), that suggest a split application of 112 kg ha^{-1} of N. Fertilizer prices used were obtained from averages of three retailers in the area of study in November 2009, and corresponded with \$0.93, \$0.53 and \$1.15 per kg of N (average of prices of urea, ammonium nitrate and ammonium sulfate), P (diammonium phosphate) and K (uriate of potash), respectively.

Calculation of manure and irrigation cost for forage production budget

Cost of liquid slurry dairy manure application was estimated using the spreadsheet-based method developed by Koehler et al. (2009), which incorporates the variable (i.e. labor, fuel) and fixed costs (machinery depreciation) related to hauling, transporting and spreading manure.

Data inputs used reflect the liquid manure applications equivalent to 144 kg ha^{-1} of P and 148 kg ha^{-1} of N during the 2007 season, calculated for 202 ha (~500 acres) of land by rapid broadcast. Since manure nutrient concentration and availability can vary widely depending on animal factors (i.e. type dairy cow, diet fed, and production level), environmental conditions (i.e. soil type, temperature, soil water status) and manure handling (Van Horn et al., 2003), values were selected from a range of reported values (Zublena et al., 1997). Thus, concentrations of total N, and K_2O per 1000 gal were set to 45-25-27, with 70-80-90 (%) availability coefficients, respectively. Nitrogen and P_2O_5 coefficients were those estimated for north Florida conditions from producer data by Van Horn et al., (2003). The K availability coefficient was that used by Koehler et al. (2009).

As with other farming activities, estimation of irrigation costs is highly variable and is best done utilizing actual farm operating and fixed costs. Because of the possible sources of variation and the lack of adequate farm-level data to calculate the cost of irrigation during the 2007 season, values were taken from hybrid bermudagrass hay production budgets developed by the University of Georgia (Lacy and Morgan, 2008), adapted with current fuel (\$0.66 L^{-1}) and Florida labor costs (9.18 h^{-1}). Irrigation cost was estimated for a center pivot system using a diesel-powered pump, applying 127 mm of water per ha during the growing season.

Least-cost ration linear program model

To evaluate the feasibility of incorporating Tifton 85 greenchop in lactating dairy cow rations, a least-cost ration linear program model was developed using the Solver®

function of Microsoft Excel®. In algebraic terms, the linear program model used had the following form:

$$minimize\ Y = \sum_{j=1}^{n} c_j x_j \qquad (5\text{-}1)$$

$$subject\ to \sum_{j=1}^{n} a_{ij} x_j \geq (\leq, =) \boldsymbol{h_1} \qquad (5\text{-}2)$$
$$x_j \geq \mathbf{0}$$

where *Y* = ration cost per cow per day, *cj* = feedstuff *j* cost, *xj* = quantity of feedstuff *j*, *aij* = quantity of nutrient *i* in ingredient *j*, and h_1 = required amount of nutrient *i* in the ration. The equality or inequality signs are determined by the nutrient of interest. Equation 5-1 represents the objective function of the model, which in our case seeks to minimize the cost of the ration (Y), which is reached by the sum of the product of the quantity and cost of the selected feedstuffs that combined meet a series of nutritional constraints (Equation 5-2). Thus, data inputs to the model can be grouped broadly into: a) lactating dairy cow requirements, b) feedstuff nutritive profile and cost, and c) greenchop nutritive value and cost. In order to test the potential use of greenchop for a wide range of lactating dairy cow nutritional requirements, 12 different scenarios were evaluated, using NRC (2001) nutrient requirements of dairy cattle guidelines for 12 lactating Holstein dairy cows, classified by different stages of lactation and production levels: cows in 1st and 3rd lactation, at 60 and 120 d into milk and producing 18, 36 and 54 kg d^{-1} of milk (Table 5-1). Thus, the daily dry matter intake (DMI) crude protein (CP), P, Ca, K and net energy for lactation (NEL) requirements were set as constraints to the model. Maximum allowable limits of CP and P (10% above NRC recommendation), also

Table 5-1. Nutritional requirements of lactating Holstein dairy cows used in linear program model

Animal identification	Lactation #	Age (months)	Body Weight (kg)	Days in Milk (d)	Milk Production† (kg d^{-1})	Actual DMI (kg d^{-1})	NEL (Mcal d^{-1})	CP diet (% DM)	Ca (g d^{-1})	P (g d^{-1})	K (g d^{-1})
1	1	26	560	42	18	14.4	21.7	15.2	89.3	54.7	194
2	1	26	560	42	36	19.6	34.1	18.8	121.5	74.5	221
3	1	26	560	42	54	24.8	46.5	20.2	153.8	94.2	248
4	1	28	560	110	18	16.6	21.7	14.1	102.9	63.1	194
5	1	28	560	110	36	22.7	34.1	15.2	140.7	86.3	221
6	1	28	560	110	54	28.7	46.5	16.7	177.9	109.1	248
7	3	52	682	42	18	15.9	23.1	15.2	98.6	60.4	198
8	3	52	682	42	36	21.1	35.6	18.8	130.8	80.2	225
9	3	52	682	42	54	26.3	48.0	20.2	163.1	99.9	252
10	3	54	682	110	18	18.4	23.1	14.1	114.1	69.9	198
11	3	54	682	110	36	24.4	35.6	15.2	151.3	92.7	225
12	3	54	682	110	54	30.5	48.0	16.7	189.1	115.9	252

† Corresponds to 3.5% Fat Corrected Milk with 3% True Protein concentration. Adapted from nutrient requirements of dairy cattle (NRC, 2001)

were included to avoid excess feeding. Urea was set at a maximum of 1% of ration DM, to avoid nutritional imbalances. Amount of forage in ration was set to a minimum of 30% of the ration for all levels of milk production, while the maximum proportion of forage in diets was set at 70, 60 and 50% for cows producing 18, 36 and 54 kg d^{-1} of milk, respectively. Silage was limited to 60% of the total forage component. Restrictions on maximum amounts of specific concentrate ingredients were incorporated to assure that nutritional constraints are met and to reflect current producer practices in the region (Table 5-2).

Table 5-2. Selected constraint levels utilized in linear program model.

Constraint (% in diet)	Range	
	Low	High
Proportion of Forage†	30	70
Proportion of Silage in Forage component	-	60
Allowable excess Phosphorus	-	10
Allowable excess Crude Protein	-	10
Allowable Urea	-	1
Soybean hulls	-	5
Wheat bran	-	10
Wheat middlings	-	10
Brewers grains	-	5
Citrus pulp	-	10
Gluten feed	-	10
Corn grains	10	-
Hominy	-	12.5
Molasses		5

† Maximum proportion of forage in diets was set at 70, 60 and 50% for cows producing 18, 36 and 54 kg d^{-1} of milk, respectively.

Costs of ration ingredients were those quoted for bulk quantities (~905 kg) of readily available feedstuffs in Florida from Suwannee Valley Feeds LLC for November 2009 (Table 5-3), and include an extra 20% that is estimated for transportation and handling costs. Nutritive value data for feedstuffs were obtained from nutrient

Table 5-3. Prices of readily available feedstuffs to dairy producers in Florida

Major feed ingredients	Price ($905 kg^{-1})	Bulk ($ kg^{-1})	Price on Farm† ($ kg^{-1})
Tifton 85 hay (16.71%CP)	85	0.0939	0.1127
Alfalfa hay	220	0.2431	0.2917
Brewers grains (25% DM)	28	0.0309	0.0371
Citrus pulp	152	0.1679	0.2016
Corn grain	185	0.2044	0.2453
Corn gluten feed	155	0.1713	0.2055
Corn silage (33% DM)	45	0.0497	0.0597
Cottonseed	170	0.1879	0.2254
Distillers grains	178	0.1967	0.2360
Hominy	150	0.1658	0.1989
Molasses	165	0.1823	0.2188
Rye silage	85	0.0939	0.1127
Sorghum silage (33% DM)	32	0.0354	0.0424
Soybean hulls	115	0.1271	0.1525
Soybean meal	360	0.3978	0.4774
Wheat midds	140	0.1547	0.1856

† Includes an extra 20% for transportation and handling costs. Prices taken from Suwannee Valley Feeds LLC (November, 2009)

requirements of dairy cattle (NRC, 2001) tables, and were classified as concentrate, silage, or forage (non-silage).

The final component of the model is that related with the production cost and nutritive value of Tifton 85 greenchop. Data from greenchop defoliation management field trials conducted in 2007 at a North Central Florida dairy sprayfield and in 2008 in an established hayfield were incorporated into the model (Chapters 3 and 4). Treatments in the trial were the combination of two stubble heights (8 and 16 cm) and four harvest intervals (21, 24, 27, and 35 d). Based on results of the trials, budgets were calculated for greenchop production under the four harvest intervals averaged across stubble heights. Thus, the information added to the model were yields (kg DM ha^{-1}), crude protein concentration (CP; % DM), phosphorus concentration (% DM), net energy for lactation (NEL; Mcal kg^{-1}) and cost (\$ kg^{-1}) per harvest interval. Crude protein is essential for dairy cow nutrition, since when absorbed from the digestive tract it provides the amino acid building blocks for the synthesis of proteins that are vital to the maintenance, growth, reproduction and lactation of dairy cattle (NRC, 2001). Net energy for lactation is the representation of the energy required for maintenance and milk production of dairy cows. It is calculated as a function of the total digestible nutrients (TDN) of the forage or feedstuff, which in turn depends on the crude protein, ether extract, ash and non-fiber carbohydrate fraction (NRC, 2001). The current equation used by NRC (2001) for the estimation of NEL from TDN is as follows:

$$\text{NEL}\left(\text{Mcal kg}^{-1}\right) = 0.0245 \times \text{TDN}(\%) - 0.12 \tag{5-3}$$

Total digestible nutrients were not determined analytically for the Tifton 85 samples taken in either 2007 or 2008. Thus, TDN (%) was estimated based on the relationship suggested by Moore (1994), which considers TDN to be numerically equivalent to IVDOM (%) if the ether extract fraction is negligible, as is the case with most tropical forages. Calculated NEL values for harvest interval means are presented in Table 5-17.

Results and Discussion

Tifton 85 bermudagrass establishment budget

The budgets formulated for establishment of Tifton 85 for use as greenchop are not different from those developed for other hybrid bermudagrasses. Analyzing the cost structure, it should be noted that most of the expenditures went to planting and fertilization, essentially because of the high costs of inputs (commercial fertilizer and vegetative planting material) and the high machinery requirement for these activities

(Table 5-4). Overall, planting accounted for approximately 44% of total costs, whereas fertilization represented 32%. The proportion of total establishment costs allocated to planting and fertilization coincide with those calculated for hybrid bermudagrasses in north Florida in 2006 (Hewitt, 2006) and Georgia in 2008 (Lacy and Morgan, 2008). Producers interviewed at the study sites also confirmed these findings, highlighting that fertilization and plating related costs are one of the most important items to consider when establishing forages, and further stress the importance of adequate nutrient management and utilization of alternative fertilizer sources.

Tifton 85 bermudagrass greenchop production budgets

Overall, when analyzing the activities required to produce hybrid bermudagrasses as greenchop or hay, we find that the former requires less use of machinery and implements than the latter, since after the forage is cut, under greenchop use the material is taken directly to the livestock, whereas when used for hay additional activities must be undertaken in the field to assure the material is adequately dried, baled and stored. Although the comparison may not be entirely justified, since hay can be used at other times when no fresh material is available, harvesting warm-season grasses as greenchop could be advantageous, given its lower production costs and apparently lower field losses.

Comparing production budgets in both years, the costs of producing greenchop in 2007 (Tables 5-5, 5-7 and 5-9) were over four times greater than in 2008 (Tables 5-11, 5-13 and 5-15), because no fertilizer or irrigation were used. Within each year, the difference in costs between harvest intervals was related solely to the increase or decrease in machinery, labor and associated costs.

Table 5-4. Establishment budget for Tifton 85 bermudagrass using vegetative tops.

Activities	Month	Unit	Quantity	Unit Cost ($)	Total Cost $ ha^{-1}
Operative Costs					
Soil Test	April		1.00	17.29	17.29
Primary Tillage					
Disc plow (TD HD 9 m fold)	April	Pass ha^{-1}	2.00	12.42	24.85
Tractor 360 4WD (313 PTO)	April	Pass ha^{-1}	2.00	2.99	5.98
Labor	April	Pass ha^{-1}	2.00	1.33	2.67
Secondary Tillage					
Leveling disc (TD 7 m rigid)	April	Pass ha^{-1}	2.00	5.09	10.18
Tractor 160 MFWD	April	Pass ha^{-1}	2.00	3.53	7.06
Labor	April	Pass ha^{-1}	1.00	1.88	1.88
Planting					
Vegetative material	June	kg ha^{-1}	1346	0.15	197.60
Planting-custom	June	Pass ha^{-1}	1.00	197.60	197.60
Weed control					
Weedmaster (Dicamba+2,4-D amine)	June	L	7.56	3.79	28.65
Application (Boom sprayer 15 m)	June	Pass ha^{-1}	1.50	10.08	15.12
Tractor 60 HP-PTO	June	Pass ha^{-1}	2.00	1.51	3.01
Labor	June	Pass ha^{-1}	2.00	0.62	1.24
Fertilization					
Nitrogen (7-10 d AP§)	June	kg	33.64	0.93	31.23
Nitrogen (30 d AP)	July	kg	78.50	0.93	72.86
Phosphorus (P2O5; 7-10 d AP)	June	kg	44.86	0.75	33.70
Potassium (7-10 d AP)	June	kg	28.03	1.55	43.37
Potassium (30 d AP)	July	kg	28.03	1.55	43.37
Lime (includes spreading)	June	Mt	908.00	0.07	59.28
Fertilizer spreader (12 m)	June-July	Pass ha^{-1}	2.00	2.03	4.06
Tractor 60 HP-PTO	June-July	Pass ha^{-1}	2.00	0.59	1.19
Labor	June-July	Pass ha^{-1}	2.00	1.14	2.27
Total Operating Costs		$			806.22
Ownership Costs					
Implement ‡					
Disc Plow		ha	1.0	9.48	9.48
Leveling Disc		ha	1.0	3.09	3.09
Boom Sprayer 15 m		ha	1.0	1.19	1.19
Fertilizer spreader 12 m		ha	1.0	1.11	1.11
Tractor‡					
Tractor 360 4WD (313 PTO)		ha	1.00	3.73	3.73
Tractor 160 MFWD		ha	1.00	1.78	1.78
Tractor 60 HP-PTO		ha	1.00	0.44	0.44
General overhead (10% Op. Costs)		$	806.22	0.10	80.62
Total Ownership Costs					101.44
Total Cost (Operative + Ownership costs)					907.96

† Includes spreading, incorporation and firming.
‡ Includes interest, insurance and housing.
§ After planting.

Consequently, this caused the price per unit weight of greenchop to vary only from 0.083 to 0.124 \$ kg DM^{-1} in 2007 (Tables 5-6, 5-8 and 5-10), and from 0.028 to 0.036 \$ kg DM^{-1} in 2008 (Tables 5-12, 5-14 and 5-16). As with the case of the establishment budgets, manure fertilization was the activity that had the highest associated costs across harvest intervals in 2007, averaging 30% of total production costs. Irrigation costs were also considerably high, amounting to 18% of total costs. It is important to note that calculating costs in 2008 without use of fertilizer or irrigation was done to reflect the experimental conditions from which the agronomic data was obtained, and that reaching comparable yields or nutritive value, and a healthy stand in subsequent years without use of fertilizer would be unlikely. Thus, agronomic fertilizer prices are important determinants of forage production profitability, and can constitute strong incentives for producers to utilize alternative fertilizer sources, such as cattle manure. Nonetheless, the economic, environmental and agronomic effects of using cattle manure for Tifton 85 nutrition should be studied further. Of special concern are the amounts of P being applied, particularly when manure is applied to meet crop N requirements. Manure applications can be an important non-point source of excess P that can leach and reach below ground water sources; emphasizing the importance of closely monitoring soil nutrient levels, manure nutrient concentration and application methods to ensure that the resource is used as best as possible without causing important environmental impacts.

Least-cost linear program model results

Data on greenchop yield, nutritive value and production cost for both years of the field trials are summarized in Table 5-17. These values were those used in the model,

Table 5-5. Production costs of Tifton 85 bermudagrass greenchop with 3 harvests per season (35 d interval) and dairy manure as fertilizer source during 2007.

Activities	Month	Unit	Quantity	Unit Cost ($)	Total Cost $ ha^{-1}
Operative Costs					
Soil Test	April		1.00	17.29	17.29
Irrigation	May-October	ha mm	127.00	1.29	164.87
Weed control					
2,4-D amine (0.48 kg/L)	June	L	5.69	2.66	15.12
Application (Boom sprayer 15 m)	June	Pass ha^{-1}	1.00	0.35	0.35
Tractor 60 HP-PTO	June	Pass ha^{-1}	1.00	0.62	0.62
Labor	June	Pass ha^{-1}	1.00	0.89	0.89
Fertilization					
Manure spreading-Custom	May	Pass ha^{-1}	1.00	256.41	256.41
Harvest					
Rotary mower/conditioner (4 m)	May-Sept.	Pass ha^{-1}	3.00	1.93	5.78
Tractor (75 HP)	May-Sept.	Pass ha^{-1}	3.00	2.12	6.37
Forage wagon	May-Sept.	Pass ha^{-1}	3.00	0.79	2.37
Labor	May-Sept.	Pass ha^{-1}	3.00	2.64	7.93
Land rent		ha	1.00	44.46	44.46
Total Operative Costs		$			522.45
Ownership Costs					
Implement†					
Rotary mower/conditioner (4 m)		ha	1.00	0.61	1.51
Forage wagon		ha	1.00	0.13	0.32
Boom Sprayer (15 m)		ha	1.00	1.19	1.19
Machinery†					
Tractor (75 HP)		ha	1.00	0.59	0.59
Tractor 60 HP-PTO		ha	1.00	0.44	0.44
Irrigation		ha	1.00	222.30	222.30
Establishment Cost (10 yr prorate)		ha	0.10	907.96	90.80
General overhead (10% Op. Costs)		$	0.10	522.45	52.25
Total Ownership Costs		$			369.39
Total Production Cost (Operative + Ownership costs)					891.85

† Includes interest, insurance and housing.

Table 5-6. Cost of DM, crude protein and net energy for lactation using T85 greenchop with 3 harvests per season (35-d harvest interval) during 2007.

	Harvest Interval (35 d)
Total dry matter yield, kg DM ha^{-1} yr^{-1}	10800
Cost of greenchop, $ kg^{-1} DM	0.083
Average cost of CP in greenchop, $ kg^{-1} CP	0.459
Average cost of Mcal in greenchop, $ kg^{-1} NEL	0.071

with the cost structure derived from the forage budgets developed for each defoliation interval (21 d with five harvests, 24 and 27 d with four, and 35 d with three). Thus, costs

Table 5-7. Production costs of Tifton 85 bermudagrass greenchop with 4 harvests per season (24- and 27-d interval) and dairy manure as fertilizer source during 2007.

Activities	Month	Unit	Quantity	Unit Cost ($)	Total Cost $ ha^{-1}
Operative Costs					
Soil Test	April		1.00	17.29	17.29
Irrigation	May-October	ha mm	127.00	1.29	164.87
Weed control					
2,4-D amine (0.48 kg/L)	June	L	5.69	2.66	15.12
Application (Boom sprayer 15 m)	June	Pass ha^{-1}	1.00	0.35	0.35
Tractor 60 HP-PTO	June	Pass ha^{-1}	1.00	0.62	0.62
Labor	June	Pass ha^{-1}	1.00	0.89	0.89
Fertilization				0.00	
Manure spreading-Custom	May	Pass ha^{-1}	1.00	256.41	256.41
Harvest					
Rotary mower/conditioner (4 m)	May-Sept.	Pass ha^{-1}	4.00	1.53	6.13
Tractor (75 HP)	May-Sept.	Pass ha^{-1}	4.00	2.15	8.60
Forage wagon	May-Sept.	Pass ha^{-1}	4.00	0.79	3.16
Labor	May-Sept.	Pass ha^{-1}	4.00	2.64	10.57
Land rent		ha	1.00	44.46	44.46
Total Operative Costs		$			528.46
Ownership Costs					
Implement†					
Rotary mower/conditioner (4 m)		ha	1.00	1.51	1.51
Forage wagon		ha	1.00	0.32	0.32
Boom Sprayer (15 m)		ha	1.00	1.19	1.19
Machinery†					
Tractor (75 HP)		ha	1.00	0.59	0.59
Tractor 60 HP-PTO		ha	1.00	0.44	0.44
Irrigation		ha	1.00	222.30	222.30
Establishment Cost (10 yr prorate)		ha	0.10	907.96	90.80
General overhead (10% Operating Costs)		$	0.10	528.46	52.85
Total Ownership Costs		$			369.99
Total Production Cost (Operative + Ownership costs)					898.45

† Includes interest, insurance and housing.

Table 5-8. Cost of DM, crude protein and net energy for lactation using T85 greenchop with 4 harvests per season (24- and 27-d harvest interval) during 2007.

	Harvest interval (d)	
	24	27
Total dry matter yield, DM yield, kg ha^{-1} yr^{-1}	7300	8500
Cost of greenchop, $ kg^{-1} DM	0.123	0.105
Average cost of CP in greenchop, $ kg^{-1} CP	0.644	0.545
Average cost of Mcal in greenchop, $ kg^{-1} NEL	0.093	0.082

for 2007 were calculated incorporating manure application and irrigation, while those of 2008 used the budgets developed without fertilizer or irrigation. For this reason, within

Table 5-9. Production costs of Tifton 85 bermudagrass greenchop with 5 harvests per season (21-d interval) and dairy manure as fertilizer source during 2007.

Activity	Month	Unit	Quantity	Unit Cost ($)	Total Cost $ ha^{-1}
Operative Costs					
Soil Test	April		1.00	17.29	17.29
Irrigation	May-October	ha mm	127.00	1.29	166.73
Weed control					
2,4-D amine (0.48 kg/L)	June	L	5.69	2.66	15.12
Application (Boom sprayer 15 m)	June	Pass ha^{-1}	1.00	0.35	0.35
Tractor 60 HP-PTO	June	Pass ha^{-1}	1.00	0.62	0.62
Labor	June	Pass ha^{-1}	1.00	0.89	0.89
Fertilization					
Manure spreading	May	Pass ha^{-1}	1.00	256.41	256.41
Harvest					
Rotary mower/conditioner (4 m)	May-Sept.	Pass ha^{-1}	5.00	1.43	7.16
Tractor (75 HP)	May-Sept.	Pass ha^{-1}	5.00	1.75	8.77
Forage wagon	May-Sept.	Pass ha^{-1}	5.00	0.79	3.95
Labor	May-Sept.	Pass ha^{-1}	5.00	2.64	13.21
Land rent		ha	1.00	44.46	44.46
Total Operative Costs		$			533.10
Ownership Costs					
Implement†					
Rotary mower/conditioner (4 m)		ha	1.00	1.51	1.51
Forage wagon		ha	1.00	0.32	0.32
Boom Sprayer (15 m)		ha	1.00	1.19	1.19
Machinery†					
Tractor (75 HP)		ha	1.00	0.59	0.59
Tractor 60 HP-PTO		ha	1.00	0.44	0.44
Irrigation		ha	1.00	222.30	222.30
Establishment Cost (10 yr prorate)		ha	0.10	907.96	90.80
General overhead (10% Operating Costs)		$	0.10	533.10	53.31
Total Ownership Cost					370.46
Total Production Cost (Operative + Ownership costs)					903.56

† Includes interest, insurance and housing.

Table 5-10. Cost of DM, crude protein and net energy for lactation using T85 greenchop with 5 harvests per season (21-d harvest interval) during 2007.

	Harvest Interval (21 d)
Total dry matter yield, kg DM ha^{-1} yr^{-1}	7300
Cost of greenchop, $ kg^{-1} DM	0.124
Average cost of CP in greenchop, $ kg^{-1} CP	0.629
Average cost of Mcal in greenchop, $ kg^{-1} NEL	0.091

each scenario, the differences between production costs of defoliation treatments were due to differences in number of harvests and the associated machinery, implement,

Table 5-11. Production budget for Tifton 85 bermudagrass greenchop with 3 harvests per season (35-d harvest interval) during 2008.

Activities	Month	Unit	Quantity	Unit Cost ($)	Total Cost $ ha^{-1}
Operative Costs					
Soil Test	April		1.00	17.29	17.29
Weed control					
2,4-D amine (0.48 kg L^{-1})	June	L	5.69	2.66	15.12
Application (Boom sprayer 15 m)	June	Pass ha^{-1}	1.00	0.35	0.35
Tractor 60 HP-PTO	June	Pass ha^{-1}	1.00	0.62	0.62
Labor	June	Pass ha^{-1}	1.00	0.89	0.89
Harvest					
Rotary mower/conditioner (4 m)	May-Sept.	Pass ha^{-1}	3.00	0.78	5.78
Tractor (75 HP)	May-Sept.	Pass ha^{-1}	3.00	0.86	6.37
Forage wagon	May-Sept.	Pass ha^{-1}	3.00	0.32	2.37
Labor	May-Sept.	Pass ha^{-1}	3.00	1.07	7.93
Land rent		ha	1.00	18.00	44.46
Total Operative Costs		$			101.17
Ownership Costs					
Implement†					
Rotary mower/conditioner (4 m)		ha	1.00	1.51	1.51
Forage wagon		ha	1.00	0.32	0.13
Boom Sprayer (15 m)		ha	1.00	1.19	1.19
Machinery†					
Tractor (75 HP)		ha	1.00	0.59	0.59
Tractor 60 HP-PTO		ha	1.00	0.44	0.44
Establishment Cost (10 yr prorate)		ha	0.10	907.96	90.80
General overhead (10% Op. Costs)		$	0.10	101.17	10.12
Total Ownership Costs		$			104.96
Total Production Cost (Operative + Ownership costs)					206.14

† Includes interest, insurance and housing.

Table 5-12. Cost of DM, crude protein and net energy for lactation using T85 greenchop with 3 harvests per season (35-d harvest interval) during 2008.

	Harvest Interval (35 d)
Total dry matter yield, DM yield, kg ha-^{1} yr^{-1}	5700
Cost of greenchop, $ kg^{-1} DM	0.036
Average cost of CP in greenchop, $ kg^{-1} CP	0.263
Average cost of Mcal in greenchop, $ kg^{-1} NEL	0.033

input and labor costs.

Results in 2007 suggest that treatments that obtained the highest DM yields in the trial also had the lowest cost per unit weight of greenchop harvested. This appeared

Table 5-13. Production budget for Tifton 85 bermudagrass greenchop with 4 harvests per season (24- and 27-d harvest intervals) during 2008.

Activities	Month	Unit	Quantity	Unit Cost ($)	Total Cost $ ha^{-1}
Operative Costs					
Soil Test	April		1.00	17.29	17.29
Weed control					
2,4-D amine (0.48 kg L^{-1})	June	L	5.69	2.66	15.12
Application (Boom sprayer 15 m)	June	Pass ha^{-1}	1.00	0.35	0.35
Tractor 60 HP-PTO	June	Pass ha^{-1}	1.00	0.62	0.62
Labor	June	Pass ha^{-1}	1.00	0.89	0.89
Harvest					
Rotary mower/conditioner (4 m)	May-Sept.	Pass ha^{-1}	4.00	1.53	6.13
Tractor (75 HP)	May-Sept.	Pass ha^{-1}	4.00	2.15	8.60
Forage wagon	May-Sept.	Pass ha^{-1}	4.00	0.79	3.16
Labor	May-Sept.	Pass ha^{-1}	4.00	2.64	10.57
Land rent		ha	1.00	44.46	44.46
Total Operative Costs		$			107.17
Ownership Costs					
Implement†					
Rotary mower/conditioner (4 m)		ha	1.00	1.51	1.51
Forage wagon		ha	1.00	0.32	0.32
Boom Sprayer (15 m)		ha	1.00	1.19	1.19
Machinery†					
Tractor (75 HP)		ha	1.00	0.59	0.59
Tractor 60 HP-PTO		ha	1.00	0.44	0.44
Establishment Cost (10 yr prorate)		ha	0.10	907.96	90.80
General overhead (10% Op. Costs)		$	0.10	107.17	10.72
Total Ownership Costs		$			105.56
Total Production Cost (Operative + Ownership costs)					212.74

† Includes interest, insurance and housing.

Table 5-14. Cost of DM, crude protein and net energy for lactation using T85 greenchop with 4 harvests per season (24- and 27-d harvest interval) during 2008.

	Harvest interval (days)	
	24	27
Total dry matter yield, DM yield, kg ha^{-1} yr^{-1}	6600	7400
Cost of greenchop, $ kg^{-1} DM	0.032	0.028
Average cost of CP in greenchop, $ kg^{-1} CP	0.218	0.200
Average cost of Mcal in greenchop, $ kg^{-1} NEL	0.027	0.025

to have a strong effect on the selection of the greenchop treatments to be included in rations. While nutritional differences among the greenchop treatments were present, the magnitude of the difference does not seem to be biologically important, particularly for cows that are receiving supplements and concentrate feed. Since no fertilization or

Table 5-15. Production budget for Tifton 85 bermudagrass greenchop with 5 harvests (21-d interval) per season during 2008.

Activities	Month	Unit	Quantity	Unit Cost	Total Cost $ ha^{-1}
Operative Costs					
Soil Test	April		1.00	17.29	17.29
Weed control					
2,4-D amine (0.48 kg L^{-1})	June	L	5.69	2.66	15.12
Application (Boom sprayer 15 m)	June	Pass ha^{-1}	1.00	0.35	0.35
Tractor 60 HP-PTO	June	Pass ha^{-1}	1.00	0.62	0.62
Labor	June	Pass ha^{-1}	1.00	0.89	0.89
Harvest					
Rotary mower/conditioner (4 m)	May-Sept.	Pass ha^{-1}	5.00	1.25	6.27
Tractor (75 HP)	May-Sept.	Pass ha^{-1}	5.00	1.75	8.77
Forage wagon	May-Sept.	Pass ha^{-1}	5.00	0.79	3.95
Labor	May-Sept.	Pass ha^{-1}	5.00	2.64	13.21
Land rent		ha	1.00	44.46	44.46
Total Operative Costs		$			110.93
Ownership Costs					
Implement†					
Rotary mower/conditioner (4 m)		ha	1.00	1.51	1.51
Forage wagon		ha	1.00	0.32	0.32
Boom Sprayer (15 m)		ha	1.00	1.19	1.19
Machinery†					
Tractor (75 HP)		ha	1.00	0.59	0.59
Tractor 60 HP-PTO		ha	1.00	0.44	0.44
Establishment Cost (10 yr prorate)		ha	0.10	907.96	90.80
General overhead (10% Op. Costs)		$	0.10	110.93	11.09
Total Ownership Costs		$			105.94
Total Production Cost (Operative + Ownership costs)					216.87

† Includes interest, insurance and housing.

Table 5-16. Cost of DM, crude protein and net energy for lactation using T85 greenchop with 5 harvests per season (21-d harvest interval) during 2008.

	Harvest Interval (21 d)
Total dry matter yield, kg DM ha^{-1}yr^{-1}	6400
Cost of greenchop, $ kg^{-1} DM^{-1}	0.034
Average cost of CP in greenchop, $ kg^{-1} CP	0.208
Average cost of Mcal in greenchop, $ kg^{-1} NEL	0.027

irrigation costs occurred in 2008, ration costs of producing milk using Tifton 85 greenchop harvested at different regrowth intervals were very similar and lower in cost than in 2007. In addition, this appears to have made the incorporation of greenchop

Table 5-17. Relevant information from Tifton 85 greenchop field trials and production cost.

Harvest interval (d)	DM yield ($kg\ ha^{-1}$)		Phosphorus (% of DM)		CP (% of DM)		NEL ($Mcal\ kg^{-1}$)		Cost ($\$\ kg^{-1}$ DM)	
	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008
21	7300	6400	0.31	0.30	19.7	16.3	1.36	1.23	0.124	0.034
24	7300	6600	0.31	0.29	19.1	14.8	1.32	1.21	0.123	0.032
27	8500	7400	0.30	0.30	19.4	14.4	1.29	1.17	0.105	0.028
35	10800	5700	0.29	0.27	18.0	13.7	1.16	1.11	0.083	0.036

from lower yielding but higher nutritive value harvest intervals (i.e. 21-d intervals) economically feasible.

Across all forage types and greenchop regrowth intervals tested in both years, ration cost increased with milk production level (Table 5-18). This was likely due to the greater DM intake, energy and protein requirements of high-producing cows. When all forage options were available in the model without restrictions, the least-expensive Tifton 85 greenchop treatment (i.e. harvest interval) was selected above purchased Tifton 85 hay or alfalfa hay in both years, for all the dairy cow profiles in the study. The likely reason for these selections is the considerably lower cost of greenchop DM, energy and protein (Table 5-19). Forage DM cost of 21- and 24-d greenchop treatments in 2007 were 10 and 9% greater in cost than purchased Tifton 85 hay, respectively (Table 5-19). On the other hand, 27- and 35-d treatments were 7 and 35% lower in cost than Tifton 85 hay in the same year. When compared with purchased alfalfa hay, the most expensive greenchop treatment (21 d) was over two times lower in cost. In 2008, all greenchop treatments were lower in cost than either purchased alfalfa or Tifton 85 hays as dietary forage sources. Even the most expensive greenchop option (35 d) was

Table 5-18. Average cost of daily rations for lactating dairy cows grouped by production level formulated with different forages.

		Milk Production Level (kg d^{-1})		
Forage source (non-silage)		18	36	54
		----------- (\$ cow^{-1} day^{-1}) ---------		
T85 greenchop (21d)				
	2007	1.81	2.84	4.06
	2008	1.39	2.36	3.59
T85 greenchop (24d)				
	2007	1.81	2.84	4.07
	2008	1.39	2.36	3.60
T85 greenchop (27d)				
	2007	1.75	2.77	3.99
	2008	1.37	2.35	3.60
T85 greenchop (35d)				
	2007	1.66	2.68	3.92
	2008	1.44	2.44	3.70
Alfalfa		2.51	3.71	5.05
Tifton 85 hay		1.79	2.84	4.11

at least 3 times lower in cost than Tifton 85 hay; with values rising to an 8-fold difference in cost when compared to alfalfa hay, under current commodity prices.

As a protein source, the highest-yielding greenchop regrowth treatment in 2007 (35 d) was 37% lower in cost than Tifton 85 hay and 2.5 times lower in cost than alfalfa hay; while under 2008 conditions, protein provided by greenchop was at least three and eight times lower in cost than either alfalfa hay or Tifton 85 hay, respectively (Table 5-19). Nonetheless, care must be taken when balancing rations on CP alone, since this considers all protein sources equal and disregards the actual amounts of metabolizable proteins and essential amino acids (i.e. lysine and methionine) present in feedstuffs.

As expected, greenchop provided less NEL per dollar than corn silage during 2007. Even with the very low production costs in 2008, NEL from greenchop was only 33% lower in cost than that in corn silage. Also, across both years and harvest intervals,

Table 5-19. Average cost of forage DM, crude protein and net energy (NEL) for lactation in purchased forages and T85 greenchop treatments.

	Purchased forages				T85 greenchop							
					---- 21 d ----		---- 24 d ----		---- 27 d ----		---- 35 d ----	
Nutrient	Corn silage	Alfalfa hay	T85 hay	Sorghum Silage	2007	2008	2007	2008	2007	2008	2007	2008
DM, $ kg^{-1}	0.060	0.292	0.112	0.042	0.124	0.034	0.123	0.032	0.105	0.028	0.083	0.036
	-------------------------------------- $ kg^{-1} nutrient in kg forage DM --------------------------------											
Crude Protein	0.72	1.62	0.63	0.47	0.63	0.21	0.64	0.22	0.55	0.20	0.46	0.26
NEL	0.04	0.26	0.10	0.04	0.09	0.03	0.09	0.03	0.08	0.03	0.07	0.03

purchased alfalfa hay and Tifton 85 hay were more expensive sources of NEL than greenchop (Table 5-19). These low NEL costs suggests that Tifton 85 bermudagrass greenchop treatments have the potential to at least partially substitute other high-quality purchased forages in dairy rations, such as corn silage, alfalfa hay or Tifton 85 hay; coinciding with previous findings by West et al. (1997) and Mandebvu et al. (1998) that suggested that Tifton 85 can be an alternative to using alfalfa hay or corn silage.

Greenchop treatments selected by the program in 2007 (35 d) indicate that for dairy production, harvest intervals that maximized DM yields were most profitable for inclusion in dairy rations (Table 5-20). It is also important to mention that this treatment was generally among the lowest in terms of CP and NEL, although the decline observed in these parameters as harvest intervals increased was generally small (Table 5-17). This suggests that for formulating rations for lactating dairy cows (under the 2007 cost structure), the small decline in nutritive value attributed to longer harvest intervals of Tifton 85 greenchop does not offset the greater DM yields obtained, possibly because the rations already include high energy (e.g. corn silage) and protein (e.g. brewer's grains) feedstuffs. This hypothesis can be supported by results from dairy grazing trials. When working with heavily supplemented dairy cows, Fontaneli et al. (2005) found that Tifton 85 was of equal or superior economic value than pearl millet, a high-quality summer annual grass, because of its longer growing season, high DM yields, lower costs and reduced benefits of feeding greater quality forages to cows receiving concentrates. Also, Fike et al. (2003) found that cows grazing Tifton 85 pastures produced 29% more milk per unit land area than those grazing rhizoma peanut, a high-

Table 5-20. Ration costs of least cost linear program model using Tifton 85 greenchop harvested in 2007 and 2008 growing seasons.

Forage source		Dairy Cow Profile 1	2	3	4	5	6	7	8	9	10	11	12	Mean
		($ cow^{-1} day^{-1})												
T85 greenchop (21 d)														
	2007	1.60	2.72	4.00	1.84	2.80	3.96	1.77	2.84	4.13	2.04	3.01	4.14	2.90
	2008‡	1.27	2.30	3.55	1.40	2.27	3.51	1.35	2.41	3.66	1.55	2.45	3.62	2.44
T85 greenchop (24 d)														
	2007	1.60	2.73	4.01	1.84	2.79	3.97	1.77	2.85	4.14	2.04	3.00	4.14	2.91
	2008	1.27	2.31	3.56	1.39	2.28	3.52	1.35	2.41	3.67	1.54	2.43	3.63	2.45
T85 greenchop (27 d)														
	2007	1.55	2.66	3.94	1.77	2.71	3.90	1.70	2.78	4.06	1.96	2.91	4.04	2.83
	2008‡	1.26	2.30	3.56	1.37	2.28	3.52	1.34	2.41	3.67	1.52	2.41	3.63	2.44
T85 greenchop (35 d)														
	2007†	1.50	2.60	3.87	1.68	2.60	3.83	1.61	2.71	4.00	1.86	2.80	3.96	2.75
	2008	1.33	2.40	3.66	1.42	2.37	3.62	1.42	2.51	3.78	1.57	2.48	3.74	2.53
Alfalfa hay		2.27	3.61	4.99	2.53	3.60	4.95	2.43	3.77	5.15	2.80	3.87	5.11	3.76
T85 hay		1.63	2.77	4.06	1.80	2.75	4.02	1.73	2.89	4.19	1.99	2.95	4.15	2.91

† and ‡ are lowest-cost options in 2007 and 2008, respectively.

quality summer perennial legume, because of its high dry matter yields, tolerance to grazing and high nutritive value.

In 2008, greenchop was selected over purchased forage options, although the greenchop treatment selected depended on the production level of the dairy cow (Table 5-21). The model selected greenchop harvested at 27-d intervals for cows producing 18 kg milk d^{-1}, while rations for cows producing 54 kg milk d^{-1} were formulated using greenchop harvested at 21 d. For the intermediate milk producing level (36 kg milk d^{-1}), the model selected 21-d greenchop as the most feasible alternative for all profiles except for profile 11, which refers to 3rd lactation cows at 110 days into milk production. Overall, the results suggest that because of the low production costs of Tifton 85 bermudagrass during 2008, the higher nutritive value of greenchop harvested at 21 d offset its slightly higher DM costs (+ $0.006) compared to the lowest-cost harvest interval, 27 d.

Overall, average ration cost for high producing cows (54 kg d^{-1} of milk) when greenchop was included ranged from \$3.60 to \$4.07 cow^{-1} day^{-1} (average = $3.79), resulting in an average cost reduction of 25 and 8% when compared to rations formulated using purchased alfalfa hay or Tifton 85 hay, respectively (Table 5-18). In addition, ration costs for low producing cows (18 kg d^{-1} of milk), were lowered on average by 52 and 12% by using greenchop instead of alfalfa or Tifton 85 hay, respectively.

The reductions in ration costs observed are important for dairy profitability in Florida, since rising feed costs have been identified as one of the most important issues currently facing dairy producers in the state (Giesy et al., 2008). Currently, feed

Table 5-21. Ration profile and costs of least-cost linear program model using Tifton 85 greenchop harvested in 2008 for selected cow profiles.

	Cow profile											
Ingredients	1	2	3	4	5	6	7	8	9	10	11	12
Forage	---------- % in ration† ----------											
Corn silage	28.0	24.0	20.0	28.0	24.0	20.0	28.0	24.0	20.0	28.0	24.0	20.0
T85 greenchop (21 d)	-	36.0	30.0	-	36.0	30.0	-	36.0	30.0	-	-	30.0
T85 greenchop (27 d)	42.0	-	-	42.0	-	-	42.0	-	-	42.0	36.0	-
Concentrate												
Brewers grain	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Citrus pulp	-	-	10.0	-	-	10.0	-	-	10.0	-	-	10.0
Gluten feed	-	2.3	1.7	-	2.5	2.4	-	2.3	2.3	-	2.4	2.4
Corn grains	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Hominy	4.9	12.5	12.5	5.0	12.5	12.5	4.9	12.5	12.5	5.0	12.5	12.5
Cotton seed	-	-	0.5	-	-	-	-	-	-	-	-	-
Soybean hulls	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Wheat middlings	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Urea	0.1	0.2	0.2	-	-	0.1	0.1	0.2	0.2	-	0.1	0.1
Total Concentrate	30.0	40.0	50.0	30.0	40.0	50.0	30.0	40.0	50.0	30.0	40.0	50.0
Ration Nutritive Profile												
Crude protein	15.2	18.8	20.2	14.1	15.2	16.7	15.2	18.8	20.2	14.1	15.2	16.7
TDN	69.1	70.6	72.0	69.1	70.7	72.0	69.1	70.6	71.9	69.1	70.6	72.0
NEL (Mcal)	21.7	34.1	46.5	23.6	34.1	46.5	23.1	35.6	48.0	26.2	36.1	48.0
Calcium	0.78	0.62	0.72	0.80	0.65	0.74	0.79	0.62	0.72	0.80	0.65	0.75
Phosphorus	0.36	0.36	0.34	0.38	0.38	0.36	0.37	0.36	0.35	0.38	0.38	0.37
Potassium	1.56	1.47	1.39	1.56	1.47	1.39	1.56	1.47	1.39	1.56	1.47	1.39
Ration cost												
$ day^{-1} cow^{-1}	1.26	2.30	3.55	1.37	2.27	3.51	1.34	2.41	3.66	1.52	2.41	3.62

† Except NEL that is measured as Mcal.

represents approximately 75% of operational costs, with an estimated 80% going into purchased feedstuffs (USDA-NASS, 2009b). Thus, any reductions in this important component of the farming system can translate into large economic gains for producers, if animal health, milk yield and quality are not affected.

Conclusions and Recommendations

Tifton 85 greenchop production is a forage management practice that requires fewer management practices than harvesting for hay or silage production. This translates into lower production costs, since less machinery, inputs and labor are required. From an agronomic perspective, fewer yield losses can be expected under this form of utilization, since the forage is not left to dry in the field, as in hay production, or placed in silos or other structures for preservation for further use. While the comparison between haying and ensiling and greenchop may not be justified completely, since they can have different purposes in feeding management, harvesting Tifton 85 bermudagrass as greenchop is a potentially attractive alternative during the summer growing season. In terms of production cost (per unit of DM weight), differences existed between the budgets calculated with different harvest intervals. Overall, more harvests imply more machinery, input and labor costs, and not always lead to increased yields or biologically significant differences in nutritive value. Also, given the high proportion of costs that go into fertilization, the source (manure vs. inorganic fertilizer) can be an important consideration for producers wishing to maximize the use of the resources at their disposal to reduce feeding costs.

With the lower production costs and high nutritive value that can be obtained with managing Tifton 85 as greenchop, it is not surprising that its use can reduce the cost of formulating rations for lactating dairy cows. This is mainly due to its high DM production and nutritive value, which make it a relatively inexpensive source of energy for lactation and protein, compared to other widely used purchased forage options. In addition, greater amounts of forage can be fed to dairy cows using Tifton 85 greenchop than with the other alternatives in the study, suggesting that this forage management practice can be a viable alternative in Florida dairies.

Further research is warranted, particularly to understand the long-term effects of this management on stand persistence, as well as evaluating the effects of fertilizer source. Animal trials would also be critical to determine if high milk production levels can be sustained using rations formulated with significant proportions of Tifton 85 greenchop, since previous research has show that silage from bermudagrass harvested at 35-d regrowth intervals can reduce milk yields compared to cows fed elephantgrass silage or corn silage (Ruiz et al., 1995). Also, comparative economical analysis of this forage use should be made with other cropping systems and feeding alternatives.

CHAPTER 6
SUMMARY AND CONCLUSIONS

Defoliation management of forages is one of the most important activities that producers control to obtain high yields and quality. Harvest interval and stubble height are known to affect the accumulation of DM, the herbage nutritive value and the stand persistence of hybrid bermudagrasses, but more information is needed to help guide harvest management practices for producers in Florida. Thus, studies were conducted during 2007 and 2008 to determine the effects of harvest interval and stubble height on DM yields, soil N and P removal and herbage nutritive value of Tifton 85 bermudagrass. In addition, a least-cost ration formulation linear program was developed in order to assess the economic impact of incorporating Tifton 85 greenchop in lactating dairy cow rations.

In terms of DM yields, year by stubble height and year by harvest interval interactions were detected. Across years, the 8-cm stubble height produced more DM than the 16-cm level, although this difference was greater under the water and N-restricted conditions in 2008, where the short stubble produced 30% more DM than the tall stubble, compared to a 9% difference between heights in 2007. In 2007, total yields were consistently greater as the harvest interval was reduced from 21 to 35 d (linear effect), suggesting that longer periods between harvests maximize DM yields. In contrast, during 2008 yields showed a cubic response to harvest interval, with the highest values observed for 27 d and lowest under 35-d intervals.

Also, DM yields varied throughout the year in response to varying environmental conditions. Overall, greater yields were typically present when conditions were most conducive to vegetative growth, particularly in terms of water availability. While harvest event × stubble height interactions were present in both years, the differences between stubble heights for a given harvest event tended to be of a lower magnitude in 2007 than in 2008. In addition, DM yields obtained by leaving 16-cm stubble tended to be more consistent throughout the season, possibly suggesting a management that may be more beneficial for producers, because of greater dependability of yields.

Removal of N and P was highest for treatments with high DM yields in both years. Consequently, 35- and 27-d harvests removed the most N and P in 2007 and 2008, respectively. Stubble height main effects were found for N and P removal, with shorter stubble heights removing more N and P. Furthermore, 35-d harvests in 2007 removed 22% of applied P and 2.1 times as much N as was applied in either manure or manure irrigation water, suggesting that Tifton 85 can be a an important tool for phytoremediation in dairy sprayfields.

Across both years of the study, herbage nutritive value tended to decline with longer harvest intervals, while appearing to be fairly homogenous between the stubble heights tested, even when grown under contrasting fertilization and soil moisture regimes. Also, total crude protein concentration was lowest at 35 d intervals, although values dropped only after 27 d in 2007, while in 2008 the decline began after 21-d harvests. Seasonally, more variability in CP concentrations was detected in 2008 than in 2007, likely a consequence of the lower soil nutrient levels and more marked water stress conditions. It also should be noted that overall, CP concentrations were highest under 2007 conditions than in 2008, further highlighting the benefits of supplying fertilization and irrigation. In relation to phosphorus concentration, although differences were found among harvest intervals, in both years concentrations remained fairly stable, and corresponded to values reported in other bermudagrass studies. Concerning digestibility, IVDOM decreased linearly and at similar rates from 21- to 35-d intervals in both years. Nonetheless, the decline in digestibility between these harvest intervals did not surpass 11%. Additionally, no differences were found between stubble heights in either year. Although some harvest events × stubble height interactions were detected within harvest interval, the variation in digestibility was relatively low for the most part. In general, IVDOM was greater and more stable in 2007, suggesting that greater nutrient availability and better soil moisture favor forage digestibility. Also the low variability observed across stubble heights and harvest intervals throughout the season suggests that across different growing conditions, Tifton 85 bermudagrass can produce dependably highly digestible herbage that could help meet the nutritional requirements of lactating dairy cows.

Neutral detergent fiber concentrations increased with decreasing harvest interval from 21- to 35-d, and were greater for 16-cm stubble than 8-cm stubble at 21-d harvests. While the reasons for the difference between stubble heights at 21-d harvests is unclear, the differences among harvest intervals could be explained by a greater accumulation of secondary cell wall components, a larger proportion of senescing or dead material, or a reduction in leaf to stem ratio with the onset of maturity. Overall, the increase in NDF concentration with longer harvest intervals, when present, was relatively small. This homogeneity between intervals can be an important advantage for producers utilizing Tifton 85 in lactating dairy cow rations, since no major adjustments in formulation would need to be made in order to maintain optimum NDF diet concentrations, although the NEL concentration will likely decline between 21- and 35-d intervals.

When compared to other harvest options, greenchop production requires fewer activities than harvesting for hay or silage production. This translates into lower production costs, since less machinery, inputs and labor are required. Also feeding freshly cut forage avoids the yield losses associated with conserved forages. However, utilizing forages as greenchop does little to solve forage availability issues in seasons of low forge production. Nonetheless, Tifton 85 bermudagrass used as greenchop is a potentially attractive alternative during the summer growing season. In terms of production costs (per unit weight), more harvests per season resulted in more machinery, input and labor costs, and did not always result in significant improvements in nutritive value. Also, given the high proportion of costs that go to supplying crop nutrients, the source of fertilizer can be an important consideration for producers wishing to lower production costs. Producers should take advantage of the readily-available manure.

Compared to the purchased forage options available to producers in the state based on 2009 prices, incorporating on-farm grown Tifton 85 greenchop can reduce ration costs for a wide range of lactating dairy cows. This is mainly due to its high DM production and nutritive value, which make it a relatively inexpensive source of energy and protein for lactation, suggesting that this forage management practice can be a viable alternative in Florida dairies.

Dairymen could potentially decrease feeding cost by substituting a portion of the rations with on-farm grown Tifton 85 greenchop, and in the process reduce nutrient inputs and remove excess N and P from dairy sprayfields.

APPENDIX

RESULTS OF LEAST-COST RATIONS FORMULATED WITH TIFTON 85 BERMUDAGRASS GREENCHOP HARVESTED AT DIFFERENT HARVEST INTERVALS

Table A-1. Ingredients and costs of rations formulated for selected lactating dairy cows using T85 greenchop harvested at 21-d intervals (2007).

	Cow profile‡											
Ingredients	1	2	3	4	5	6	7	8	9	10	11	12
Forage	% in ration											
Corn silage	45.5	39.0	32.5	45.5	39.0	32.5	45.5	39.0	32.5	45.5	39.0	32.5
T85 greenchop (21 d)	24.5	21.0	17.5	24.5	21.0	17.5	24.5	21.0	17.5	24.5	21.0	17.5
Total forage in ration	70.0	60.0	50.0	70.0	60.0	50.0	70.0	60.0	50.0	70.0	60.0	50.0
Concentrate												
Brewers grain	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Citrus pulp	-	2.3	10.0	-	2.4	10.0	-	2.3	10.0	-	2.4	8.6
Gluten feed	-	-	2.2	-	-	2.4	-	-	2.2	-	-	3.8
Corn grains	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Hominy	4.9	12.5	12.5	5.0	12.5	12.5	4.9	12.5	12.5	5.0	12.5	12.5
Soybean hulls	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Wheat middlings	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Urea	0.1	0.2	0.3	-	0.1	0.1	0.1	0.2	0.3	-	0.1	0.1
Total Concentrate	30.0	40.0	50.0	30.0	40.0	50.0	30.0	40.0	50.0	30.0	40.0	50.0
Ration Nutritive Profile												
Crude protein	15.2	18.8	20.2	14.1	15.2	16.7	15.2	18.8	20.2	14.1	15.2	16.7
TDN	70.7	72.0	73.0	70.7	72.1	73.1	70.7	72.0	73.0	70.7	72.1	73.1
NEL (Mcal)	21.9	34.1	46.5	25.2	35.4	46.5	24.1	35.6	48.0	27.9	38.1	48.6
Calcium	0.62	0.56	0.54	0.62	0.62	0.61	0.62	0.57	0.55	0.62	0.62	0.62
Phosphorus	0.40	0.37	0.32	0.40	0.42	0.38	0.40	0.39	0.33	0.40	0.42	0.42
Potassium	1.39	1.32	1.27	1.39	1.32	1.27	1.39	1.32	1.27	1.39	1.32	1.28
Ration cost												
$ day^{-1} cow^{-1}	1.60	2.72	4.00	1.84	2.80	3.96	1.77	2.84	4.13	2.04	3.01	4.14

† Except NEL that is measured as Mcal.
‡ Cow 1 is a Holstein in 1st lactation, at 42 days in milk producing 18 kg milk d^{-1}; Cow 2 is a Holstein in 1st lactation, at 42 days in milk producing 36 kg milk d^{-1}; Cow 3 is a Holstein in 1st lactation, at 42 days in milk producing 54 kg milk d^{-1}; Cow 4 is a Holstein in 1st lactation, at 110 days in milk producing 18 kg milk d^{-1}; Cow 5 is a Holstein in 1st lactation, at 110 days in milk producing 36 kg milk d^{-1}; Cow 6 is a Holstein in 1st lactation, at 110 days in milk producing 54 kg milk d^{-1}; Cow 7 is a Holstein in 3rd lactation, at 42 days in milk producing 18 kg milk d^{-1}; Cow 8 is a Holstein in 3rd lactation, at 42 days in milk producing 36 kg milk d^{-1}; Cow 9 is a Holstein in 3rd lactation, at 42 days in milk producing 54 kg milk d^{-1}; Cow 10 is a Holstein in 3rd lactation, at 110 days in milk producing 18 kg milk d^{-1}; Cow 11 is a Holstein in 3rd lactation, at 110 days in milk producing 36 kg milk d^{-1}; Cow 12 is a Holstein in 3rd lactation, at 110 days in milk producing 54 kg milk d^{-1}.

Table A-2. Ingredients and costs of rations formulated for selected lactating dairy cows using T85 greenchop harvested 24-d intervals (2007)

	Cow profile‡											
Ingredients	1	2	3	4	5	6	7	8	9	10	11	12
Forage	------------------------------------- % in ration ---------------------------------											
Corn silage	45.5	39.0	32.5	45.5	39.0	32.5	45.5	39.0	32.5	45.5	39.0	32.5
T85 greenchop (24 d)	24.5	21.0	17.5	24.5	21.0	17.5	24.5	21.0	17.5	24.5	21.0	17.5
Total forage in ration	70.0	60.0	50.0	70.0	60.0	50.0	70.0	60.0	50.0	70.0	60.0	50.0
Concentrate												
Brewers grain	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Citrus pulp	-	2.3	10.0	-	2.4	10.0	-	2.3	10.0	-	2.4	8.5
Gluten feed	-	-	2.2	-	-	2.4	-	-	2.2	-	-	3.8
Corn grains	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Hominy	4.9	12.5	12.5	5.0	12.5	12.5	4.9	12.5	12.5	5.0	12.5	12.5
Soybean hulls	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Wheat middlings	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Urea	0.1	0.2	0.3	-	0.1	0.1	0.1	0.2	0.3	-	0.1	0.1
Total Concentrate	30.0	40.0	50.0	30.0	40.0	50.0	30.0	40.0	50.0	30.0	40.0	50.0
Ration Nutritive Profile												
Crude protein	15.2	18.8	20.2	14.1	15.2	16.7	15.2	18.8	20.2	14.1	15.2	16.7
TDN	70.7	72.0	73.0	70.7	72.1	73.1	70.7	72.0	73.0	70.7	72.1	73.1
NEL (Mcal)	21.7	34.1	46.5	25.1	35.3	46.5	24.0	35.6	48.0	27.8	37.9	48.4
Calcium	0.62	0.55	0.54	0.62	0.62	0.61	0.62	0.57	0.55	0.62	0.62	0.62
Phosphorus	0.40	0.37	0.32	0.40	0.42	0.37	0.40	0.38	0.33	0.40	0.42	0.42
Potassium	1.39	1.32	1.27	1.39	1.32	1.27	1.39	1.32	1.27	1.39	1.32	1.28
Ration cost												
\$ day^{-1} cow^{-1}	1.60	2.73	4.01	1.84	2.79	3.97	1.77	2.85	4.14	2.04	3.00	4.14

† Except NEL that is measured as Mcal.

‡ Cow 1 is a Holstein in 1st lactation, at 42 days in milk producing 18 kg milk d^{-1}; Cow 2 is a Holstein in 1st lactation, at 42 days in milk producing 36 kg milk d^{-1}; Cow 3 is a Holstein in 1st lactation, at 42 days in milk producing 54 kg milk d^{-1}; Cow 4 is a Holstein in 1st lactation, at 110 days in milk producing 18 kg milk d^{-1}; Cow 5 is a Holstein in 1st lactation, at 110 days in milk producing 36 kg milk d^{-1}; Cow 6 is a Holstein in 1st lactation, at 110 days in milk producing 54 kg milk d^{-1}; Cow 7 is a Holstein in 3rd lactation, at 42 days in milk producing 18 kg milk d^{-1}; Cow 8 is a Holstein in 3rd lactation, at 42 days in milk producing 36 kg milk d^{-1}; Cow 9 is a Holstein in 3rd lactation, at 42 days in milk producing 54 kg milk d^{-1}; Cow 10 is a Holstein in 3rd lactation, at 110 days in milk producing 18 kg milk d^{-1}; Cow 11 is a Holstein in 3rd lactation, at 110 days in milk producing 36 kg milk d^{-1}; Cow 12 is a Holstein in 3rd lactation, at 110 days in milk producing 54 kg milk d^{-1}.

Table A-3. Ingredients and costs of rations formulated for selected lactating dairy cows using T85 greenchop harvested 27-d intervals (2007)

	Cow profile‡											
Ingredients	1	2	3	4	5	6	7	8	9	10	11	12
Forage	------------- % in ration -------------											
Corn silage	45.5	39.0	32.5	45.5	39.0	32.5	45.5	39.0	32.5	45.5	39.0	32.5
T85 greenchop (27 d)	24.5	21.0	17.5	24.5	21.0	17.5	24.5	21.0	17.5	24.5	21.0	17.5
Total forage in ration	70.0	60.0	50.0	70.0	60.0	50.0	70.0	60.0	50.0	70.0	60.0	50.0
Concentrate												
Brewers grain	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Citrus pulp	-	2.3	10.0	-	2.4	10.0	-	2.3	10.0	-	2.4	8.5
Gluten feed	-	-	2.2	-	-	2.4	-	-	2.2	-	-	3.8
Corn grains	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Hominy	4.9	12.5	12.5	5.0	12.5	12.5	4.9	12.5	12.5	5.0	12.5	12.5
Soybean hulls	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Wheat middlings	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Urea	0.1	0.2	0.3	-	0.1	0.1	0.1	0.2	0.3	-	0.1	0.1
Total Concentrate	30.0	40.0	50.0	30.0	40.0	50.0	30.0	40.0	50.0	30.0	40.0	50.0
Ration Nutritive Profile												
Crude protein	15.2	18.8	20.2	14.1	15.2	16.7	15.2	18.8	20.2	14.1	15.2	16.7
TDN	70.7	72.0	73.0	70.7	72.1	73.1	70.7	72.0	73.0	70.7	72.1	73.1
NEL (Mcal)	21.7	34.1	46.5	24.9	35.1	46.5	23.9	35.6	48.0	27.6	37.7	48.2
Calcium	0.62	0.55	0.54	0.62	0.62	0.61	0.62	0.57	0.56	0.62	0.62	0.62
Phosphorus	0.39	0.37	0.32	0.39	0.42	0.37	0.39	0.38	0.33	0.39	0.42	0.42
Potassium	1.39	1.32	1.27	1.39	1.32	1.27	1.39	1.32	1.27	1.39	1.32	1.28
Ration cost												
\$ day^{-1} cow^{-1}	1.55	2.66	3.94	1.77	2.71	3.90	1.70	2.78	4.06	1.96	2.91	4.04

† Except NEL that is measured as Mcal.

‡ Cow 1 is a Holstein in 1st lactation, at 42 days in milk producing 18 kg milk d^{-1}; Cow 2 is a Holstein in 1st lactation, at 42 days in milk producing 36 kg milk d^{-1}; Cow 3 is a Holstein in 1st lactation, at 42 days in milk producing 54 kg milk d^{-1}; Cow 4 is a Holstein in 1st lactation, at 110 days in milk producing 18 kg milk d^{-1}; Cow 5 is a Holstein in 1st lactation, at 110 days in milk producing 36 kg milk d^{-1}; Cow 6 is a Holstein in 1st lactation, at 110 days in milk producing 54 kg milk d^{-1}; Cow 7 is a Holstein in 3rd lactation, at 42 days in milk producing 18 kg milk d^{-1}; Cow 8 is a Holstein in 3rd lactation, at 42 days in milk producing 36 kg milk d^{-1}; Cow 9 is a Holstein in 3rd lactation, at 42 days in milk producing 54 kg milk d^{-1}; Cow 10 is a Holstein in 3rd lactation, at 110 days in milk producing 18 kg milk d^{-1}; Cow 11 is a Holstein in 3rd lactation, at 110 days in milk producing 36 kg milk d^{-1}; Cow 12 is a Holstein in 3rd lactation, at 110 days in milk producing 54 kg milk d^{-1}.

Table A-4. Ingredients and costs of rations formulated for selected lactating dairy cows using T85 greenchop harvested 35-d intervals (2007).

	Cow profile‡											
Ingredients	1	2	3	4	5	6	7	8	9	10	11	12
Forage	------------------------------------- % in ration ----------------------------------											
Corn silage	45.5	39.0	32.5	45.5	39.0	32.5	45.5	39.0	32.5	45.5	39.0	32.5
T85 greenchop (35 d)	24.5	21.0	17.5	24.5	21.0	17.5	24.5	21.0	17.5	24.5	21.0	17.5
Total forage in ration	70.0	60.0	50.0	70.0	60.0	50.0	70.0	60.0	50.0	70.0	60.0	50.0
Concentrate												
Brewers grain	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Citrus pulp	-	2.3	10.0	-	2.4	10.0	-	2.3	10.0	-	2.4	10.0
Gluten feed	-	-	2.2	-	-	2.4	-	-	2.2	-	-	2.4
Corn grains	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Hominy	4.9	12.5	12.5	5.0	12.5	12.5	4.9	12.5	12.5	5.0	12.5	12.5
Soybean hulls	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Wheat middlings	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Urea	0.1	0.2	0.3	-	0.1	0.1	0.1	0.2	0.3	-	0.1	0.1
Total Concentrate	30.0	40.0	50.0	30.0	40.0	50.0	30.0	40.0	50.0	30.0	40.0	50.0
Ration Nutritive Profile												
Crude protein	15.2	18.8	20.2	14.1	15.2	16.7	15.2	18.8	20.2	14.1	15.2	16.7
TDN	70.7	72.0	73.0	70.7	72.1	73.1	70.7	72.0	73.0	70.7	72.1	73.1
NEL (Mcal)	21.7	34.1	46.5	24.4	34.5	46.5	23.4	35.6	48.0	27.1	37.1	48.0
Calcium	0.60	0.54	0.54	0.62	0.62	0.60	0.62	0.56	0.55	0.62	0.62	0.62
Phosphorus	0.38	0.36	0.32	0.39	0.42	0.37	0.39	0.38	0.32	0.39	0.42	0.38
Potassium	1.39	1.32	1.27	1.39	1.32	1.27	1.39	1.32	1.27	1.39	1.32	1.27
Ration cost												
$ day^{-1} cow^{-1}	1.50	2.60	3.87	1.68	2.60	3.83	1.61	2.71	4.00	1.86	2.80	3.96

† Except NEL that is measured as Mcal.

‡ Cow 1 is a Holstein in 1st lactation, at 42 days in milk producing 18 kg milk d^{-1}; Cow 2 is a Holstein in 1st lactation, at 42 days in milk producing 36 kg milk d^{-1}; Cow 3 is a Holstein in 1st lactation, at 42 days in milk producing 54 kg milk d^{-1}; Cow 4 is a Holstein in 1st lactation, at 110 days in milk producing 18 kg milk d^{-1}; Cow 5 is a Holstein in 1st lactation, at 110 days in milk producing 36 kg milk d^{-1}; Cow 6 is a Holstein in 1st lactation, at 110 days in milk producing 54 kg milk d^{-1}; Cow 7 is a Holstein in 3rd lactation, at 42 days in milk producing 18 kg milk d^{-1}; Cow 8 is a Holstein in 3rd lactation, at 42 days in milk producing 36 kg milk d^{-1}; Cow 9 is a Holstein in 3rd lactation, at 42 days in milk producing 54 kg milk d^{-1}; Cow 10 is a Holstein in 3rd lactation, at 110 days in milk producing 18 kg milk d^{-1}; Cow 11 is a Holstein in 3rd lactation, at 110 days in milk producing 36 kg milk d^{-1}; Cow 12 is a Holstein in 3rd lactation, at 110 days in milk producing 54 kg milk d^{-1}.

Table A-5. Ingredients and costs of rations formulated for selected lactating dairy cows using T85 greenchop harvested 21-d intervals (2008).

	Cow profile‡											
Ingredients	1	2	3	4	5	6	7	8	9	10	11	12
Forage	---------- % in ration ----------											
Corn silage	28.0	24.0	20.0	28.0	24.0	20.0	28.0	24.0	20.0	28.0	24.0	20.0
T85 greenchop (21d)	42.0	36.0	30.0	42.0	36.0	30.0	42.0	36.0	30.0	42.0	36.0	30.0
Total forage in ration	70.0	60.0	50.0	70.0	60.0	50.0	70.0	60.0	50.0	70.0	60.0	50.0
Concentrate												
Brewers grain	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Citrus pulp	-	-	10.0	-	0.0	10.0	-	-	10.0	-	-	10.0
Gluten feed	-	2.3	1.7	-	2.5	2.4	-	2.3	2.3	-	2.5	2.4
Corn grains	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Hominy	4.9	12.5	12.5	5.0	12.5	12.5	4.9	12.5	12.5	5.0	12.5	12.5
Soybean hulls	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Wheat middlings	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Urea	-	0.2	0.2	-	-	0.1	-	0.2	0.2	-	-	0.1
Total Concentrate	30.0	40.0	50.0	30.0	40.0	50.0	30.0	40.0	50.0	30.0	40.0	50.0
Ration Nutritive Profile												
Crude protein	15.2	18.8	20.2	14.1	15.2	16.7	15.2	18.8	20.2	14.1	15.2	16.7
TDN	69.1	70.6	72.0	69.2	70.7	72.0	69.1	70.6	71.9	69.2	70.7	72.0
NEL (Mcal)	21.7	34.1	46.5	24.1	34.1	46.5	23.1	35.6	48.0	26.7	36.7	48.0
Calcium	0.79	0.62	0.72	0.80	0.65	0.74	0.80	0.62	0.72	0.80	0.65	0.75
Phosphorus	0.37	0.36	0.34	0.38	0.38	0.36	0.38	0.36	0.35	0.38	0.38	0.37
Potassium	1.56	1.47	1.39	1.56	1.47	1.39	1.56	1.47	1.39	1.56	1.47	1.39
Ration cost												
$ day^{-1} cow^{-1}	1.27	2.30	3.55	1.40	2.27	3.51	1.35	2.41	3.66	1.55	2.45	3.62

† Except NEL that is measured as Mcal.

‡ Cow 1 is a Holstein in 1st lactation, at 42 days in milk producing 18 kg milk d^{-1}; Cow 2 is a Holstein in 1st lactation, at 42 days in milk producing 36 kg milk d^{-1}; Cow 3 is a Holstein in 1st lactation, at 42 days in milk producing 54 kg milk d^{-1}; Cow 4 is a Holstein in 1st lactation, at 110 days in milk producing 18 kg milk d^{-1}; Cow 5 is a Holstein in 1st lactation, at 110 days in milk producing 36 kg milk d^{-1}; Cow 6 is a Holstein in 1st lactation, at 110 days in milk producing 54 kg milk d^{-1}; Cow 7 is a Holstein in 3rd lactation, at 42 days in milk producing 18 kg milk d^{-1}; Cow 8 is a Holstein in 3rd lactation, at 42 days in milk producing 36 kg milk d^{-1}; Cow 9 is a Holstein in 3rd lactation, at 42 days in milk producing 54 kg milk d^{-1}; Cow 10 is a Holstein in 3rd lactation, at 110 days in milk producing 18 kg milk d^{-1}; Cow 11 is a Holstein in 3rd lactation, at 110 days in milk producing 36 kg milk d^{-1}; Cow 12 is a Holstein in 3rd lactation, at 110 days in milk producing 54 kg milk d^{-1}.

Table A-6. Ingredients and costs of rations formulated for selected lactating dairy cows using T85 greenchop harvested 24-d intervals (2008).

	Cow profile‡											
Ingredients	1	2	3	4	5	6	7	8	9	10	11	12
Forage	------------------------------------- % in ration ----------------------------------											
Corn silage	28.0	24.0	20.0	28.0	24.0	20.0	28.0	24.0	20.0	28.0	24.0	20.0
T85 greenchop (24 d)	42.0	36.0	30.0	42.0	36.0	30.0	42.0	36.0	30.0	42.0	36.0	30.0
Total forage in ration	70.0	60.0	50.0	70.0	60.0	50.0	70.0	60.0	50.0	70.0	60.0	50.0
Concentrate												
Brewers grain	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Citrus pulp	-	-	10.0	-	-	10.0	-	-	10.0	-	-	10.0
Gluten feed	-	2.3	2.0	-	2.4	2.4	-	2.3	2.2	-	2.4	2.4
Corn grains	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Hominy	4.9	12.5	12.5	5.0	12.5	12.5	4.9	12.5	12.5	5.0	12.5	12.5
Soybean hulls	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Wheat middlings	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Urea	0.1	0.2	0.3	-	0.1	0.1	0.1	0.2	0.3	-	0.1	0.1
Total Concentrate	30.0	40.0	50.0	30.0	40.0	50.0	30.0	40.0	50.0	30.0	40.0	50.0
Ration Nutritive Profile												
Crude protein	15.2	18.8	20.2	14.1	15.2	16.7	15.2	18.8	20.2	14.1	15.2	16.7
TDN	69.1	70.6	71.9	69.1	70.6	72.0	69.1	70.6	71.9	69.1	70.6	72.0
NEL (Mcal)	21.7	34.1	46.5	23.9	34.1	46.5	23.1	35.6	48.0	26.5	36.4	48.0
Calcium	0.79	0.62	0.72	0.81	0.65	0.74	0.81	0.62	0.72	0.81	0.66	0.76
Phosphorus	0.36	0.35	0.34	0.38	0.38	0.36	0.38	0.35	0.34	0.38	0.38	0.37
Potassium	1.56	1.47	1.39	1.56	1.47	1.39	1.56	1.47	1.39	1.56	1.47	1.39
Ration cost												
\$ day^{-1} cow^{-1}	1.27	2.31	3.56	1.39	2.28	3.52	1.35	2.41	3.67	1.54	2.43	3.63

† Except NEL that is measured as Mcal.

‡ Cow 1 is a Holstein in 1st lactation, at 42 days in milk producing 18 kg milk d^{-1}; Cow 2 is a Holstein in 1st lactation, at 42 days in milk producing 36 kg milk d^{-1}; Cow 3 is a Holstein in 1st lactation, at 42 days in milk producing 54 kg milk d^{-1}; Cow 4 is a Holstein in 1st lactation, at 110 days in milk producing 18 kg milk d^{-1}; Cow 5 is a Holstein in 1st lactation, at 110 days in milk producing 36 kg milk d^{-1}; Cow 6 is a Holstein in 1st lactation, at 110 days in milk producing 54 kg milk d^{-1}; Cow 7 is a Holstein in 3rd lactation, at 42 days in milk producing 18 kg milk d^{-1}; Cow 8 is a Holstein in 3rd lactation, at 42 days in milk producing 36 kg milk d^{-1}; Cow 9 is a Holstein in 3rd lactation, at 42 days in milk producing 54 kg milk d^{-1}; Cow 10 is a Holstein in 3rd lactation, at 110 days in milk producing 18 kg milk d^{-1}; Cow 11 is a Holstein in 3rd lactation, at 110 days in milk producing 36 kg milk d^{-1}; Cow 12 is a Holstein in 3rd lactation, at 110 days in milk producing 54 kg milk d^{-1}.

Table A-7. Ingredients and costs of rations formulated for selected lactating dairy cows using T85 greenchop harvested 27-d intervals (2008).

	Cow profile‡											
Ingredients	1	2	3	4	5	6	7	8	9	10	11	12
Forage	---------- % in ration ----------											
Corn silage	28.0	24.0	20.0	28.0	24.0	20.0	28.0	24.0	20.0	28.0	24.0	20.0
T85 greenchop (27 d)	42.0	36.0	30.0	42.0	36.0	30.0	42.0	36.0	30.0	42.0	36.0	30.0
Total forage in ration	70.0	60.0	50.0	70.0	60.0	50.0	70.0	60.0	50.0	70.0	60.0	50.0
Concentrate												
Brewers grain	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Citrus pulp	-	0.4	10.0	-	-	10.0	-	-	10.0	-	-	10.0
Gluten feed	0.0	1.9	0.5	0.0	2.4	2.4	0.0	2.3	2.2	0.0	2.4	2.4
Corn grains	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Hominy	4.9	12.5	12.5	5.0	12.5	12.5	4.9	12.5	12.5	5.0	12.5	12.5
Soybean hulls	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Wheat middlings	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Urea	0.1	0.2	0.3	-	0.1	0.1	0.1	0.2	0.3	-	0.1	0.1
Total Concentrate	30.0	40.0	50.0	30.0	40.0	50.0	30.0	40.0	50.0	30.0	40.0	50.0
Ration Nutritive Profile												
Crude protein	15.2	18.8	20.2	14.1	15.2	16.7	15.2	18.8	20.2	14.1	15.2	16.7
TDN	69.1	70.6	72.0	69.1	70.6	72.0	69.1	70.6	71.9	69.1	70.6	72.0
NEL (Mcal)	21.7	34.1	46.5	23.6	34.1	46.5	23.1	35.6	48.0	26.2	36.1	48.0
Calcium	0.78	0.63	0.72	0.80	0.64	0.73	0.79	0.62	0.72	0.80	0.65	0.75
Phosphorus	0.36	0.35	0.34	0.38	0.37	0.36	0.37	0.36	0.35	0.38	0.38	0.37
Potassium	1.56	1.47	1.39	1.56	1.47	1.39	1.56	1.47	1.39	1.56	1.47	1.39
Ration cost												
$ day^{-1} cow^{-1}	1.26	2.30	3.56	1.37	2.28	3.52	1.34	2.41	3.67	1.52	2.41	3.63

† Except NEL that is measured as Mcal.

‡ Cow 1 is a Holstein in 1st lactation, at 42 days in milk producing 18 kg milk d^{-1}; Cow 2 is a Holstein in 1st lactation, at 42 days in milk producing 36 kg milk d^{-1}; Cow 3 is a Holstein in 1st lactation, at 42 days in milk producing 54 kg milk d^{-1}; Cow 4 is a Holstein in 1st lactation, at 110 days in milk producing 18 kg milk d^{-1}; Cow 5 is a Holstein in 1st lactation, at 110 days in milk producing 36 kg milk d^{-1}; Cow 6 is a Holstein in 1st lactation, at 110 days in milk producing 54 kg milk d^{-1}; Cow 7 is a Holstein in 3rd lactation, at 42 days in milk producing 18 kg milk d^{-1}; Cow 8 is a Holstein in 3rd lactation, at 42 days in milk producing 36 kg milk d^{-1}; Cow 9 is a Holstein in 3rd lactation, at 42 days in milk producing 54 kg milk d^{-1}; Cow 10 is a Holstein in 3rd lactation, at 110 days in milk producing 18 kg milk d^{-1}; Cow 11 is a Holstein in 3rd lactation, at 110 days in milk producing 36 kg milk d^{-1}; Cow 12 is a Holstein in 3rd lactation, at 110 days in milk producing 54 kg milk d^{-1}.

Table A-8. Ingredients and costs of rations formulated for selected lactating dairy cows using T85 greenchop harvested 35-d intervals (2008).

	Cow profile‡											
Ingredients	1	2	3	4	5	6	7	8	9	10	11	12
Forage	---------- % in ration ----------											
Corn silage	28.0	24.0	32.5	28.0	24.0	32.5	28.0	24.0	32.5	28.0	24.0	32.5
T85 greenchop (35 d)	42.0	36.0	17.5	42.0	36.0	17.5	42.0	36.0	17.5	42.0	36.0	17.5
Total forage in ration	70.0	60.0	50.0	70.0	60.0	50.0	70.0	60.0	50.0	70.0	60.0	50.0
Concentrate												
Brewers grain	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Citrus pulp	-	2.3	10.0	-	-	10.0	-	2.1	10.0	-	-	10.0
Gluten feed	-	-	2.2	-	2.4	2.3	-	0.2	2.2	-	2.4	2.3
Corn grains	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Hominy	4.9	12.5	12.5	5.0	12.5	12.5	4.9	12.5	12.5	5.0	12.5	12.5
Soybean hulls	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Wheat middlings	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Urea	0.1	0.2	0.3	-	0.1	0.2	0.1	0.2	0.3	-	0.1	0.2
Total Concentrate	30.0	40.0	50.0	30.0	40.0	50.0	30.0	40.0	50.0	30.0	40.0	50.0
Ration Nutritive Profile												
Crude protein	15.2	18.8	20.2	14.1	15.2	16.7	15.2	18.8	20.2	14.1	15.2	16.7
TDN	69.1	70.7	73.0	69.1	70.6	73.1	69.1	70.7	73.0	69.1	70.6	73.1
NEL (Mcal)	21.7	34.1	46.5	23.2	34.1	46.5	23.1	35.6	48.0	25.7	35.6	48.0
Calcium	0.79	0.67	0.54	0.82	0.65	0.60	0.80	0.66	0.55	0.82	0.66	0.62
Phosphorus	0.35	0.33	0.31	0.38	0.37	0.36	0.37	0.33	0.32	0.38	0.38	0.37
Potassium	1.56	1.46	1.27	1.56	1.47	1.27	1.56	1.46	1.27	1.56	1.47	1.27
Ration cost												
$ day^{-1} cow^{-1}	1.33	2.40	3.66	1.42	2.37	3.62	1.42	2.51	3.78	1.57	2.48	3.74

† Except NEL that is measured as Mcal.

‡ Cow 1 is a Holstein in 1st lactation, at 42 days in milk producing 18 kg milk d^{-1}; Cow 2 is a Holstein in 1st lactation, at 42 days in milk producing 36 kg milk d^{-1}; Cow 3 is a Holstein in 1st lactation, at 42 days in milk producing 54 kg milk d^{-1}; Cow 4 is a Holstein in 1st lactation, at 110 days in milk producing 18 kg milk d^{-1}; Cow 5 is a Holstein in 1st lactation, at 110 days in milk producing 36 kg milk d^{-1}; Cow 6 is a Holstein in 1st lactation, at 110 days in milk producing 54 kg milk d^{-1}; Cow 7 is a Holstein in 3rd lactation, at 42 days in milk producing 18 kg milk d^{-1}; Cow 8 is a Holstein in 3rd lactation, at 42 days in milk producing 36 kg milk d^{-1}; Cow 9 is a Holstein in 3rd lactation, at 42 days in milk producing 54 kg milk d^{-1}; Cow 10 is a Holstein in 3rd lactation, at 110 days in milk producing 18 kg milk d^{-1}; Cow 11 is a Holstein in 3rd lactation, at 110 days in milk producing 36 kg milk d^{-1}; Cow 12 is a Holstein in 3rd lactation, at 110 days in milk producing 54 kg milk d^{-1}.

Table A-9. Ingredients and costs of rations formulated for selected lactating dairy cows using alfalfa hay.

	Cow profile‡											
Ingredients	1	2	3	4	5	6	7	8	9	10	11	12
Forage	% in ration†											
Corn silage	45.5	39.0	32.5	45.5	39.0	32.5	45.5	39.0	32.5	45.5	39.0	32.5
Alfalfa hay	24.5	21.0	17.5	24.5	21.0	17.5	24.5	21.0	17.5	24.5	21.0	17.5
Total forage in ration	70.0	60.0	50.0	70.0	60.0	50.0	70.0	60.0	50.0	70.0	60.0	50.0
Concentrate												
Brewers grain	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Citrus pulp	-	1.8	5.9	-	2.4	6.5	-	1.9	6.0	-	2.4	6.6
Corn grains	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Hominy	9.9	12.5	12.5	5.0	12.5	12.5	4.9	12.5	12.5	5.0	12.5	12.5
Cotton seed	-	0.5	6.4	-	-	5.9	-	0.4	6.3	-	-	5.8
Soybean hulls	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Wheat middlings	0.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Urea	0.1	0.2	0.2	-	0.1	0.1	0.1	0.2	0.2	-	0.1	0.1
Total Concentrate	30.0	40.0	50.0	30.0	40.0	50.0	30.0	40.0	50.0	30.0	40.0	50.0
Ration Nutritive Profile												
Crude protein	15.2	18.8	20.2	14.1	15.2	16.7	15.2	18.8	20.2	14.1	15.2	16.7
TDN	68.7	69.9	71.2	68.2	70.0	71.3	68.2	69.9	71.2	68.2	70.0	71.3
NEL (Mcal)	21.7	34.1	46.5	24.2	34.3	46.5	23.2	35.6	48.0	26.8	36.8	48.0
Calcium	0.64	0.54	0.52	0.63	0.62	0.60	0.63	0.55	0.53	0.63	0.62	0.62
Phosphorus	0.37	0.36	0.35	0.38	0.42	0.40	0.38	0.37	0.36	0.38	0.42	0.41
Potassium	1.37	1.32	1.27	1.39	1.32	1.27	1.39	1.32	1.27	1.39	1.32	1.27
Ration cost												
\$ day^{-1} cow^{-1}	2.27	3.61	4.99	2.53	3.60	4.95	2.43	3.77	5.15	2.80	3.87	5.11

† Except NEL that is measured as Mcal.

‡ Cow 1 is a Holstein in 1st lactation, at 42 days in milk producing 18 kg milk d^{-1}; Cow 2 is a Holstein in 1st lactation, at 42 days in milk producing 36 kg milk d^{-1}; Cow 3 is a Holstein in 1st lactation, at 42 days in milk producing 54 kg milk d^{-1}; Cow 4 is a Holstein in 1st lactation, at 110 days in milk producing 18 kg milk d^{-1}; Cow 5 is a Holstein in 1st lactation, at 110 days in milk producing 36 kg milk d^{-1}; Cow 6 is a Holstein in 1st lactation, at 110 days in milk producing 54 kg milk d^{-1}; Cow 7 is a Holstein in 3rd lactation, at 42 days in milk producing 18 kg milk d^{-1}; Cow 8 is a Holstein in 3rd lactation, at 42 days in milk producing 36 kg milk d^{-1}; Cow 9 is a Holstein in 3rd lactation, at 42 days in milk producing 54 kg milk d^{-1}; Cow 10 is a Holstein in 3rd lactation, at 110 days in milk producing 18 kg milk d^{-1}; Cow 11 is a Holstein in 3rd lactation, at 110 days in milk producing 36 kg milk d^{-1}; Cow 12 is a Holstein in 3rd lactation, at 110 days in milk producing 54 kg milk d^{-1}.

Table A-10. Ingredients and costs of rations formulated for selected lactating dairy cows using purchased Tifton 85 hay.

	Cow profile‡											
Ingredients	1	2	3	4	5	6	7	8	9	10	11	12
Forage	---------- % in ration ----------											
Corn silage	45.5	39.0	32.5	45.5	39.0	32.5	45.5	39.0	32.5	45.5	39.0	32.5
Tifton 85 hay	24.5	21.0	17.5	24.5	21.0	17.5	24.5	21.0	17.5	24.5	21.0	17.5
Total forage in ration	70.0	60.0	50.0	70.0	60.0	50.0	70.0	60.0	50.0	70.0	60.0	50.0
Concentrate												
Brewers grain	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Citrus pulp	-	2.3	10.0	-	2.4	10.0	-	2.3	10.0	-	2.4	10.0
Gluten feed	-	-	2.2	-	-	2.4	-	-	2.2	-	-	2.4
Corn grains	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Hominy	9.9	12.5	12.5	5.0	12.5	12.5	5.2	12.5	12.5	5.0	12.5	12.5
Cotton seed	-	0.5	6.4	-	-	5.9	-	0.4	6.3	-	-	5.8
Soybean hulls	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Wheat middlings	-	5.0	5.0	5.0	5.0	5.0	4.7	5.0	5.0	5.0	5.0	5.0
Urea	0.1	0.2	0.3	-	0.1	0.1	0.1	0.2	0.3	-	0.1	0.1
Total Concentrate	30.0	40.0	50.0	30.0	40.0	50.0	30.0	40.0	50.0	30.0	40.0	50.0
Ration Nutritive Profile												
Crude protein	15.2	18.8	20.2	14.1	15.2	16.7	15.2	18.8	20.2	14.1	15.2	16.7
TDN	71.2	72.0	73.0	70.7	72.1	73.1	70.7	72.0	73.0	70.7	72.1	73.1
NEL (Mcal)	21.7	34.1	46.5	24.1	34.2	46.5	23.1	35.6	48.0	26.7	36.7	48.0
Calcium	0.60	0.54	0.54	0.62	0.62	0.60	0.62	0.55	0.55	0.62	0.62	0.61
Phosphorus	0.37	0.36	0.32	0.39	0.42	0.36	0.39	0.37	0.32	0.39	0.42	0.37
Potassium	1.37	1.32	1.27	1.39	1.32	1.27	1.39	1.32	1.27	1.39	1.32	1.27
Ration cost												
\$ day^{-1} cow^{-1}	1.63	2.77	4.06	1.80	2.75	4.02	1.73	2.89	4.19	1.99	2.95	4.15

† Except NEL that is measured as Mcal.

‡ Cow 1 is a Holstein in 1st lactation, at 42 days in milk producing 18 kg milk d^{-1}; Cow 2 is a Holstein in 1st lactation, at 42 days in milk producing 36 kg milk d^{-1}; Cow 3 is a Holstein in 1st lactation, at 42 days in milk producing 54 kg milk d^{-1}; Cow 4 is a Holstein in 1st lactation, at 110 days in milk producing 18 kg milk d^{-1}; Cow 5 is a Holstein in 1st lactation, at 110 days in milk producing 36 kg milk d^{-1}; Cow 6 is a Holstein in 1st lactation, at 110 days in milk producing 54 kg milk d^{-1}; Cow 7 is a Holstein in 3rd lactation, at 42 days in milk producing 18 kg milk d^{-1}; Cow 8 is a Holstein in 3rd lactation, at 42 days in milk producing 36 kg milk d^{-1}; Cow 9 is a Holstein in 3rd lactation, at 42 days in milk producing 54 kg milk d^{-1}; Cow 10 is a Holstein in 3rd lactation, at 110 days in milk producing 18 kg milk d^{-1}; Cow 11 is a Holstein in 3rd lactation, at 110 days in milk producing 36 kg milk d^{-1}; Cow 12 is a Holstein in 3rd lactation, at 110 days in milk producing 54 kg milk d^{-1}.

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BIOGRAPHICAL SKETCH

José Alejandro Clavijo Michelangeli (a.k.a. Pepe) was born in the town of Maracay, north-central Venezuela in 1982. He spent his early years living in Montreal, Canada from 1986 to 1991 and Gainesville, FL from 1995 to 1996 with his family. He settled back in his hometown to finish middle and high school at the Unidad Educativa "Calicantina", graduating in the 2000 class. That same year he began his undergraduate degree as an Agronomical Engineer at the Universidad Central de Venezuela. As an undergraduate, he was a teaching assistant in Statistics and Experimental Design, an ecotourism guide working for national and international birdwatching companies, an intern in an environmental consulting agency and a cattle ranching consortium, and an assistant in several research programs spanning molecular biology, entomology and ornithology.

Upon graduation in 2006, he continued to work in ecotourism and ornithology research until he began his Master of Science degree in agronomy at the University of Florida in January 2008, under the mentorship of Dr. Yoana Newman. During this time, he has been a research assistant in the forage extension program, and participated as a student research assistant in the Ornithology Laboratory of the Florida Museum of Natural History during 2008. Upon completing his MSc degree, Pepe will pursue a PhD degree focusing on natural resource policy. After his graduate studies, he plans on working for governments or non-government organizations developing sustainable land-use policies for developing nations.