MANAGEMENT INTENSITY EFFECTS ON ANIMAL PERFORMANCE AND HERBAGE RESPONSE IN BAHIAGRASS PASTURES

By

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A THESIS PRESENTED TO THE GRADUATE SCHOOL
OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF SCIENCE

UNIVERSITY OF FLORIDA

2003

To my wife Beth.

ACKNOWLEDGMENTS

The author would like to begin by thanking Dr. Lynn E. Sollenberger, chairman of the supervisory committee and mentor. His guidance and direction throughout the graduate school programs and the writing of this thesis have been greatly appreciated. Also thanks go to the rest of the advisory committee, Dr. Martin B. Adjei, Dr. Carrol G. Chambliss, and Dr. Adegbola Adesogan, for their willingness to serve on the graduate committee, thoughtful input, and for reviewing the thesis.

Thanks are also due to many who assisted in both field and lab tasks. They include fellow graduate students José Dubeux and Joaó Vendramini, who spent hours upon hours at the Beef Research Unit helping collect data, Sid Jones and Dwight Thomas, at the Forage Evaluation Field Laboratory, for providing valuable help with field exercises, and Richard Fethiere and the crew of the Forage Evaluation Support Laboratory, for assistance in sample analysis. Dr. Yoana C. Newman provided excellent advice on topics ranging from field techniques to statistical analyses. Also thanks are expressed to Dr. Jerry M. Bennett, department chair, and Dr. David S. Wofford, graduate coordinator, for the opportunity to study in the Agronomy Department.

Thanks are due to fellow graduate students Deke Alkire, Nathan and Wimberley Krueger, Brad Austin, Sindy Interrante, Paul Davis, Marcía Grise, and others for their help, but more importantly for their friendship over the past two years.

Last, but not least, the author would like to thank his family. His wife, Beth, was supportive of his decisions and many tasks throughout graduate school. Also, his parents, Robert and Martha Stewart, have always emphasized the importance of education and have been encouraging throughout the many educational processes. Also thanks go to the two best sisters in the world, Kate and Sally.

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August 2003

Chairman: Lynn E. Sollenberger
Major Department: Agronomy

Bahiagrass (*Paspalum notatum* Flügge) pasture covers approximately one million hectares in Florida, 90% of which is utilized by beef cattle. Urbanization may force beef producers to achieve economic livelihood on reduced land area. One option for producers is to increase intensity of management of the remaining pasture resource. The objectives of this research were 1) to evaluate the effects of management intensity (MI), defined as combinations of N fertilization and stocking rates (SR), on yearling beef heifer and bahiagrass pasture performance (Exp. 1), and 2) to evaluate bahiagrass forage responses to continuous and rotational stocking (Exp. 2). Treatments in Exp. 1 included LOW (40 kg N ha^{-1} yr^{-1}, 1.2 animal units [AU, one AU=500 kg live weight] ha^{-1} SR), MODERATE (120 kg N ha^{-1} yr^{-1}, 2.4 AU ha^{-1} SR), and HIGH MI (360 kg N ha^{-1} yr^{-1}, 3.6 AU ha^{-1} SR). Treatments in Exp. 2 were continuous stocking, and rotational stocking with 1-, 3-, 7-, and 21-d grazing periods. All rotational treatments had a 21-d rest period.

Herbage mass (3.0 Mg ha^{-1}) and herbage allowance (4.0 kg forage kg^{-1} animal weight) in Exp. 1 were greater for LOW and decreased as MI increased to HIGH (2.6 Mg ha^{-1} and 1.1 kg forage kg^{-1} animal weight). This occurred despite herbage accumulation rate being greater for HIGH (33 kg ha^{-1} d^{-1}) than LOW (19 kg ha^{-1} d^{-1}). Nutritive value increased with increasing MI, in part because of greater N rate and also because the higher stocking rates likely increased the frequency at which cattle revisited grazing locations. Average daily gain decreased from LOW to HIGH (0.46 to 0.36 kg d^{-1}) because of the decrease in herbage allowance for HIGH. Gain per hectare increased with increasing MI due to a greater utilization of the forage present. Bahiagrass cover increased with the HIGH MI (7.1%) and decreased with LOW (-6.4) and MODERATE (-4.7%). Decreases in cover were associated with the invasion of vaseygrass (*Paspalum urvillei*) and smutgrass (*Sporobolus indicus*) and occurred because of decreased grazing pressure that allowed these species to mature and become unpalatable to cattle.

In Exp. 2, rotational stocking increased herbage accumulation rate and digestibility over continuous stocking, but it had no effect on herbage crude protein. Continuous stocking resulted in greater bahiagrass cover, while rotational stocking led to reduced cover due to the encroachment of vaseygrass and smutgrass.

These experiments demonstrated increased bahiagrass production and quality with increasing management intensity. However, the magnitude of these improvements is not sufficient to compensate for the additional costs associated with greater management intensity above MODERATE and the greater risk of damage to the environment. Therefore, if the need for increased production per unit land area becomes acute, the use of another more management-responsive grass species likely will be required.

CHAPTER 1
INTRODUCTION

Grasslands occupy large areas of Florida and the southeastern USA and serve as an important source of feed to the livestock industry. In the state of Florida, the human population has grown significantly over the past 40 yr, from approximately five million people in 1960 to approximately sixteen million in 2000 (U.S. Census Bureau, 2002). This three-fold increase has led to a large increase in urbanization and associated loss of area devoted to grasslands. Current projections are that population will increase to twenty-four million by 2030 (Arndorfer, 2003). In the future, producers may be faced with land constraints and may need to consider intensification of grassland management as a means of maintaining overall production on a decreasing land resource.

Changes in management intensity could include greater nitrogen (N) fertilization and stocking rates and use of rotational stocking. These changes have the potential to affect productivity and profitability of the system; however, some may also increase the potential for negative environmental impact. Before increasing management intensity can be recommended, its impact on the environment and on plant and animal performance must be determined.

The beef industry is a vital component of Florida's large agriculture industry. In 2001 Florida had a total of 975,000 beef cows; this ranks twelfth in the nation and third for states east of the Mississippi River. Revenues from the beef cattle industry in Florida totaled 371 million dollars in 2000, accounting for 5.3% of the states total agricultural cash receipts (Florida Dept. of Agriculture, 2002).

Bahiagrass (*Paspalum notatum* Flügge) is an essential resource to the beef industry in Florida. It is the most widely planted grass in the state, covering approximately one million hectares. Of this area, 90% is grazed by beef cattle (Chambliss, 2000). Bahiagrass is an aggressive grass that is relatively tolerant of drought and low fertility soils (Prates et al., 1975). This makes bahiagrass well adapted to the range of environmental conditions in Florida. The most widely distributed bahiagrass cultivar is Pensacola, and it is known for its relatively high yields and moderate animal performance (Chambliss, 2000). Nitrogen is generally the most limiting nutrient for bahiagrass growth (Gates et al., 2004), and research has shown a potentially large increase in production and forage N concentration with increasing N rate (Blue, 1988). Thus, there is potential to achieve greater livestock production on bahiagrass by increasing N fertilization rate.

Stocking method plays an important role in grazing systems. Because of its grazing tolerance and to minimize cost of production, many bahiagrass pastures in Florida are continuously stocked during the summer grazing season. Rotational stocking generally allows for a higher stocking rate and higher gains per unit land area (Blaser, 1986), so potential exists to increase livestock production per hectare on bahiagrass pastures by using rotational stocking.

Stocking rate is the relationship between number of animals and the area of pasture to which they are assigned over an extended period of time. Stocking rate is generally considered to be the most important grazing management decision because it has a major impact on both forage production and performance of grazing animals (Matches, 1992). Increasing stocking rate improves the consumption of available herbage per hectare of grassland, often decreasing individual animal production but increasing animal production per hectare (Burns et al., 2003). Thus, stocking rate is a powerful tool influencing production of a given area of grassland.

The thesis research that was conducted was part of a larger project that evaluated nutrient dynamics and cycling, animal grazing behavior, pasture characteristics, and animal performance on grazed bahiagrass. The particular areas of focus in the research reported herein are animal performance and pasture attributes of grazed bahiagrass pastures managed at different intensities (defined by stocking rate, N fertilizer rate, and grazing method).

The research was divided into two experiments. The first experiment evaluated animal performance and forage response of continuously stocked bahiagrass pastures using three treatments that were defined by stocking rate and N fertilizer rate. Animal performance was measured as average daily gain of yearling beef heifers and weight gain per unit land area. Forage responses measured included nutritive value, herbage mass, herbage allowance, and herbage accumulation. From these data the relationships between heifer daily gain and bahiagrass herbage mass and bahiagrass herbage allowance were determined. Results from this study will help to assess the extent to which increasing management intensity (stocking rate and N fertilization) of bahiagrass pasture increases pasture and animal performance.

The second experiment evaluated forage responses to four rotational stocking and one continuous stocking treatment on bahiagrass pasture. The rotational treatments were defined by length of the grazing period and all had the same rest period. Forage responses measured include nutritive value, herbage mass, herbage accumulation, and bahiagrass cover. These data will allow comparison of bahiagrass pasture characteristics across a wide range of grazing methods and allow conclusions to be drawn about the potential for increasing bahiagrass pasture performance by changing grazing method.

Data from these experiments are useful from several perspectives. Producers can use them to make informed management decisions. In addition, this research furthers the understanding of intensive management and its effect on animal performance and herbage response. Scientists can use these data to guide future research and to develop models related to intensified management. In summary, this research is relevant to the agricultural industry as it explores options for maintaining sustainability in an increasingly urbanized community, and to the rest of society as it evaluates possible environmental and economic impacts of management strategies.

CHAPTER 2
LITERATURE REVIEW

Characteristics of Bahiagrass

General

Bahiagrass (*Paspalum notatum* Flügge) originated in Brazil and northern Argentina and was introduced to the southeastern USA in the early 1900s. It has spread extensively in the southeast and is grown throughout Florida for pasture, turf, and hay (Chambliss, 2000). Bahiagrass is the most widely planted perennial pasture grass in Florida, covering more than one million hectares (Chambliss, 2000), and is extensively utilized by the state's beef industry which numbers 975,000 cows (Florida Dept. of Agriculture, 2002).

Bahiagrass is a warm-season, deep-rooted, perennial grass that forms a dense, thick sod from an extensive root and rhizome system (Burson and Watson, 1995). This morphology makes it less prone to encroachment from other grasses and weeds. Bahiagrass is characterized by horizontal stems at the soil surface, and purple leaf sheaths (Gates et al., 2004). Leaf blades are flat or slightly folded, 3 to 12 cm wide and can grow from 3 to 30 cm long. Bahiagrass is also characterized by a tall raceme inflorescence (Gates et al., 2004).

Bahiagrass is aggressive and well acclimated to the variety of environmental conditions throughout Florida (Prates et al., 1975). It can persist in both well-drained and low-lying, poorly drained soils. Adapted to the southern USA Coastal Plain region, bahiagrass performs best in sandy soils with a pH of 5.5 to 6.5 (Twidwell et al., 1998). Except for highly infertile sites, nutrients needed for adequate growth are limited to N

(Gates et al., 2004). Bahiagrass is also resilient to pressure from most pests. The only major pest problem is the recent emergence of the mole cricket (*Scapteriscus sp.*), which can destroy pasture stands by damaging the root system. Fall armyworms (*Spodoptera frugiperda*) can also defoliate stands, but usually only during seasons when more preferred forages are not available (Burson and Watson, 1995).

Bahiagrass has the C_4 photosynthetic metabolism and responds to high temperature and moisture. 'Pensacola' bahiagrass exhibits little growth under 15°C, which limits the length of its productive period in Florida to April to late October (Mislevy, 1985). During the spring growing season, bahiagrass is characterized by high nutritive value and low forage production. This can be attributed to drought and to lower temperatures which depress plant respiration, preserving nonstructural carbohydrates, and decreased lignification resulting in greater cell wall digestiblility (Blaser, 1986). During the peak of the growing season from July to early September, pastures produce higher herbage masss and digestibility decreases. Performance of animals grazing bahiagrass follows a similar pattern, with gains being higher in the early growing season, peaking, and then leveling off or decreasing later in the growing season (Twidwell et al., 1998).

Yield

Forages for production systems should ideally be high yielding and high in nutritive value to support exceptional animal performance. Pensacola bahiagrass is highly tolerant of many unfavorable conditions such as overgrazing; however, it is also known as a low nutritive value forage with lower than average herbage yield among the adapted warm-season perennial grasses (Sollenberger, 2001). Cuomo et al. (1996) conducted a study of plant morphology and nutritive value of three bahiagrassses (Pensacola, 'Argentine,' and 'Tifton 9') as affected by harvest frequency. They found no differences among cultivars in herbage production, and means were 11.2 Mg ha^{-1} for Argentine, 11.9 Mg ha^{-1} for Pensacola, and 11.8 Mg ha^{-1} for Tifton 9. Differences were obvious during the month of May when Argentine produced 1.9 Mg ha^{-1} as compared to higher values of 3.1 and 2.9 Mg ha^{-1} by Pensacola and Tifton 9, respectively. Under high rates of N fertilizer (450 to 700 kg ha^{-1}), bahiagrass yields up to 15.6, 15.1, and 19.9 Mg ha^{-1} have been reported in various states in the southeastern USA (Stanley, 1994; Burton et al., 1997; Twidwell et al., 1998).

Nutritive Value

Cuomo et al. (1996) found Pensacola to contain a neutral detergent fiber (NDF) concentration of 657 g kg^{-1} as compared to 642 g kg^{-1} for Argentine bahiagrass and 640 g kg^{-1} in Tifton 9 bahiagrass over a growing season. In this study acid detergent fiber (ADF) and lignin were similar for the three grasses, and averaged 323 and 44 g kg^{-1}, respectively. Muchovej and Mullahey (2000) reported NDF values over a growing season to be higher; Pensacola NDF was 790 g kg^{-1}, as compared to 783 and 787 g kg^{-1} for Argentine and Tifton 9, respectively.

The in vitro true digestibility (IVTD) of Pensacola (588 g kg^{-1}) was comparable to that of Argentine (589 g kg^{-1}) but was lower than Tifton 9 (598 g kg^{-1}) with an N rate of 336 kg ha^{-1} (Cuomo, 1996). However, Muchovej and Mullahey (2000) found Pensacola IVTD to be similar to Tifton 9 (510 and 508 g kg^{-1}, respectively) with an N rate of 56 kg ha^{-1}. Crude protein (CP) of Pensacola and Tifton 9 were identical, 113 g kg^{-1}, but they were slightly lower than that of the Argentine (118 g kg^{-1}; Cuomo, 1996). Under clipping management, Muchovej and Mullahey (2000) found no significant differences in Pensacola CP values over the growing season (average of 96 g kg^{-1}).

Cuomo et al. (1996) also compared NDF and lignin concentrations of different plant parts (leaf, stem, and whole plant) for the three bahiagrass cultivars over the entire growing season. They found stem, leaf, and whole-plant NDF to be higher in Pensacola (646, 701, and 660 g kg^{-1}, respectively) than Tifton 9 (636, 669, and 640 g kg^{-1}). Lignin was also slightly higher in Pensacola than Tifton 9 (40, 59, 44 g kg^{-1} versus 37, 54, and 41 g kg^{-1}, respectively).

Nutritive value of grazed bahiagrass declines over the growing season due to high temperature and accumulation of mature material and reproductive structures. Utley et al. (1974) reported IVOMD of 679 g kg^{-1} for bahiagrass clipped in May compared to 429 g kg^{-1} in late September. Cuomo also found a decrease in in vitro organic matter digestibility (IVOMD) across the season with values of 629 g kg^{-1} in late May and 562 g kg^{-1} in early September at 20-d harvests intervals. Crude protein decreased from 139 to 110 g kg^{-1} over the same period, while NDF, ADF, and lignin increased from late May to early September (629 to 657, 302 to 328, and 38 to 47 g kg^{-1}, respectively).

Animal Performance

In livestock operations, animal performance is the essential goal. Bahiagrass is known to withstand heavy grazing and poor growing environments; however, it is also known for its average to lower than average animal performance. This is particularly a problem in Florida during hot summer months when cattle are under stress and sometimes have negative average daily gains (ADG). In a study by Prates et al. (1975) ADG was measured monthly on continuously stocked Pensacola bahiagrass from May through October. This study utilized the put and take system to adjust stocking rate, and fertilizer was applied at 193 kg ha^{-1} yr^{-1} of elemental N. They reported ADG to be 1.00 kg d^{-1} in May; however, ADG steadily declined to -0.52 kg d^{-1} in September with only a slight increase to 0.15 kg d^{-1} in October. Also in this study, gain ha^{-1} was measured in each month. In May, cattle gained 122 kg ha^{-1}. They lost 97 kg ha^{-1} in September, and gained 10 kg ha^{-1} in October. Twidwell et al. (1998) reported ADG of steers grazing Pensacola bahiagrass pastures to be 0.43 kg compared to 0.49 kg for steers grazing 'Coastal' bermudagrass [*Cynodon dactylon* (L.)] over a 4-yr grazing trial. Additional animal performance data will be discussed later in the literature review as it relates to specific management practices.

Nitrogen Fertilization

Cool-Season and Native Grasses

Research has shown that C_3 grasses have the potential to respond to N application. Tall fescue (*Festuca arundinacea* Schreb.) is grown in many areas of the temperate USA. Moyer et al. (1995) evaluated forage production and N concentration of fescue at three N application rates: 13, 112, and 168 kg ha^{-1}. As N rates increased, forage DM production increased from 3.26 to 4.11 to 4.49 Mg ha^{-1}, respectively. At these N rates, forage CP concentrations were 140, 176, and 194 g kg^{-1}, respectively, showing a significant increase as N rate increased. Zhang et al. (1995) evaluated annual ryegrass (*Lolium multiflorum* L.) N and N constituents. In this study, total N increased from 29.8 to 50.4 g kg^{-1} as N application increased from 0 to 224 g kg^{-1}. Also it was reported that as N fertilization increased, ADF-bound N, as a constituent of total N, decreased from 7.63 to 3.41 g kg^{-1}. From this it is concluded that increasing N application can decrease ADF-bound N in addition to increasing N concentration in forages.

Texas bluegrass (*Poa arachnifera* Torr.) is a cool-season perennial grass used for pasture in the southern Great Plains. Pitman et al. (2000) evaluated the response of bluegrass to N fertilization rates of 0 and 100 kg N ha $^{-1}$. At these levels, forage yields across 2 yr were 1.8 and 4.1 Mg ha^{-1}, respectively.

Native range grasses also are an important part of many forage production systems. Lorenz and Rogler (1972) evaluated response of a mixture of prairie vegetation to four N fertilization rates across an 8-yr study. Among the species tested were western wheatgrass (*Agropyron smithii* Rydb.), blue grama (*Bouteloua gracilis* [H.B.H.] Lag.), threadleaf sedge (*Carex filifolia*, Nutt.), and needle-and-thread (*Stipa comata* Trin. & Rupr.). At N rates of 0, 45, 90, and 180 kg ha^{-1}, forage DM production was 0.8, 1.9, 3.0, and 3.1 Mg ha^{-1}, respectively. Nichols et al. (1990) also evaluated the response of smooth bromegrass (*Bromus inermis* Leyss.), redtop (*Agrostis stolonifera* L.), timothy (*Phleum pratense* L.), slender wheatgrass [*Agropyron trachycaulum* (Link) Malte], quackgrass [*A. repens* (L.) Beauv.], Kentucky bluegrass (*Poa pratensis* L.), prairie cordgrass (*Spartina pectinata* Link) and several sedges (*Carex* spp. L) and rushes (*Juncus* spp. L.) to N application over a 4-yr trial. Nitrogen was applied at rates of 0, 45, 90, and 135 kg ha $^{-1}$. At these levels, forage DM production was 6.1, 6.9, 8.1, and 8.7 Mg ha^{-1}, respectively. This study also reported the nutritive value response to increasing N rates. Across the treatments, there were no significant differences in either CP or IVDMD.

Barley (*Hordeum vulgare* L.), a cool-season annual grass, can serve as an important alternative feed crop in the southeastern USA (DiRienzo et al., 1991). DiRienzo et al. (1991) evaluated barley yield responses to spring N applications across 2 yr. At N rates of 0, 45, 90, and 135 kg ha^{-1} forage DM yields were 9.6, 10.5, 11.0, and 11.5 Mg ha^{-1}, respectively. Barley showed higher DM yields, however, response to N decreased as N rate increased having an initial response of 20 kg forage kg^{-1} N, but decreasing to 13 kg forage kg^{-1} N at the highest fertilization rate.

Tropical Grasses

Tropical C_4 grasses are used throughout the southern USA. Because of the growing environment, these grasses account for a large proportion of the nutrients in many ruminant animal diets in this region. These grasses also have the potential for response to N application.

Bermudagrass is a C_4 grass used widely throughout the southeastern USA as a forage for livestock. Thom et al. (1990) evaluated 'Tifton 44' bermudagrass yield and nutritive value responses to N fertilization over a 5-yr period. At N rates of 0, 135, 270, 405, and 540 kg ha^{-1}, forage DM yields were 2.5, 9.1, 15.8, 16.6, and 16.0 Mg ha^{-1}, respectively. Bermudagrass DM yield responded up to the 405 kg ha^{-1} rate, but yield decreased at 540 kg ha^{-1}. Looking at nutritive value, N application did not significantly increase the IVDMD of the bermudagrass; all treatments averaged approximately 600 g kg^{-1}. Wiendenfeld (1988) evaluated Costal bermudagrass and 'Renner' lovegrass [*Eragrostis curvula* (Schard.) Ness] response to N fertilization. In this study N was applied at 0, 112, and 224 kg ha^{-1}. At these treatment levels, bermudagrass increased yield per unit N with increasing N rates. These responses suggest that bermudagrass could possibly have made efficient use of N above those applied in this study. In a study by Prine and Burton (1956), the effect of N rate was evaluated on yield and CP concentration of Coastal bermudagrass. At N levels of 0, 112, 336, 672, and 1008 kg ha^{-1} hay DM yields were 4.9, 7.5, 13.5, 17.2, and 18.4 Mg ha^{-1}, respectively. Bermudagrass showed the highest increase in production (kg forage/kg N ha^{-1}) at the 336 kg ha^{-1} rate and then showed a smaller response above this level. The forage CP concentrations were

97, 113, 150, 170, and 190 g kg^{-1}. Similar to yield, the greatest response to N was at 336 kg ha^{-1}, and response leveled off at higher N rates.

Limpograss [*Hemarthria altissima* (Poir) Stapf & C.E. Hubb] is another C_4 grass that serves an important role in the livestock industry in Florida. Limpograss is also known for its seasonally low N concentrations (Lima et al., 1999) and has the potential for a response to applied N. Christiansen et al. (1988) compared the response of three cultivars of limpograss to three N fertilization rates (0, 120, and 480 kg ha^{-1}) and several defoliation intervals. At a defoliation interval of 3 wk, ‘Floralta’ limpograss responded to these N rates with DM yields of 2.7, 4.4, and 6.8 Mg ha^{-1}, respectively. Both CP and IVOMD increased in response to N rate and were 75, 90, and 97 g kg^{-1}, and 499, 507, and 518 g kg^{-1}, respectively. Lima et al. (1999) compared limpograss at N rates of 50 and 150 kg ha^{-1}. Increasing the N rate resulted in an increase in carrying capacity of approximately 100 heifer days ha^{-1} in the year when rainfall was near normal, and carrying capacity was increased by 37 heifer days ha^{-1} in a drier than normal year (58% of the 70-yr average rainfall). Forage DM production increased to support the increase in carrying capacity. Increasing the N rate also increased CP and IVOMD of the blade, sheath, and stem portions of the plant. Velez-Santiago and Arroyo-Aguilu (1983) measured limpograss production and nutritive value at several fertilization rates. At rates of 224, 448, and 896 kg ha^{-1}, DM production of ‘Bigalta’ was 2.7, 3.5, and 4.4 Mg ha^{-1}, respectively. At these N rates, CP concentrations also increased at a harvest interval of 30 d and were 94, 106, and 119 g kg^{-1}. From these data it is apparent that limpograss has the potential to increase DM production and CP up to high levels of N application. Limpograss also shows an IVOMD response to N unlike many other tropical grasses.

Other tropical grasses respond to N fertilization in terms of DM production and CP concentration. Faría et al. (1999) evaluated the nutritive value of 'Mott' dwarf elephantgrass (*Pennisetum purpureum* Schum.) in response to N fertilization. At N rates of 0, 150, 300, and 450 kg ha^{-1}, CP ranged from 80 to 83 g kg^{-1} and was not different among treatments. The IVDMD ranged from 600 to 620 g kg^{-1}; these values were also not significantly different.

Springer and Taliaferro (2001) evaluated N fertilization of buffalograss [*Buchloë dactyloides* (Nutt.) Engelm] across a range from 0 to 134 kg ha^{-1}. At these levels, forage DM production significantly increased from approximately 1.8 to 2.7 Mg ha^{-1}. The N rate also had a significant effect on CP, increasing it from 90 to 124 g kg^{-1}; however, there was no significant effect on IVDMD.

In a study by George et al. (1990), forage production and nutritive value of switchgrass (*Panicum virgatum* L.) were compared at two N levels, 0 and 90 kg ha^{-1}. There was an increase in DM production from 1100 to 1800 kg ha^{-1} with N application. Also there was a significant increase in CP and IVDMD, with CP increasing from 120 to 160 g kg^{-1} and IVOMD from 670 to 700 g kg^{-1}, respectively.

Tyagi and Singh (1986) reported the effect of N application on forage production and nutritive value in dinanathgrass (*Pennisetum pedicellatum* Trin), a tropical grass native to Africa and India. In this study, N was applied at rates ranging from 0 to 160 kg ha^{-1}. Forage DM productions increased from 9.1 to 20 Mg ha^{-1} with increasing N, but production did not increase above 120 kg ha^{-1}. Forage CP significantly increased from 59 to 91 g kg^{-1} as N application increased from 0 to 160 kg ha^{-1}, and digestibility increased from 606 to 658 g kg^{-1} over the same range of N rates.

These data suggest that N fertilization increases grass production and CP concentration across a wide range of grass species and N rates. Nitrogen effects on other measures of forage nutritive value are less consistent. The next section of the review focuses on bahiagrass response to N fertilization.

Bahiagrass

Nitrogen is generally the most limiting nutrient for bahiagrass (Gates et al., 2004). In Florida's sandy soils, soil nutrient retention capacity is minimal due to their coarse texture and low organic matter concentration. Significant amounts of fertilizer are required in order for pastures to produce high production of forage and animal product.

Blue (1988) conducted an experiment that evaluated Pensacola bahiagrass response to three rates of N application applied using five different schedules of application. He found that application date did not have a significant effect on total annual DM production; however, there was a large increase in production and forage N concentration with increasing N rate. Twidwell et al. (1998) reported that an increase in N rate from 0 to 445 kg ha^{-1} increased total DM production from 4.0 to 15.6 Mg ha^{-1} (3.9-fold yield increase). Burton et al. (1997) reported that increasing N rate from 56 to 448 kg ha^{-1} on Pensacola bahiagrass increased production from 6.0 to 15.1 Mg ha^{-1}. Stanley (1994) applied N to Tifton 9 bahiagrass at rates of 0, 84, 168, 336, and 672 kg ha^{-1}. In this study, he found DM productions of 7.4, 8.7, 10.9, 15.5, and 19.9 Mg ha^{-1}, respectively. Forage production per unit N applied increased up to 336 kg ha^{-1} (24.1 kg forage/kg N ha^{-1}), and decreased thereafter (18.6 kg forage/kg N ha^{-1} at 672 kg ha^{-1}). Ruelke and Prine (1971) evaluated Pensacola bahiagrass along with seven other grasses at three fertility levels, 134, 269, and 538 kg N ha^{-1}. Across 4 yr, the bahiagrass DM response to N was 6.7, 9.0, and 11.7 Mg ha^{-1}. These data indicate that bahiagrass production can increase dramatically in response to increasing N fertilization.

The potential for N fertilization to increase forage CP and change cell composition has been explored in previous studies. Twidwell et al. (1998) reported that an increase in N rate from 0 to 445 kg ha^{-1} increased total herbage CP from 105 to 144 g kg^{-1}, respectively. Burton et al. (1997) reported that increasing N rate from 56 to 448 kg ha^{-1} on Pensacola bahiagrass increased forage N concentration from 11 to 17 g kg^{-1}. Blue (1988) reported 2-yr average forage N concentrations of 35, 115, and 204 kg ha^{-1} for N applications of 0, 100, and 200 kg ha^{-1}, respectively. Stanley et al. (1977) evaluated cell wall constituents across N rates of 0, 84, 168, and 336 kg ha^{-1}. This study found no significant difference in cell wall composition across fertilization rates.

From recent literature for bahiagrass, it is apparent that there is potential to increase production of bahiagrass in response to N fertilization. Also there is evidence of increased CP concentration as a result of N fertilization; however, the response of IVOMD is not consistent.

Environmental Implications

From the reviewed literature, it is evident that N fertilization increases grass yield and crude protein, and in turn, has the potential to increase animal production. However, increasing N rates will reach a point where there are diminishing returns to forage production and possibly significant N losses to the environment. The sandy, low organic matter soils in Florida have limited ability to retain N. Therefore, regulatory agencies are concerned with the potential of surface and ground water contamination from excessive N applications on agricultural land (Muchovej and Rechcigl, 1994). With increased stocking rates, there is also potential of increased nutrient loading from animal waste.

Runoff and leaching of nutrients from animal waste may contaminated water supplies (Hammond, 1994). Proper management of animals and resources under increased management intensity is required to avoid these potentially harmful environmental impacts.

Grazing Management

Grazing management involves a series of choices that determine the nature of the plant-animal interaction on pasture. Primary choices include those of grazing method, grazing frequency, and grazing intensity. These will be discussed in the section that follows.

Grazing Method

Stocking method plays an important role in a grazing system. There are two general stocking methods utilized, rotational and continuous stocking. Rotational stocking consists of subdividing pastures into paddocks that have periods of both grazing and rest. This method generally allows for a higher stocking rate than continuous stocking (Blaser, 1986). In contrast, continuous stocking allows constant access to all areas of the pasture. At moderate stocking rates this method often results in greater gain per animal, associated with increased opportunity for diet selection, however, gain per unit land area may be less than with rotational stocking because of lower stocking rate (Blaser, 1986).

Sollenberger et al. (1988) compared animal performance of Pensacola bahiagrass and Floralta limpograss on continuously stocked pastures. Pastures were fertilized at a N rate of 200 and 180 kg N ha^{-1} during a 2-yr study. A variable stocking rate was used and average stocking rates were 5.4 and 5.2 animals ha^{-1} for limpograss and bahiagrass, respectively (based on 320-kg animals). Cattle on bahiagrass had ADG of 0.38 kg d^{-1}

across the two grazing seasons, compared to 0.33 kg d^{-1} on limpograss. These authors pointed out that the lack of difference in ADG between forages might be associated with the low CP concentration of limpograss, even though limpograss IVOMD was higher than bahiagrass (539 and 484 g kg^{-1}, respectively). Also in mid- to late summer, limpograss pastures had an accumulation of stem material that may have limited voluntary intake.

Sollenberger et al. (1989) also compared animal performance on rotationally stocked Floralta limpograss and Pensacola bahiagrass pastures across three grazing seasons. The N rate for this study averaged 180 kg ha^{-1} yr^{-1}. The ADG of animals grazing bahiagrass remained the same as that observed under continuous stocking and averaged 0.38. Cattle gains on limpograss were 0.41 kg d^{-1} and not different than those on bahiagrass. Average stocking rates of bahiagrass pastures under rotational stocking were 5.3 animals ha^{-1} compared to 6.7 animals ha^{-1} on limpograss.

Williams and Hammond (1999) compared rotational and continuous intensive stocking of cattle on bahiagrass pastures. Cattle weight gains did not differ over the 3-yr trial. Forage IVOMD and CP were similar between rotational and continuous stocking. Hammond et al. (1997) also compared rotational stocking and continuous stocking as it affected animal performance of Angus cattle. This study found no difference in ADG among methods (0.68 kg d^{-1} for rotational and 0.67 kg d^{-1} for continuous).

Mathews et al. (1994) compared Holstein heifer and ‘Callie’ bermudagrass pasture response to rotational and continuous stocking over a 2-yr period. In this study, treatments were defined as rotational stocking (15 paddocks) with short grazing periods (1.5 to 2.5 d $paddock^{-1}$) (RS-SG), rotational stocking (3 paddocks) with long grazing periods (10 to 14 d paddock^{-1}) (RS-LG), and continuous stocking (CS). The study found no difference in season-long ADG for the rotational treatments in both years. During the first year, ADG on CS was significantly higher than either of the RS treatments; however there were no differences among treatments in the second year. Comparing average stocking rate among treatments showed that RS-SG was greater than RS-LG and CS during the first year (3920, 3200, and 3230 kg liveweight ha^{-1} d^{-1}, respectively), and there were trends toward a similar response during the second year. The IVOMD values were not different across treatments during the first year; however, in the second year the RS-LG treatment was significantly higher than the CS, 574 and 558 g kg^{-1}, respectively. There were no significant differences among CP values across treatments. The authors concluded that effect of grazing method on heifer performance was slight, but potential exists for long-term differences because Callie persistence was greater under rotational stocking.

Tharel (1989) compared rotational and continuous stocking of three bermudagrass cultivars (Common, Tifton 44, and Midland). Both continuously and rotationally stocked pastures were 1 ha in size, and the rotational pastures were subdivided into 10, 0.1-ha paddocks. Average daily gains across cultivars were higher for continuous compared to rotational stocking, 0.7 and 0.6 kg d^{-1}, respectively. On a gain per hectare basis, rotationally stocked pastures outperformed continuous, 730 and 600 kg ha^{-1}, respectively.

Grazing Frequency

Data indicate a potential for increasing DM production with increasing intervals between grazing (decreasing grazing frequency; Mislevy and Brown (1991). Frequent removal of forage may decrease non-structural carbohydrate reserves, decreasing the plants ability to produce DM; however, as interval between grazings increases, CP and

IVOMD decrease. Frequent grazing prevents plants from reaching maturity, thus increasing the proportion of young, lush herbage.

Mislevy and Brown (1991) evaluated bahiagrass at four grazing frequencies, 2, 3, 5, and 7 wk across 3 yr. As interval between grazing increased, DM production increased from 7.1 to 10.8 Mg ha^{-1} yr^{-1}. The grazing frequency effect on IVOMD was less in early season, but in mid-summer IVOMD decreased from 540 g kg^{-1} at 2 wk to 480 g kg^{-1} at 7 wk. The CP decreased with increasing interval between grazing in June (140 to 80 g kg^{-1}) and in mid-summer (110 to 70 g kg^{-1} at 2 and 7 wk, respectively). Gates et al. (1999) evaluated bahiagrass at three cutting intervals, 2, 4, and 8 wk, during three growing seasons. With the exception of the 8-wk interval in Year 2, DM production increased as cutting interval increased. There was no change in IVDMD among cutting intervals, but there was a slight decreasing trend as interval increased. Cuomo et al. (1996) compared three grazing frequencies, 20, 30, and 40 d, of bahiagrass across two growing seasons. At these frequencies, total forage dry matter production was 10.6, 11.8, and 12.3 Mg ha^{-1}, respectively. Herbage CP was significantly higher at the 20-d grazing frequency (124 g kg^{-1}), but it was equal for the 30 and 40-d intervals (110 g kg^{-1}). In vitro true digestibility did not significantly change across grazing frequencies. Beaty et al. (1970) evaluated bahiagrass across six harvest frequencies, 1, 2, 3, 4, 5, and 6 wk. At these frequencies, average DM productions for the 2 yr study were 3.5, 3.4, 3.0, 2.7, 3.8, and 2.6 Mg ha^{-1}, respectively, showing little effect of clipping frequency. Stanley (1994) compared bahiagrass at harvest intervals of 1, 2, 4, 8, and 16 wk, with a N rate of 336 kg ha^{-1}. Forage DM production was highest for the 8-wk interval (18.9 Mg ha^{-1}). Relative production for the remaining harvest intervals (with DM productions of the 8-wk treatment assigned a value of 1.00) were 0.36, 0.53, 0.81, and 0.75 for the 1, 2, 4, and 16-wk treatments, respectively; illustrating an increase in forage production as harvest interval increases to 8-wk, but no further increase with delayed harvest.

Adjei et al. (1989) compared bahiagrass, limpograss, and bermudagrass at four grazing frequencies (2, 4, 6, and 8 wk) for two growing seasons. At these grazing frequencies, Pensacola bahiagrass did not show a significant increase in DM production with longer intervals between grazing. ‘Hemarthria 869’ limpograss and ‘Tifton 79’ bermudagrass both showed a linear increase in DM production from the 2 to 8 wk interval, 1.8 to 5.6 Mg ha^{-1} and 4.3 to 7.8 Mg ha^{-1}, respectively. There were linear and quadratic decreases in bahiagrass CP (130 to 73 g kg^{-1}) as interval increased from 2 to 8 wk. Limpograss and bermudagrass CP also declined markedly with increasing interval, 107 to 57 g kg^{-1} and 160 to 65 g kg^{-1}, respectively. Bahiagrass IVOMD decreased linearly with increasing interval between grazing (560 to 460 g kg^{-1}). Limpograss did not show a significant change in IVOMD, but bermudagrass IVOMD decreased linearly from 610 to 470 g kg^{-1}. This study also evaluated forage persistence at these grazing frequencies. Over all grass entries, there was a significant linear decrease in common bermudagrass invasion, from 51% to 36%, as interval between grazing increased.

These data suggest that production responses of bahiagrass to defoliation frequency are likely smaller than those of more upright-growing grasses. This is probably due to the ability of bahiagrass to maintain leaf area even under frequent, close grazing and to self shading as regrowth interval increases.

Grazing Intensity

In a forage system, grazing intensity is an important means by which both animal and forage production can be manipulated. It is important to maximize forage utilization, but at the same time maintain a vigorous pasture stand. Grazing intensity can be characterized in a number of ways including grazing height and stocking rate.

Stocking rate is defined as the relationship between the number or weight of animals and the area of pasture which is available for grazing over an extended period of time. Stocking rate has a major influence on forage production and animal performance, thus, it is considered to be the most significant grazing management decision (Matches, 1992). Increasing stocking rate increases the removal of available forage per unit land area; however, nutritive value or available forage may decrease as grazing height decreases. This reduction in quantity and or quality causes consumed energy to be reallocated from maximum daily animal growth to meeting the maintenance requirement (Burns et al., 2003), thus reducing production per animal. Conversely, increasing the stocking rate of an underutilized pasture causes an increase in animal production per unit land area up to a point (Mott and Lucas, 1952). Exceeding this point causes a decrease in production per unit land area due to the decline in forage availability and daily animal production; the latter occurs because a greater proportion of total forage intake is devoted to meeting the maintenance requirement of the animal. Consequently, stocking rate is an important factor influencing production of a given pasture.

Adjei et al. (1980) evaluated pasture and animal response of three stargrass cultivars to three stocking rates (SR): 7.5, 10, and 15 cattle ha^{-1} (cattle = 250 kg avg. liveweight). Across 2 yr, forage DM production increased from 17.0 to 20.1 t ha^{-1}, as SR increased from 7.5 to 15 cattle ha^{-1}. For UF-5 stargrass, IVOMD and CP increased as SR increased (460, 488, and 523 g kg^{-1}and 87, 102, and 111 g kg^{-1}, respectively). Average daily gain (ADG) of cattle on UF-5 decreased as stocking rate increased (0.46, 0.37, and 0.24 kg d^{-1}). Gain per unit land area increased from the 7.5 to 10.0 SR (570 to 610 kg ha^{-1}, respectively), but decreased to 590 kg ha^{-1}, as SR increased to 15 cattle ha^{-1}. Conrad et al. (1981) compared performance of beef steers on two cultivars and three experimental hybrids of bermudagrass at four SR. Average SR across grasses were 4.6, 6.8, 8.8, and 9.0 head ha^{-1}. With increasing SR, ADG decreased (0.83, 0.70, 0.48, and 0.38 kg $head^{-1}$ d^{-1}, respectively). Animal performance on a per unit land area basis increased from 581 to 738 kg ha^{-1} as SR increased from 4.6 to 6.8 head ha^{-1}, but then decreased as SR increased to 8.8 and 9.0 head ha^{-1} (651 and 641 kg ha^{-1}, respectively).

Even though there are a lack of data related to stocking rate of bahiagrass pastures, from the data presented for other grasses, it appears likely that stocking rate will affect both forage and animal responses significantly.

Summary

Bahiagrass serves as an important feedstuff to the beef cattle industry in the Southeastern USA. Bahiagrass response to N fertilization is well documented in the literature, but the effects of grazing method and grazing intensity on pasture and animal responses have received less attention from researchers in the region. Research assessing the effects of management intensity, defined as combinations of N rate, stocking rate, and grazing method, on productivity of bahiagrass-livestock systems is thus deemed important for the future of these systems in Florida and the Southeast. The research that follows includes two experiments that address these issues.

CHAPTER 3
HERBAGE AND ANIMAL PERFORMANCE RESPONSES TO MANAGEMENT INTENSITY OF CONTINUOUSLY STOCKED BAHIAGRASS PASTURES

Introduction

‘Pensacola’ bahiagrass (*Paspalum notatum* Flügge) is widely adapted in Florida and the Gulf Coast; however, it is lower in nutritive value and yield than many warm-season perennial grasses (Sollenberger, 2001). Consequently, performance per animal and per unit land area on bahiagrass pastures are often below levels typically observed for other planted C_4 grasses. Despite these limitations, bahiagrass tolerates close grazing and a wide range of soil conditions, and it is relatively easy to establish and resistant to weed encroachment. Due to these advantages, bahiagrass covers more area (1 million hectares) than any other planted grass in Florida (Chambliss, 2000). Approximately 80% of all planted grasslands in Florida are seeded to bahiagrass, and more than 90% of bahiagrass pastures are used for grazing by beef cattle.

Over the past 40 yr, the population of Florida has grown from approximately five million to 16 million and is projected to reach 24 million by the year 2030 (Arndorfer, 2003). Given this scenario, it is likely that land area available for agricultural uses will decrease further, and producers may face the task of maintaining economic livelihood on less land. A possible solution to this problem is to increase management intensity to achieve equal or higher gains on smaller amounts of land. Management intensity within the context of bahiagrass-based grassland systems includes N fertilizer rate, animal stocking rate, and grazing management. Currently there is little information in the literature regarding the effect of increasing N fertilizer rate and stocking rate on performance of animals grazing bahiagrass pasture.

Nitrogen is generally the most limiting nutrient for bahiagrass swards (Gates et al., 2004), and N fertilization has the potential to increase both herbage accumulation and crude protein (CP) concentration (Blue, 1988; Burton et al., 1997; Twidwell et al., 1998). With increased herbage accumulation, stocking rate can be increased to utilize the additional herbage while potentially maintaining the same rate of daily live weight gain. Should this occur, the result would be an increase in gain per unit land area on N fertilized bahiagrass pastures.

Therefore research was conducted to evaluate the effect of a range of management intensities of continuously stocked bahiagrass pastures on performance of yearling beef heifers. Treatments were chosen to encompass and exceed the range in management intensity used by current producers. The specific objectives of this study were to evaluate the effects of combinations of N fertilizer rate and stocking rate of bahiagrass pastures on herbage mass, accumulation, and nutritive value, and yearling beef heifer daily gain and gain per hectare.

Methods and Materials

Experimental Site

This experiment was conducted at the Beef Research Unit, located northeast of Gainesville, FL (29° 43' N lat.). Pastures used were well-established swards of Pensacola bahiagrass that had been stocked rotationally at similar stocking rates (1.5 animal units [AU, one AU=500 kg live weight] ha^{-1}) during the previous five summer grazing seasons. Soils at the site were predominantly of the Pomona and Smyrna series of sandy Spodisols with average pH of 5.9. Soil P, K, Ca, and Mg concentrations were 5.3, 28, 553, and 98 mg kg^{-1}, respectively.

Treatments and Design

For the purposes of this experiment, management intensity was defined as a combination of a N fertilizer rate and an animal stocking rate. The three management intensity treatments were LOW (40 kg N ha^{-1} yr^{-1}, 1.2 AU ha^{-1} stocking rate), MODERATE (120 kg N ha^{-1} yr^{-1}, 2.4 AU ha^{-1} stocking rate), and HIGH (360 kg N ha^{-1} yr^{-1}, 3.6 AU ha^{-1} stocking rate), and treatments were arranged in two replicates of a randomized block design. Pasture sizes were varied to achieve the treatment stocking rates and were 1, 0.5, and 0.33 ha for the LOW, MODERATE, and HIGH treatments, respectively. The target stocking rates were chosen based on the projection that heifers with an average initial weight of 270 to 275 kg would be assigned to all treatments and would gain 0.35 kg d^{-1} (based on Sollenberger et al., 1989) over a 160-d trial to achieve a final weight of 325 to 330 kg. This would result in an average weight of approximately 300 kg during the grazing season and an average stocking rate appropriate for that treatment. Because heifer live weights were greater than expected at the start of grazing each year, actual SR was greater than our target and is reported in Table 3-1.

The range of treatments was selected to bound those used by most beef cow-calf producers in Florida. The LOW treatment approximates the current industry average, while MODERATE represents the most intensive of current management practices. The HIGH treatment represents a considerable increase in management intensity from any current management, but one that is within reason should land limitations to cattle production become severe. The choices of N rate and stocking rate for HIGH were based on data from Burton (1997) and Twidwell et al. (1998) who found that bahiagrass forage production was approximately three times greater for N rates near the highest compared to the lowest used in the current study, thus keeping forage mass and stocking rate nearly in balance across these treatments.

Table 3-1. List of actual stocking rates (SR) of continuously stocked bahiagrass pastures.

Target SR (AU† ha^{-1})	Actual SR (AU† ha^{-1})	
	2001	2002
1.2	1.5	1.4
2.4	3.0	2.8
3.6	4.4	4.1

† AU = 500 kg live weight

Pasture and Animal Management

Bahiagrass pastures were continuously stocked during the growing seasons of 2001 (112 d) and 2002 (168 d). Grazing was initiated in the spring or early summer of each year when adequate forage was available to support the livestock (26 June 2001 and 22 May 2002). Grazing was delayed in 2001 because of April and May drought (Table 3-2). The LOW and MODERATE treatment pastures received 40 kg N ha^{-1} when temperature and soil moisture conditions favored a response to N (June 2001 and April 2002). It is typical for all N to be applied to grazed bahiagrass during spring by Florida beef producers because forage is in short supply and the breeding season is underway. The MODERATE pastures received two additional applications of 40 kg N ha^{-1}, one in mid-July, and the other in mid-August. The HIGH pastures received four applications of 90 kg N ha^{-1} in 2002, in late April/early May, mid-June, mid-July, and mid-August.

Because the grazing season was shorter than normal in 2001, the HIGH treatment only received 270 instead of 360 kg N ha^{-1} yr^{-1}. Actual N fertilization dates for both years are reported in Table 3-3. Phosphorus (17 kg ha^{-1}) and K (66 kg ha^{-1}) were applied to all treatments prior to N application in 2001 (17 April) and at the first N application in 2002 (30 April). MODERATE and HIGH treatments received a second application of the same rates on 15 July 2002.

Table 3-2. Rainfall at the experiment site for years 2001-2002 and the 30-yr average for Gainesville, FL.

	Rainfall (mm)				
		2001		2002	
Month	30-yr Average	Actual	Departure From normal	Actual	Departure From normal
Jan	83	12	-71	99	15
Feb	99	25	-74	25	-74
Mar	93	164	71	50	-43
Apr	75	28	-47	62	-12
May	106	22	-85	33	-73
June	168	176	8	135	-34
July	180	248	68	249	69
Aug	203	71	-132	165	-38
Sept	142	183	40	133	-10
Oct	59	9	-50	63	4
Nov	52	20	-31	95	43
Dec	81	50	-31	128	47

Two crossbred (Angus X Brahman) yearling beef heifers of average 344 and 313 kg liveweight were assigned to each pasture in 2001 and 2002, respectively. No other animals were added to the pasture throughout the course of the grazing season. Cattle were provided free-choice access to water and a trace mineral mix (Table 3-4). Artificial shade (3.1 x 3.1 m) was available on all treatments.

Table 3-3. Nitrogen application dates on continuously stocked bahiagrass pastures.

	N application dates (rates in kg ha^{-1})	
Treatment	2001	2002
Low	13 June (40)	30 Apr (40)
Moderate	13 June (40)	30 Apr (40)
	20 July (40)	15 July (40)
	24 Aug (40)	20 Aug (40)
High	13 June (90)	30 Apr (40)
	20 July (90)	14 May (50)
	24 Aug (90)	12 June (90)
		15 July (90)
		20 Aug (90)

Table 3-4. Composition of mineral supplement.

Mineral	g kg^{-1}
Ca	200 – 230
P	≥60
Na	230 – 250
Fe	≥10
F	≤0.6
Co	≥0.0005
Cu	≥0.005
I	≥0.0005
Mn	≥0.02
Se	≥0.00012
Zn	≥0.04

Pasture Responses

Pastures were sampled just prior to initiation of grazing and every 14 d thereafter during the grazing season. Herbage mass, herbage accumulation, and herbage nutritive value (CP and in vitro digestibility) were measured. Double sampling was used to determine herbage mass. Double sampling refers to a technique that includes both a direct and indirect measure of the response of interest. In this case the indirect measure was settling height of a 0.25-m^2 aluminum disk, and the direct measure was hand clipping of all herbage from 2 cm above soil level to the top of the canopy. At each sampling date, 30 disk heights were taken in each pasture. Sites were chosen by walking a fixed number of steps between drops of the disk and all sections of the pasture were represented. Every 28 d, 20 double samples were taken, approximately three to four in each of the six experimental pastures. Sites were chosen that represented the range of herbage mass present on the pastures. At each site the disk height was measured and the forage clipped. Clipped forage was dried for 48 h and weighed. Actual herbage mass was regressed on disk height to develop a calibration equation. This equation from the double samples was used to predict pasture herbage mass using the average disk height (from the 30 disk heights) for each pasture. Regression equations are presented in Table 3-5.

Because cattle were resident on these pastures at all times, a cage technique was used to measure herbage accumulation. Six 1-m^2 cages were used per pasture. The cages were placed in the pasture at the initial sampling date. Sites were chosen that had a disk settling height that was approximately the same (±1cm) as that of the average on that pasture. Disk settling height was recorded at a specific site and the cage placed. After 14 d, the cage was removed and the new disk settling height recorded. Herbage accumulation was calculated as the change in herbage mass during the 14 d that the cage was present. At the end of each 14-d period, cages were moved to new locations on the pasture that approximated the average disk settling height for the pasture.

Table 3-5. Herbage mass double sample regression equations.

2001			2002		
Date	Equation	R^2	Date	Equation	R^2
11 July	y = 220 – 97	0.82	22 May	y = 235x – 313	0.86
8 Aug.	y = 251x - 250	0.84	19 June	y = 260x – 331	0.75
4 Sept.	y = 337x - 401	0.85	14 July	y = 336x - 724	0.78
2 Oct.	y = 279x + 359	0.80	14 Aug.	y = 328x – 648	0.83
			11 Sept.	y = 299x - 277	0.81
			9 Oct.	y = 357x - 447	0.82

Forage allowance is defined as herbage mass per unit of animal liveweight. Forage allowance was calculated for each pasture during each 28-d period as the average herbage mass (mean across three sampling dates in that 28-d period) divided by the average total liveweight during that period.

Herbage CP and in vitro organic matter digestibility (IVOMD) were used as measures of nutritive value. At initiation of grazing and every 14 d thereafter, hand-plucked samples were taken from each pasture. This technique attempts to represent the diet consumed by the grazing animal by removing only the top 5 cm of herbage at approximately 30 locations across each pasture. The herbage was dried at 60°C and ground to pass a 1-mm screen. Analyses were conducted at the Forage Evaluation

Support Laboratory using the micro-Kjeldahl technique for N (Gallaher et al., 1975) and the two-stage technique for IVOMD (Moore and Mott, 1974).

Bahiagrass cover was estimated visually at the beginning of the 2001 grazing season and the end of the 2002 grazing season. Five equally spaced line transects were established for each paddock. Percent bahiagrass was estimated at eight locations along each transect for a total of 40 observations per paddock. Data reported are changes in bahiagrass cover between those two dates.

When pasture data are reported as total-season averages, the data are the averages of all of the 14-d sampling interval data across the season. When reported as 28-d period averages, the data are the average of the three sampling dates within each 28-d period (Days 0, 14, and 28).

Animal Responses

Cattle were weighed at initiation of the experiment and every 28 d thereafter. Weights were taken at 0800 h following a 16-h feed and water fast. Average daily gain was calculated for each 28-d period and for the entire grazing season. Weight gain per hectare was calculated for each pasture over the entire grazing season.

Statistical Analysis

Data representing annual totals or averages (e.g., total herbage accumulation, average pasture herbage mass, average herbage accumulation rate, average herbage allowance, average CP and IVOMD, and average daily gain, gain per hectare) were analyzed using analysis of variance in PROC GLM of SAS (SAS Institute Inc., 1996) with treatment as the main plot and year the subplot. Data representing time trends throughout the season (measured every 14 or 28 d and including herbage accumulation rate, herbage mass, herbage allowance, average daily gain by period, CP, IVOMD) were analyzed using repeated measures analysis of variance in PROC GLM of SAS (SAS Institute Inc., 1996) with treatment as a fixed effect and sampling date as the repeated variable. In addition to analysis of variance to determine treatment effects on forage allowance, regression analysis was conducted using PROC REG of SAS (SAS Institute Inc., 1996) to assess the relationship between forage allowance and heifer average daily gain.

Results and Discussion

The average maximum temperature for both experimental periods of 2001 and 2002 was 31°C, and the average minimum temperature was 19°C (Table 3-6). Total annual rainfall was 1008 and 1236 mm for 2001 and 2002, respectively (30-yr average of 1342 mm; Table 3-2). Rainfall during the experimental period was 540 mm in 2001 and 751 mm in 2002.

Table 3-6. Monthly average temperatures at the experiment site for years 2001-2002.

	Temperature (°C)			
	2001		2002	
Month	Min	Max	Min	Max
Jan	18.8	1.3	19.7	5.2
Feb	24.4	9.3	20.7	5.3
Mar	22.2	9.2	25.5	8.9
Apr	27.4	10.5	29.4	16.0
May	30.4	15.0	30.8	15.6
June	32.3	20.3	31.2	20.4
July	32.2	22.1	32.3	21.3
Aug	32.7	21.6	31.4	21.0
Sept	29.9	19.1	31.4	21.7
Oct	26.8	12.7	28.9	17.7
Nov	25.0	10.8	22.7	8.1
Dec	23.1	9.2	19.6	4.5

Herbage Mass

There was a trend toward a year effect (P=0.06) on average herbage mass, with mass tending to be greater in 2001. This trend can be explained in part due to starting sooner in 2002 and the experimental period including late spring/early summer. Herbage mass values were lower and caused the seasonal average to be lower than in 2001. There was no year X management intensity interaction for herbage mass (P=0.79; Table 3-7). Across years, herbage mass was greater for the LOW treatment than for MODERATE or HIGH. Bahiagrass herbage accumulation generally increases with increasing N rate (Beaty et al., 1977; Burton, 1997; Blue, 1988), but in this experiment, the increase in stocking rate associated with greater N rates apparently more than compensated for the greater pasture growth rates in MODERATE and HIGH and resulted in lower herbage mass.

The three treatments all followed a similar seasonal pattern in herbage mass (Figures 3-1 and 3-2). Herbage mass was relatively low (1.5-2.8 Mg ha^{-1}) early in the grazing season, increased to a maximum, and decreased late in the season in both years. Previous research has shown a similar pattern of herbage mass in bahiagrass pastures, peaking in mid-summer (July August) under typical rainfall conditions (Sumner et al., 1991; Johnson et al., 2001).

There were no intensity effects on herbage mass during any 28-d weighing periods through the 2001 grazing season (P=0.19, P=0.20, P=0.26, and P=0.87); however, there was a trend for the LOW treatment to have higher average herbage mass in the first three periods. There was a management intensity X period interaction for herbage during 2002. This occurred because herbage mass for the HIGH treatment was significantly higher

Table 3-7. Pasture herbage mass (HM) and herbage accumulation rate (HAR) responses to management intensity of continuously stocked bahiagrass pastures.

Treatment‡	HM†			HAR†		
	2001	2002	AVG§	2001	2002	AVG§
	-----------------Mg ha^{-1}-----------------			---------------kg ha^{-1} d^{-1}----------		
Low	3.18	2.77	2.98 a	23.7	15.2	19.4 b
Moderate	2.76	2.31	2.54 b	21.3	44.5	32.9 a
High	2.69	2.44	2.56 b	30.3	43.7	37.0 a
LSD (0.05)			0.04			7.4
S.E.			0.007			1.22

† There was no treatment X year interaction for HM (P=0.79) or HAR (P=0.20).

‡ Treatments = Low (1.2 animal units [AU] ha^{-1} and 40 kg N ha^{-1}); Moderate (2.4 AU ha^{-1} and 120 kg N ha^{-1}); High (3.6 AU ha^{-1} and 360 kg N ha^{-1}).

§ Means within a column followed by the same letter are not significantly different at the 0.05 probability level.

than for LOW at the first two dates (Fig. 3-2), but by the last observation of the season, HIGH herbage mass was significantly lower than for the LOW treatment (2.1 and 3.2 Mg ha^{-1}). Higher herbage mass early in the season on HIGH was likely due to a greater N rate, but that advantage disappeared over time due to greater stocking rate than on LOW. During mid-summer of the 2002 grazing season, there were no differences among treatments (P=0.11, P=0.18, and P=0.16) but the trends favored the LOW treatment.

Herbage Accumulation Rate

There was no year or year X management intensity effect on average herbage accumulation rate (P=0.19 and P=0.20), but there was an effect of management intensity ($P \leq 0.02$). This was a result of the MODERATE and HIGH treatments having greater

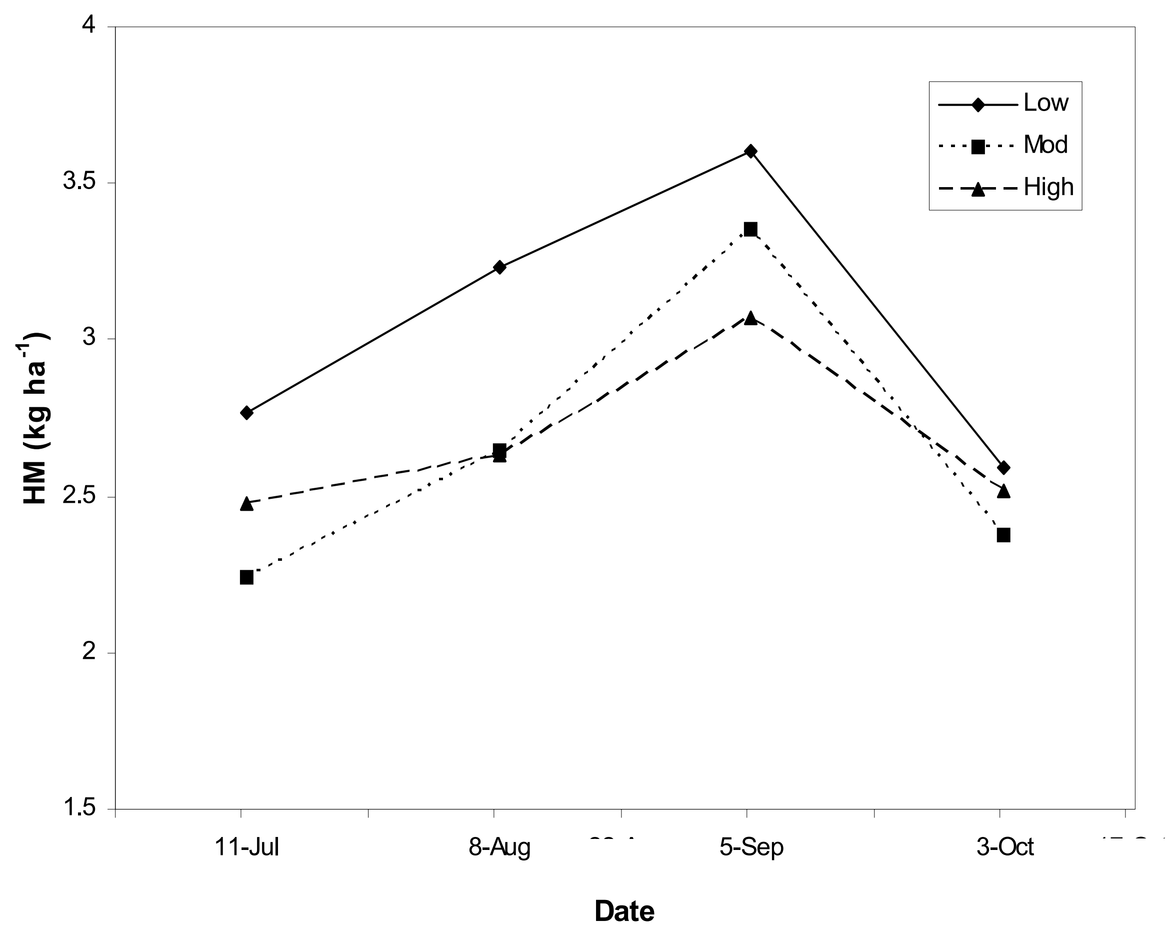

Figure 3-1. Herbage mass (HM) response to three levels of management intensity on continuously stocked bahiagrass pastures in 2001. Dates are the midpoint of 28-d weighing periods. There were no differences among treatments on 11 July (P=0.19), 8 August (P=0.20), 5 September (P=0.26), and 3 October (P=0.87). Standard errors for means on 11 July, 8 August, 5 September, and 3 October are 0.13, 0.17, 0.16, and 0.28, respectively.

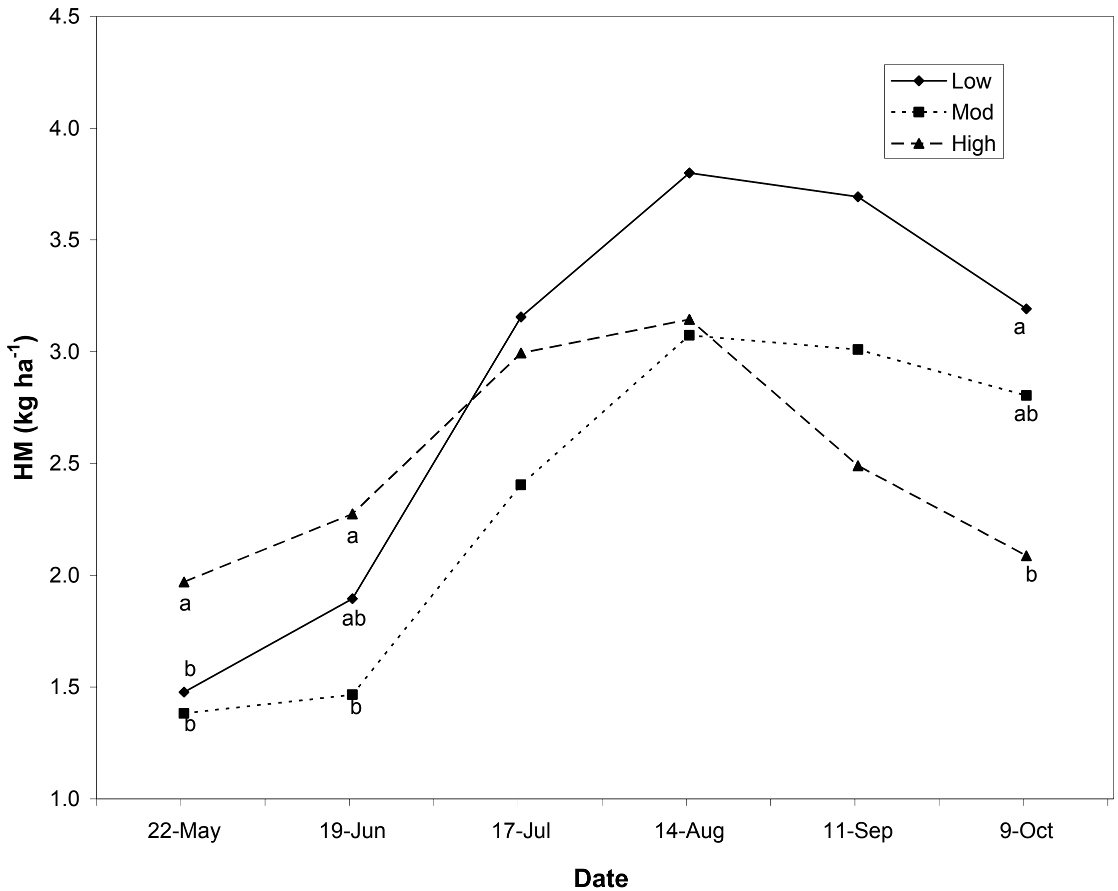

Figure 3-2. Herbage mass (HM) response to three levels of management intensity on continuously stocked bahiagrass pastures in 2002. Dates are the midpoint of 28-d weighing periods. There were no differences among treatments on 17 July (P=0.11), 14 August (P=0.18), and 11 September (P=0.16). Means within other dates bordered by the same letter are not different using the least significant difference test (P=0.05). Standard errors for means on 22 May, 19 June, 17 July, 14 August, 11 September, and 9 October are 0.06, 0.11, 0.14, 0.19, 0.26, and 0.16, respectively.

herbage accumulation rate than the LOW treatment (Table 3-7). Previous research (Ruelke and Prine, 1971; and Stanley, 1994) has shown bahiagrass herbage accumulation increasing dramatically as a result of increased N fertilization. Previous studies of other tropical grasses also show increasing herbage mass as a result of higher growth rates under greater N application (Thom et al., 1990; Wiendenfeld, 1988). In the current study herbage accumulation rate was greater for HIGH and MODERATE than LOW despite LOW having greater average herbage mass. HIGH and MODERATE received more N to increase herbage accumulation; however, the grazing pressure from the increasing SR of these treatments removed the herbage at a faster rate, causing herbage mass to decrease.

During the 2001 grazing season (26 June to 16 October), there were no differences in herbage accumulation rate among treatments during any 28-d period (Figure 3-3); however, there were trends ($P \leq 0.21$) favoring HIGH during three of the four periods. The LOW and HIGH treatments followed similar patterns with decreasing herbage accumulation from the beginning of grazing to late summer, and then slightly increasing in early fall. The MODERATE treatment increased slightly from grazing initiation to mid-summer, then decreased in late summer, and leveled off during early fall.

During the 2002 grazing season (8 May to 23 October) there were no differences in herbage accumulation rate among treatments during any 28-d period (Figure 3-4). All treatments followed a similar trend through the grazing season, with low accumulation rates in spring, increasing to a maximum during mid-summer, and then decreasing in late summer/early fall. This response is similar to the herbage mass seasonal trend in 2001, and can be explained in part by the change in temperature and rainfall at the beginning

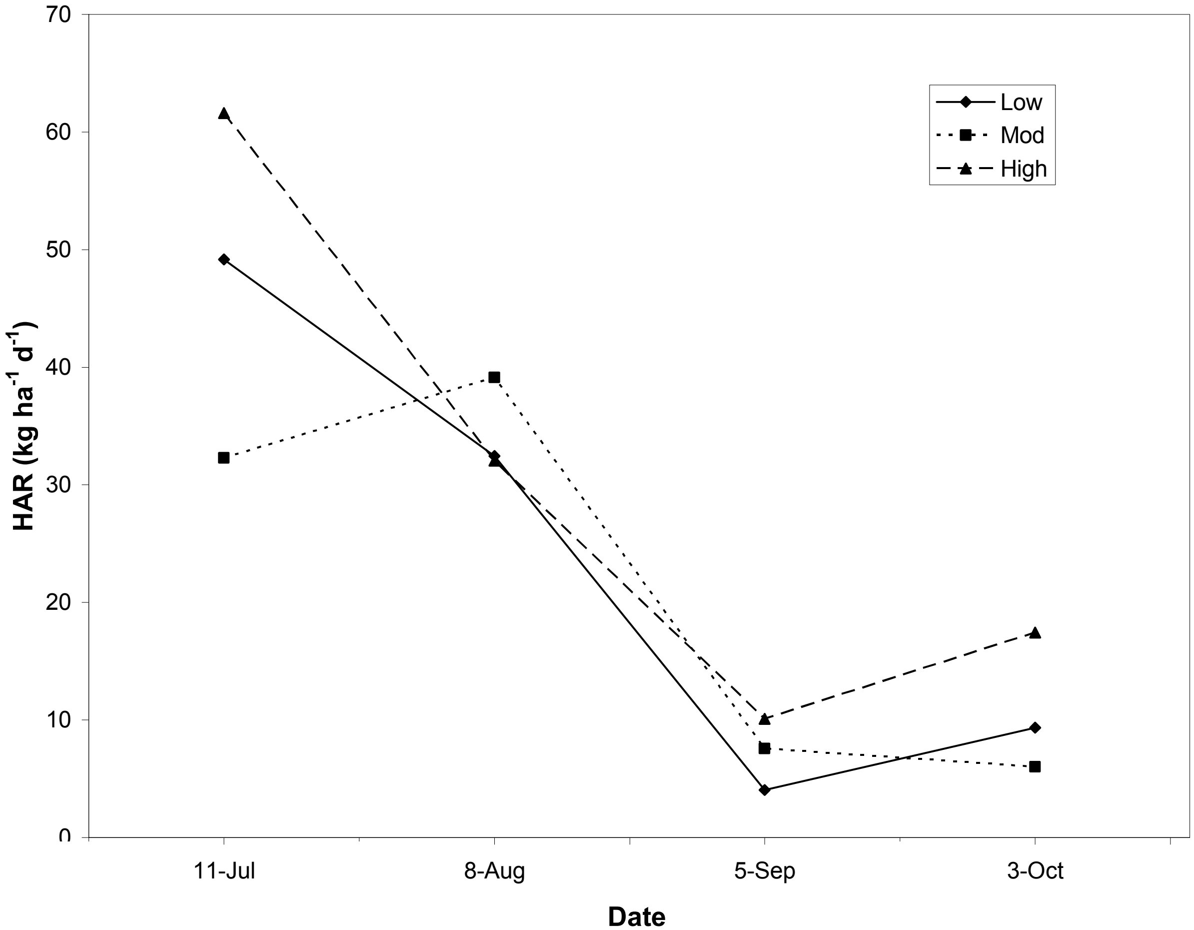

Figure 3-3. Herbage accumulation rate (HAR) response to three levels of management intensity on continuously stocked bahiagrass pastures in 2001. Dates are the midpoint of 28-d weighing periods. There were no differences among treatments on 11 July (P=0.14), 8 August (P=0.93), 5 September (P=0.21) and 3 October (P=0.15). Standard errors for means on 11 July, 8 August, 5 September, and 3 October are 4.5, 14.8, 19.4, and 2.5, respectively.

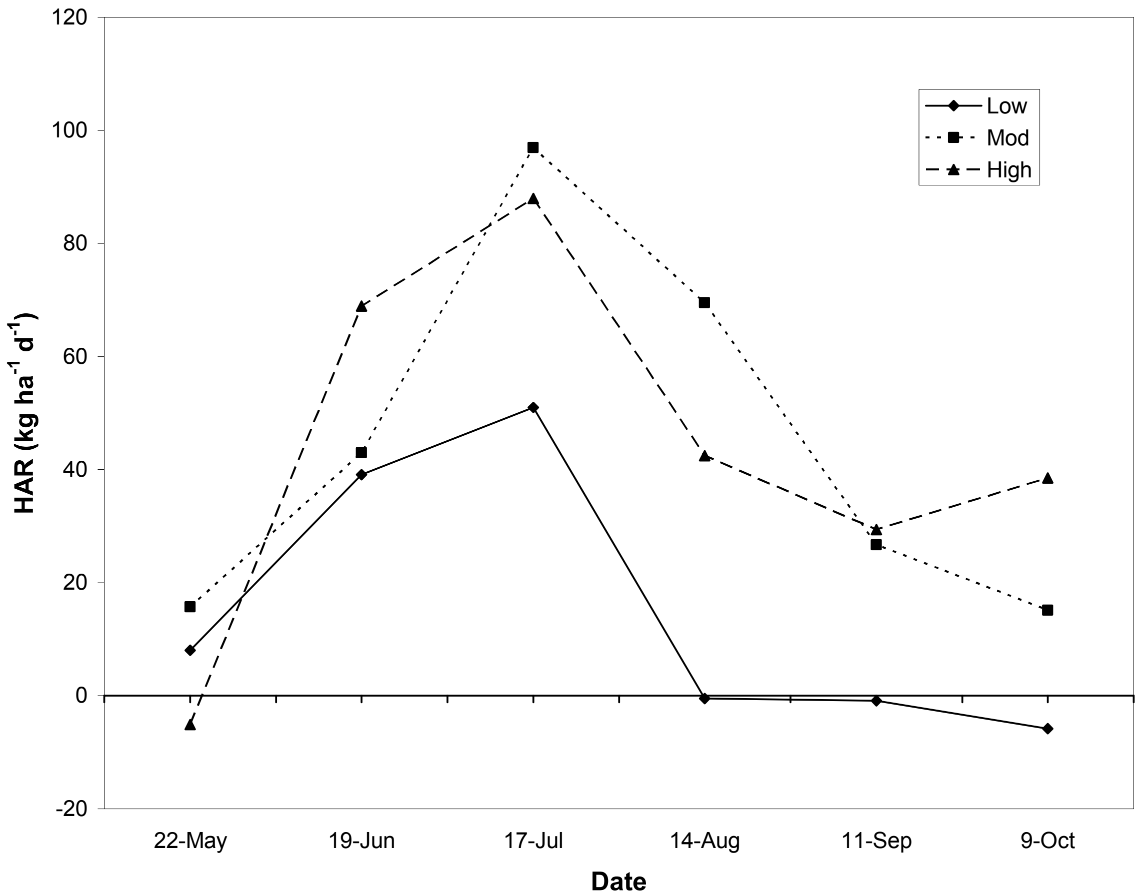

Figure 3-4. Herbage accumulation rate (HAR) response to three levels of management intensity on continuously stocked bahiagrass pastures in 2002. Dates are the midpoint of 28-d weighing periods. There were no differences among treatments on 22 May (P=0.59), 19 June (P=0.35), 17 July (P=0.16), 14 August (P=0.12), 11 September (P=0.33), and 9 October (P=0.13). Standard errors for means on 22 May, 19 June, 17 July, 14 August, 11 September, and 9 October are 12.6, 6.5, 11.6, 12.8, 11.7 and 8.6, respectively.

and end of the growing season. The decline in growth rate experienced in mid- to late summer, however, is more likely a response to decreasing daylength (Sinclair et al., 2003). In both grazing seasons, herbage accumulation rate reached its maximum in mid-July and then decreased throughout the remainder of the season. This is a typical growth pattern for C_4 grasses in this environment (Sumner et al., 1991).

Crude Protein

There was no year effect (P=0.19) on average herbage CP, nor was there a year X management intensity treatment interaction (P=0.56). There was an effect (P≤0.05) of management intensity on herbage CP. This effect was reflected in the general increase in CP as management intensity increased (Table 3-8). Increasing CP with greater N rates is commonly reported for bahiagrass and other tropical grasses (Velez-Santiago and Arroyo-Aguilu, 1983; Christiansen et al., 1988; Burton et al., 1997; Twidwell et al., 1998). The response of bahiagrass forage CP to increased levels of N is not as large as other tropical grasses, but the increase in bahiagrass stolon-root N is greater (Blue et al., 1980). The reported increase in forage N harvested was 68 kg ha^{-1} as N increased from 0 to 336 kg ha^{-1} compared to 104 for Ona stargrass (*Cynodon nlemfuensis* Vanderyst var. *nlemfuensis*). The increase in bahiagrass stolon-root N was 86 kg ha^{-1} compared to an actual decrease of 3 kg ha^{-1} in stargrass. Therefore, even though bahiagrass herbage may not show as great an increase in N, it is still utilized, but stored in the stolons.

During the 2001 grazing season (11 July to 3 October), there were no differences in CP among treatments during the first 28-d period (P=0.22), but there were differences among treatments at the remaining periods. The HIGH treatment had greater CP than both MODERATE and LOW, and MODERATE was greater than LOW (Figure 3-5).

All treatments followed a similar seasonal trend, decreasing from mid- to late-summer, and then remaining relatively constant for the remainder of the grazing season.

Table 3-8. Herbage crude protein (CP) and in vitro organic matter digestibility (IVOMD) responses to management intensity of continuously stocked bahiagrass pastures.

	CP†			IVOMD†		
Treatment ‡	2001	2002	AVG§	2001	2002	AVG§
	------------------g kg^{-1}------------------			-----------------g kg^{-1}--------------		
Low	92	102	97 b	426	478	452 b
Moderate	111	111	111 b	445	496	471 b
High	133	143	138 a	453	536	495 a
Average				441 b¶	503 a	
LSD (0.05)			15			23
S.E.			2.5			3.78

† There was no treatment X year interaction for CP (P=0.56) or IVOMD (P=0.57).

‡ Treatments = Low (1.2 animal units [AU] ha^{-1} and 40 kg N ha^{-1}); Moderate (2.4 AU ha^{-1} and 120 kg N ha^{-1}); High (3.6 AU ha^{-1} and 360 kg N ha^{-1}).

§ Means within a column followed by the same letter are not significantly different at the 0.05 probability level.

¶ There was a year effect on IVOMD (P=0.02).

During the 2002 grazing season (22 May to 9 October), there were no differences among treatments on 17 July (P=0.17), but before and thereafter there were differences among treatments for all dates. Herbage CP for HIGH was greater than for both MODERATE and LOW throughout the grazing season (Figure 3-6). All treatments followed a similar seasonal pattern. Herbage CP increased to mid-summer, decreased slightly to late summer, and then remained relatively constant level for the remainder of the season.

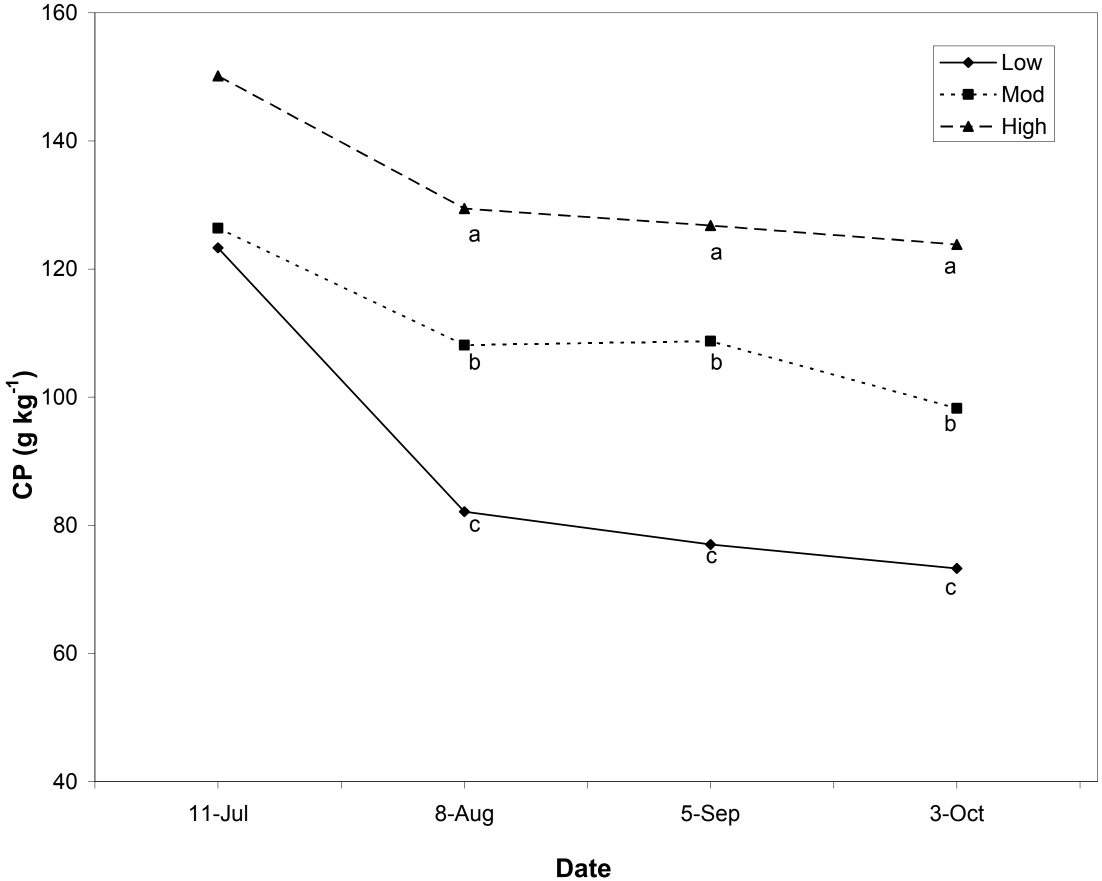

Figure 3-5. Herbage crude protein (CP) response to three levels of management intensity on continuously stocked bahiagrass pastures in 2001. Dates are the midpoint of 28-d weighing periods. There were no differences among treatments on 11 July (P=0.22). Means within other dates bordered by the same letter are not different using the least significant difference test (P=0.05). Standard errors for means on 11 July, 8 August, 5 September, and 3 October are 7.8, 2.9, 2.3, and 1.7, respectively.

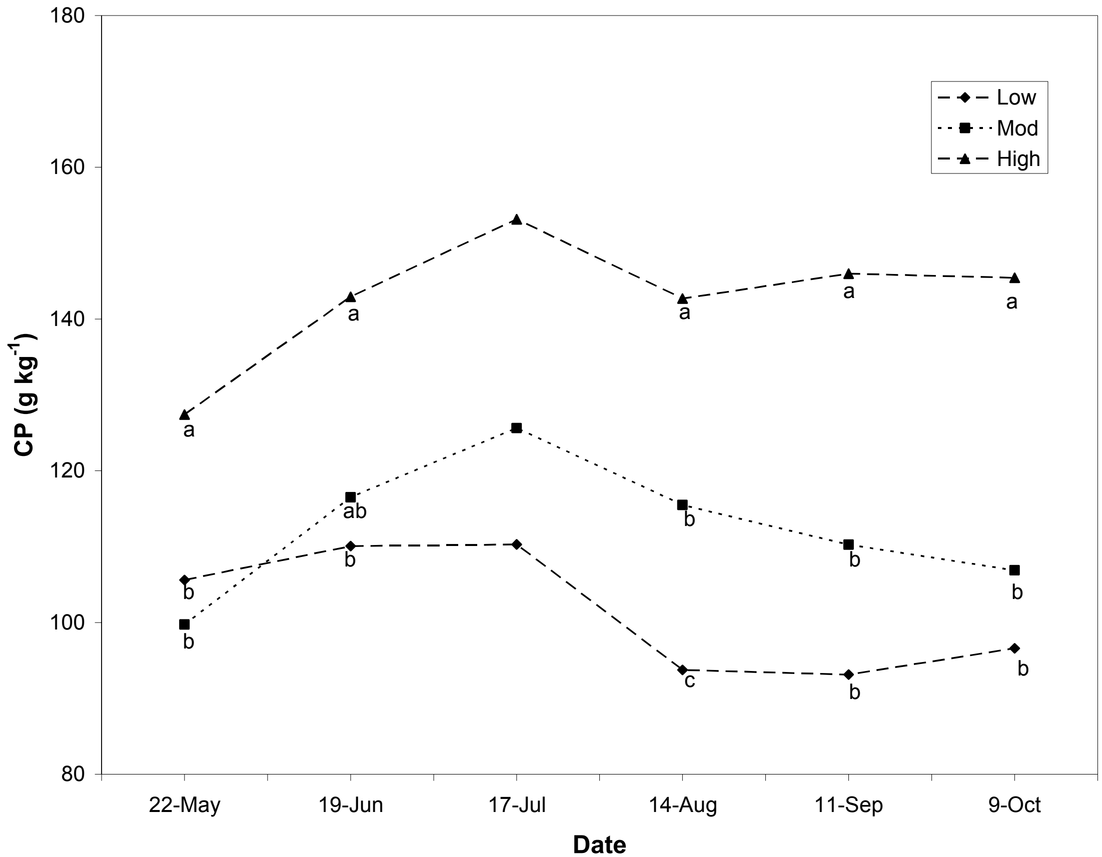

Figure 3-6. Herbage crude protein (CP) response to three levels of management intensity on continuously stocked bahiagrass pastures in 2002. Dates are the midpoint of 28-d weighing periods. There were no differences among treatments on 17 July ($P=0.17$). Means within other dates bordered by the same letter are not different using the least significant difference test ($P=0.05$). Standard errors for means on 22 May, 19 June, 17 July, 14 August, 11 September, and 9 October are 2.6, 5.2, 9.8, 3.4, 4.5 and 5.1, respectively.

In Vitro Organic Matter Digestibility

There was a year effect on average herbage IVOMD (P=0.02). This can be attributed in part to the inclusion of the late spring/early summer portion of the grazing season in 2002, a time generally characterized by higher forage digestibility (Blaser, 1986). There was no year X management intensity interaction (P=0.57), but there was a management intensity effect across years (P=0.03). The HIGH treatment had greater IVOMD than either the LOW or MODERATE treatments (Table 3-8). Increasing N application often has little or no effect on IVOMD of bahiagrass and other tropical grasses (Adjei et al., 1980; Thom et al., 1990). In the current experiment, the greater IVOMD for the HIGH treatment is most likely due to the increase in stocking rate. Higher stocking rate likely decreased the time period between animal visits to a given site in the pasture. This resulted in more frequent removal of grass, causing it to be less mature on average, thus having greater digestibility (Mislevy and Brown, 1991; Hernandez Garay et al., in review).

During the 2001 grazing season there were no differences in herbage IVOMD among treatments during the first three sampling periods, however, during the last observation period of the season, IVOMD of HIGH was greater than that of LOW (Figure 3-7). During the 2002 grazing season (22 May to 9 October), there were no differences among treatments for the 17 July, 11 September, and 9 October periods, however for the remaining periods there was an effect of management intensity on IVOMD. Herbage IVOMD on HIGH was greater than on LOW on 22 May and 14 August and greater than both LOW and MODERATE on 19 June (Figure 3-8). Generally, the treatments followed similar patterns each year, with IVOMD decreasing

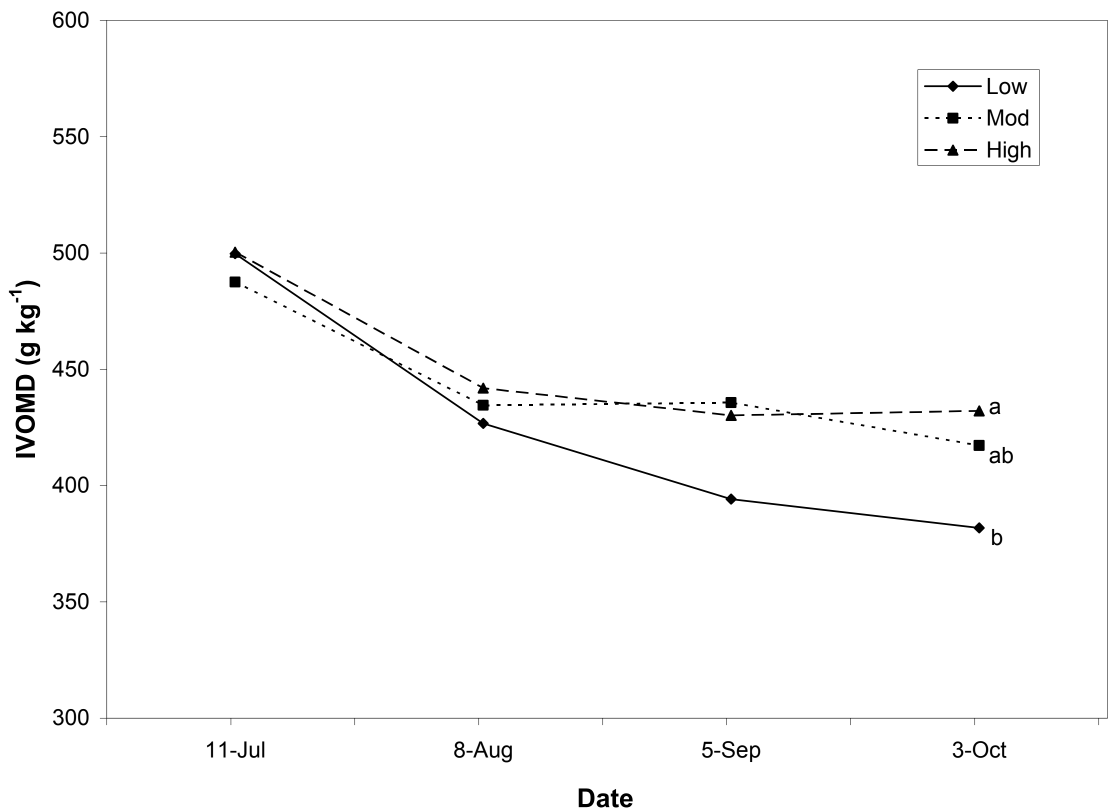

Figure 3-7. Herbage in vitro organic matter digestibility (IVOMD) response to three levels of management intensity on continuously stocked bahiagrass pastures in 2001. Dates are the midpoint of 28-d weighing periods. There were no differences among treatments on 11 July (P=0.22), 8 Aug (P=0.67), and 5 September (P=0.21). Means within a date bordered by the same letter are not different using the least significant difference test (P=0.05). Standard errors for means on 11 July, 8 August, 5 September, and 3 October are 7.1, 10.7, 11.5, and 6, respectively.

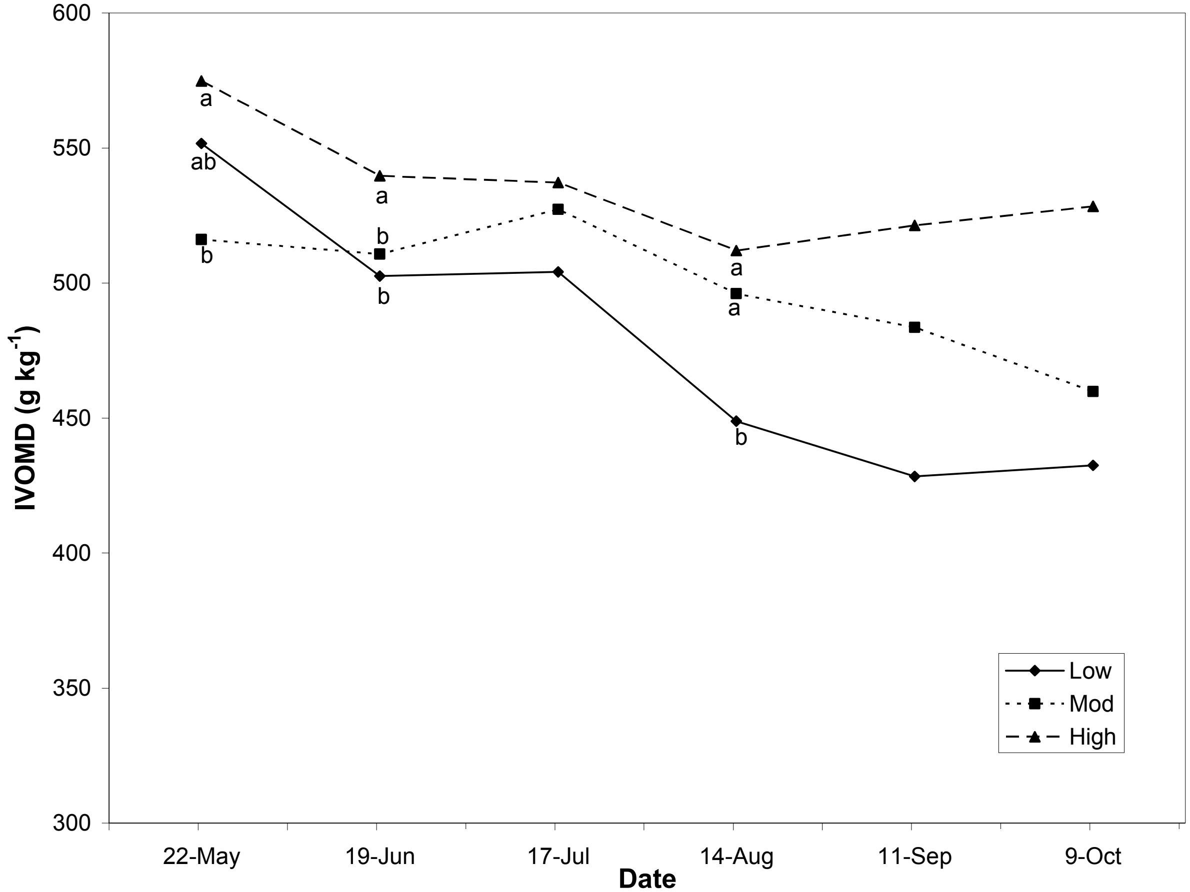

Figure 3-8. Herbage in vitro organic matter digestibility (IVOMD) response to three levels of management intensity on continuously stocked bahiagrass pastures in 2002. Dates are the midpoint of 28-d weighing periods. There were no differences among treatments on 17 July (P=0.32), 11 September (P=0.59), and 9 October (P=0.11). Means within a date bordered by the same letter are not different using the least significant difference test (P=0.05). Standard errors for means on 22 May, 19 June, 17 July, 14 August, 11 September, and 9 October are 7.1, 2.2, 11.6, 2.8, 20.6 and 17.3, respectively.

slowly through the season. This decrease can partly be explained by high temperatures and increased rain through mid-summer (Jones, 1985; Wilson, 1983). An exception was the HIGH treatment in 2002 which increased slightly during late summer/early fall. On this heavily stocked treatment, the IVOMD likely responded this way because of decreasing herbage mass (Fig. 3-2) and more and more frequent visits by cattle to grazing stations in the pasture.

Herbage Allowance

There was no year effect (P=0.79) or year X management intensity interaction (P=0.55) on herbage allowance. There was an effect (P≤0.05) of management intensity on herbage allowance, and allowance decreased as management intensity increased above the LOW treatment (Table 3-9). This was a result of lower herbage mass and increasing stocking rate. Increasing stocking rate increases the removal of available forage per unit land area (Burns et al., 2003), resulting in decreasing herbage mass and allowance (Hernandez Garay et al., in review).

Seasonal herbage allowance followed similar trends in both 2001 and 2002. Allowance increased to a maximum in mid- to late summer and then decreased in early fall. There were differences among treatments during all periods of the 2001 grazing season. Allowance on the LOW treatment was greater than on HIGH during mid- to late summer (8 August and 5 September), and greater than both HIGH and MODERATE at the beginning and end of the season (11 July and 3 October) (Figure 3-9). During the 2002 grazing season, there were no differences among treatments on 22 May (P=0.39) and 19 June (P=0.43), but as the season progressed, the LOW treatment had a greater allowance than MODERATE and HIGH on 17 July. For the remainder of the season there were differences among all treatments, with LOW having the highest allowance,

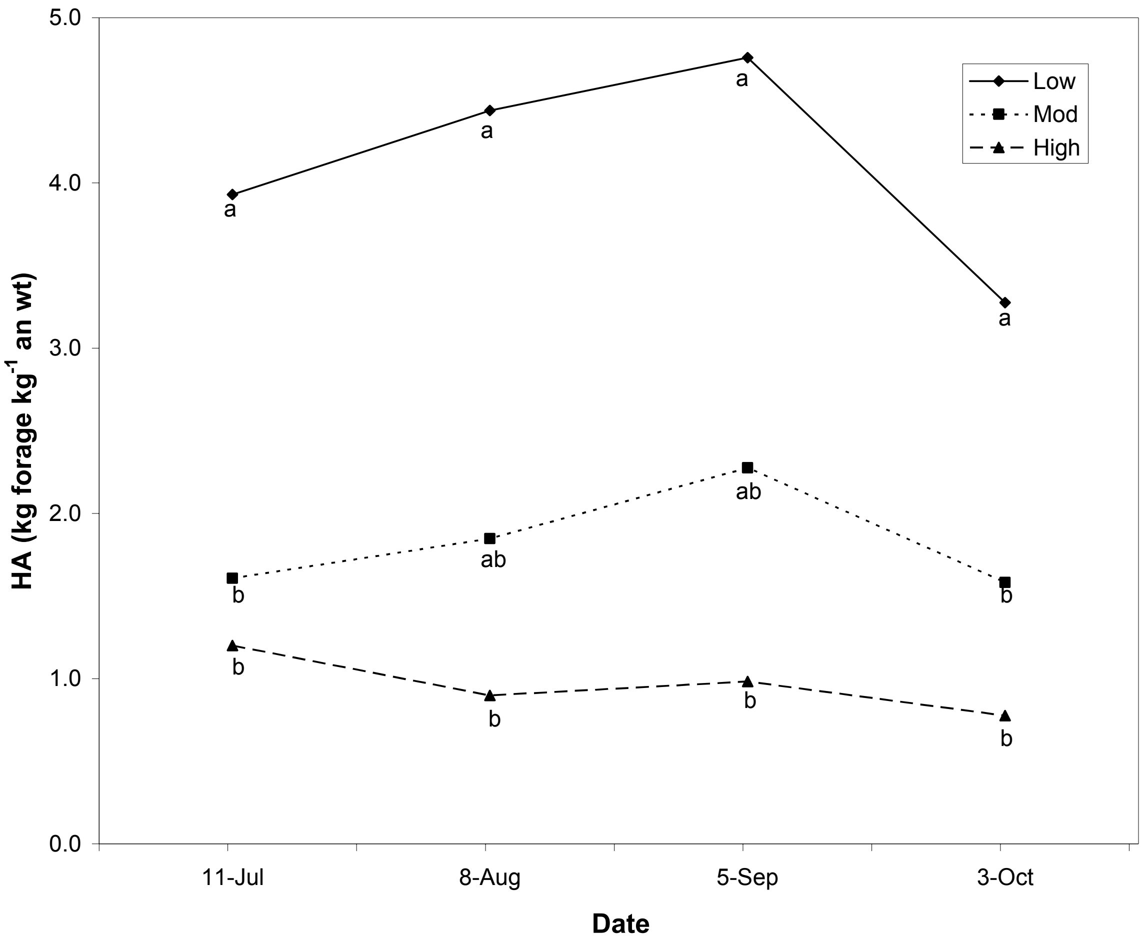

Figure 3-9. Herbage allowance (HA) response to three levels of management intensity on continuously stocked bahiagrass pastures in 2001. Dates are the midpoint of 28-d weighing periods. Means within a date bordered by the same letter are not different using the least significant difference test (P=0.05). Standard errors for means on 11 July, 8 August, 5 September, and 3 October are 0.37, 0.53, 0.61, and 0.20, respectively.

followed by MODERATE and then HIGH (Figure 3-10). These trends can be explained by the seasonal changes of herbage mass. As HM increases during mid-summer, allowance increases and as HM decrease later in the season so does allowance. The changes in herbage allowance are reflected in the seasonal changes in ADG, which will be discussed later.

Table 3-9. Herbage allowance response to management intensity.

Treatment †	2001	2002	AVG ‡§
	--------kg forage kg^{-1} an. wt.-------		
Low	4.10	3.93	4.01 a
Moderate	1.83	1.65	1.74 b
High	0.96	1.19	1.07 b
LSD (0.05)			1.77
S.E.			0.29

† Treatments = Low (1.2 animal units [AU] ha^{-1} and 40 kg N ha^{-1}); Moderate (2.4 AU ha^{-1} and 120 kg N ha^{-1}); High (3.6 AU ha^{-1} and 360 kg N ha^{-1})

‡ Means within a column followed by the same letter are not significantly different at the 0.05 probability level.

§ There was no treatment X year interaction for CP (P=0.55).

Average Daily Gain

There was no year effect (P=0.12) on average daily gain (ADG) nor was there a year X management intensity interaction (P=0.65). There was an effect of management intensity on ADG (P≤ 0.01). Across years, ADG decreased as management intensity increased (Table 3-10). This did not occur because of changes in herbage nutritive value, because it was greater for HIGH than LOW. Instead it appears to be related to quantity of herbage, and both herbage mass and herbage allowance decreased with increased

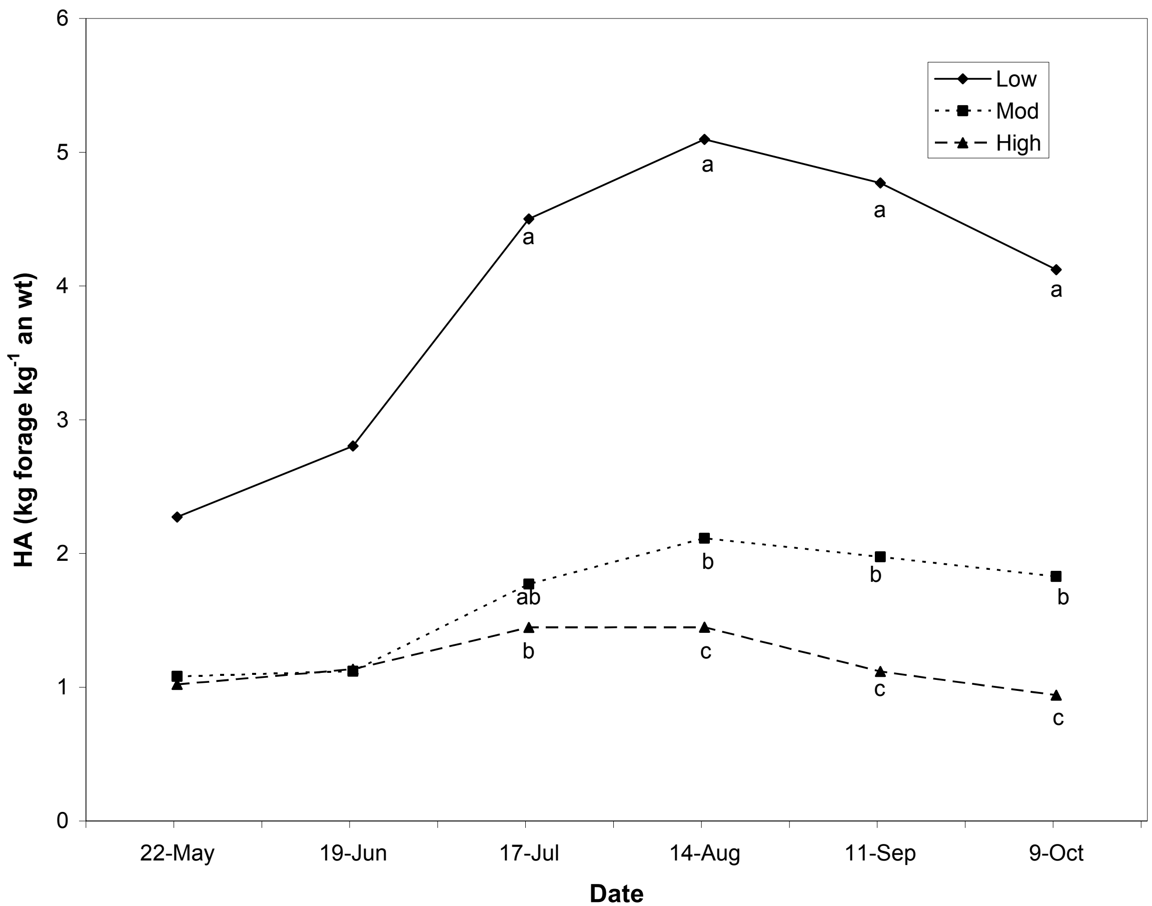

Figure 3-10. Herbage allowance (HA) response to three levels of management intensity on continuously stocked bahiagrass pastures in 2002. Dates are the midpoint of 28-d weighing periods. There were no differences among treatments on 22 May (P=0.39), and 19 June (P=0.43). Means within other dates bordered by the same letter are not different using the least significant difference test (P=0.05). Standard errors for means on 22 May, 19 June, 17 July, 14 August, 11 September, and 9 October are 0.39, 0.43, 0.45, 0.08, 0.08 and 0.06, respectively.

management intensity. Therefore, even though the herbage present was higher in nutritive value, there was not enough herbage to support increased gains as management intensity increased. Similar responses were observed for stargrass in Jamaica (Hernandez Garay et al., in review) and for bermudagrass [*Cynodon dactylon* (L.) Pers.] in Texas (Conrad et al., 1981).

Table 3-10. Heifer average daily gain (ADG) and gain per hectare (GPH) responses to management intensity.

	ADG†			GPH†		
Treatment ‡	2001	2002	AVG§	2001	2002	AVG§
	------------------kg d^{-1}------------------			-------------kg ha^{-1}----------------		
Low	0.49	0.42	0.46 a	109	143	126 b
Moderate	0.50	0.38	0.44 b	225	253	239 a
High	0.38	0.34	0.36 c	257	342	299 a
LSD (0.05)			0.01			
S.E.			0.002			10

† There was no treatment X year interaction for ADG (P=0.65) or GPH (P=0.70).

‡ Treatments = Low (1.2 animal units [AU] ha^{-1} and 40 kg N ha^{-1}); Moderate (2.4 AU ha^{-1} and 120 kg N ha^{-1}); High (3.6 AU ha^{-1} and 360 kg N ha^{-1}).

§ Means within a column followed by the same letter are not significantly different at the 0.05 probability level.

During the 2001 grazing season there were no differences in cumulative ADG among treatments for the 11 July (P=0.10), 8 August (P=0.67), and 3 October (P=0.21) periods. For the 5 September period, ADG for the LOW treatment was greater than for the HIGH treatment (Figure 3-11). During the grazing season, ADG on the LOW treatment decreased to mid-summer, increased to late summer, and then decreased

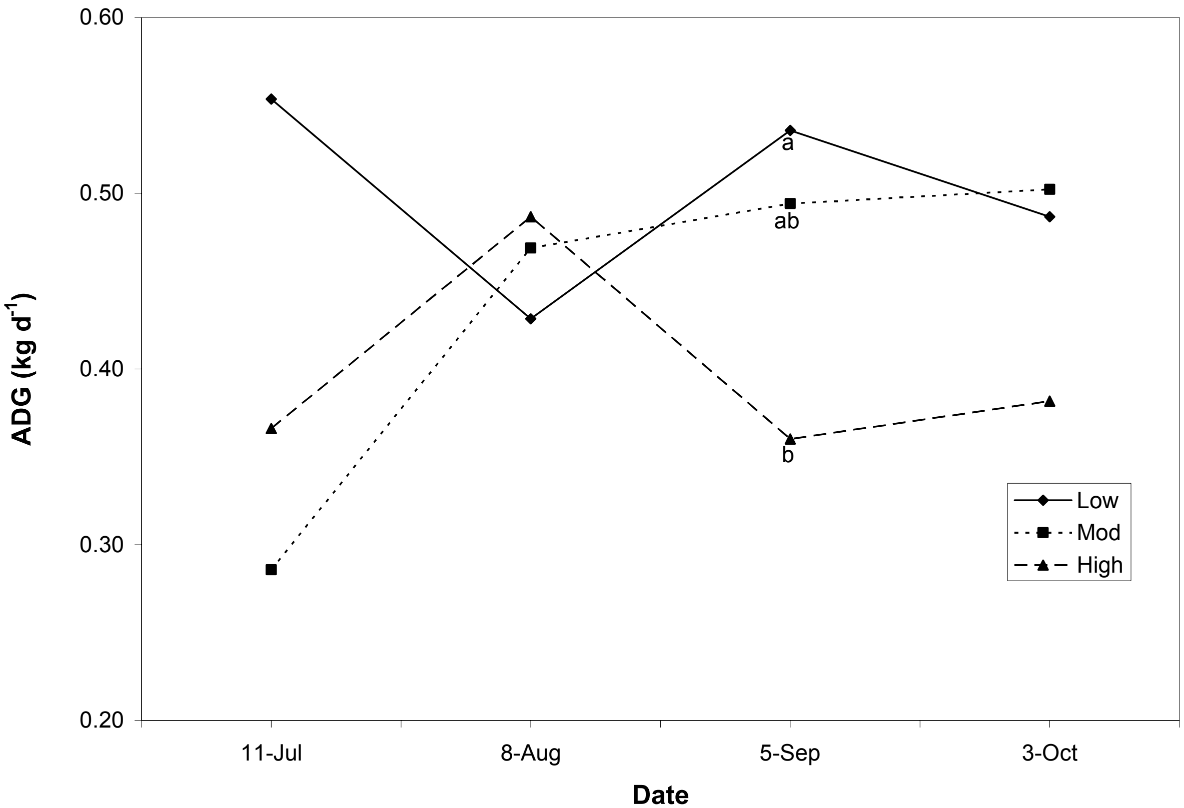

Figure 3-11. Yearling beef heifer cumulative average daily gain (ADG) response to three levels of management intensity on continuously stocked bahiagrass pastures in 2001. There were no differences among treatments on 25 July (P=0.10), 22 August (P=0.81), and 17 October (P=0.22). Means on 19 September bordered by the same letter are not different using the least significant difference test (P=0.05). Standard errors for means on 8 July, 7 August, 6 September, and 1 October are 0.05, 0.06, 0.03, and 0.04, respectively.

slightly to early fall. The MODERATE treatment had a steep increase to mid summer and then increased slightly through the remainder of the season. The HIGH treatment increased to mid-summer, decreased to late summer, and increased slightly to early fall.

During the 2002 grazing season (22 May to 9 October), there were no differences in cumulative ADG among treatments for the 19 June ($P=0.35$), 14 August ($P=0.14$), 11 September ($P=0.21$), and 9 October ($P=0.45$) periods. On 22 May and 17 July, ADG on the LOW treatment was greater than the HIGH treatment (Figure 3-12). During the grazing season, all treatments followed a similar trend, decreasing after the first observation, then increasing and leveling off in mid-summer, and decreasing to late summer/early fall.

Herbage allowance incorporates both pasture and animal aspects, therefore it can be useful in explaining animal responses in trials with wide ranges of pasture herbage mass (Hernandez Garay et al., unpublished data). These authors report a strong relationship between increasing herbage allowance and ADG. During the 2001 season in the current study there was no relationship between ADG and herbage mass ($P=0.99$). There was a trend towards both a linear and quadratic relationship between ADG and herbage allowance ($P=0.12$ and $P=0.14$). During 2002 there was no relationship between ADG and herbage mass ($P\geq 0.81$) or ADG and herbage allowance ($P\geq0.48$).

Gain per Hectare

There was no year effect ($P=0.19$) on gain per hectare, nor was there a year X management intensity interaction ($P=0.70$). There was an effect of management intensity ($P\leq0.05$). Gain per hectare increased as management intensity increased from LOW to MODERATE (Table 3-10) and was not different between MODERATE and HIGH. Understocked pastures accumulate forage that becomes both underutilized and overly

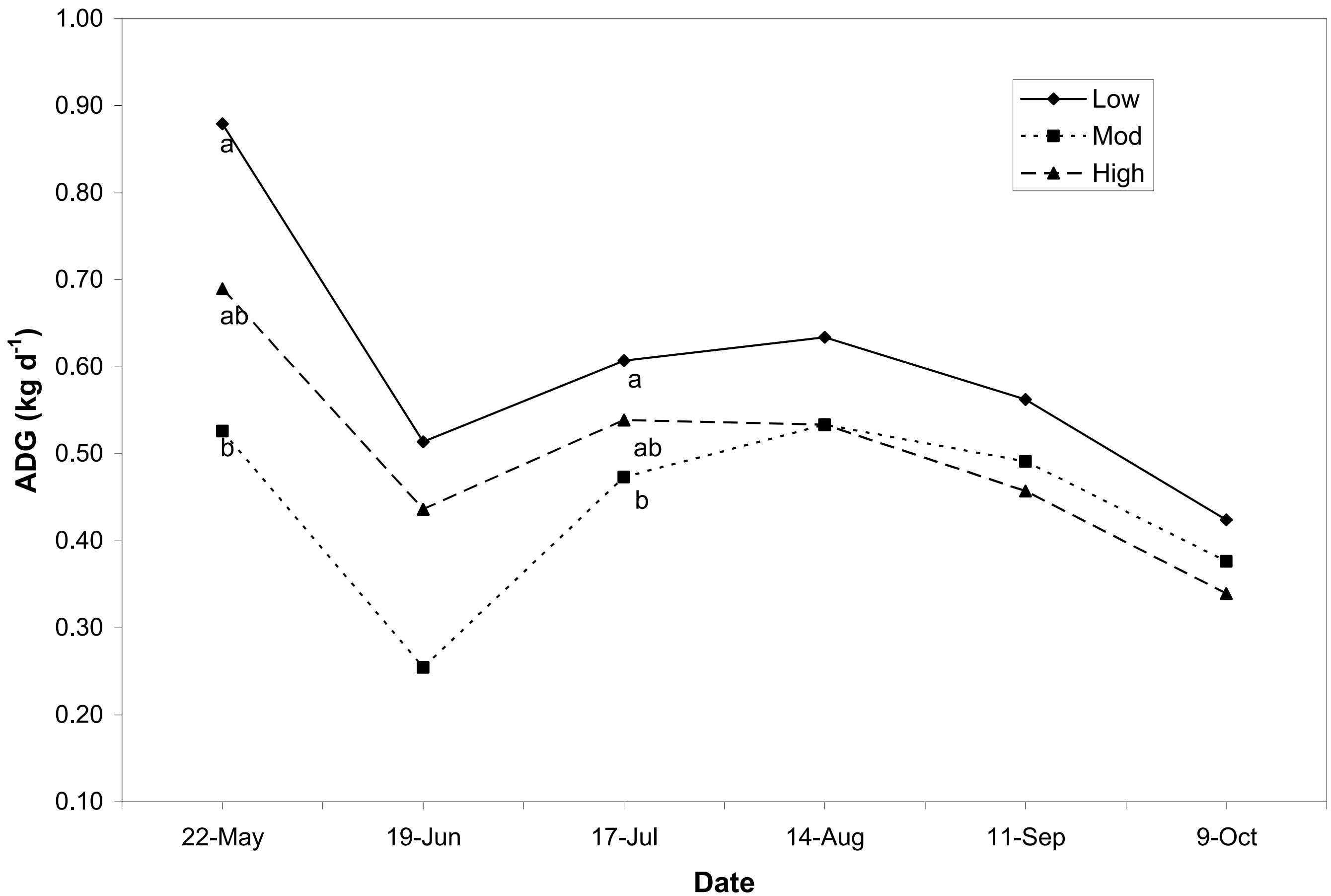

Figure 3-12. Yearling beef heifer cumulative average daily gain (ADG) response to three levels of management intensity on continuously stocked bahiagrass pastures in 2002. There were no differences among treatments on 19 June (P=0.35), 14 August (P=0.14), 11 September (P=0.21), and 9 October (P=0.45). Means within other dates bordered by the same letter are not different using the least significant difference test (P=0.05). Standard errors for means on 22 May, 19 June, 17 July, 14 August, 11 September, and 9 October are 0.05, 0.10, 0.01, 0.02, 0.03, and 0.04, respectively.

mature. Increasing SR increases forage utilization thus increasing animal production on a per unit land area basis (Mott and Lucas, 1952). Conrad et al. (1981) reported similar results on bermudagrass, however they noted that an increase in production per unit land area can only increase to a certain extent, and then the forage genetics become the limiting factor. On similar tropical forages, intake per animal decreases with increasing SR; however, higher percentages of the seasonal DM yield are utilized per unit land area, thus increasing production per unit land area (Adjei et al., 1980).

Bahiagrass Cover

There was a management intensity effect on percentage unit change in bahiagrass cover (P=0.02) during 2 yr of grazing. The HIGH treatment had a positive effect on percent bahiagrass cover (7.1%) and the LOW and MODERATE treatments both had a negative effect (-6.4 and -4.7%). This negative change was predominantly due to the invasion of vaseygrass (*Paspalum urvillei* Steud) and smutgrass [*Sporobolus indicus* (L.) R. Br.], both of which are bunch grass weeds. Some grass weed species such as vaseygrass are palatable to cattle at immature growing stages and are grazed (Sollenberger et al., 1997). With increasing management intensity, greater SR increases the frequency of animal visits to a given site in a pasture. This may result in more frequent grazing of herbage, including weeds, such that they remain more palatable to cattle. Newman et al. (2003) found a greater decrease of vaseygrass plant density in limpograss [*Hemarthria altissima* (Poir.) Stapf & Hubb.] pastures when forage was grazed to 20 cm as opposed to 40 and 60 cm. The loss in vaseygrass plant density was attributed to its inability to adequately refoliate and restore carbohydrate reserves after consecutive grazing events. This along with the low growth habit and strong ability for photosynthesis or a sizeable carbohydrate reserve from which to draw for regrowth of bahiagrass (Beaty et al., 1970) allows it to out compete the weedy bunch grasses under heavier grazing pressure.

Summary and Conclusions

The objectives of this research were to assess the effects of management intensity on forage and yearling beef heifer performance in Pensacola bahiagrass. For this experiment, management intensity was defined as a combination of a N fertilizer rate and an animal stocking rate and levels of intensity were chosen to reflect and extend those used by beef producers in Florida. The three management intensity treatments were LOW (40 kg N ha^{-1} yr^{-1}, 1.2 animal units [AU, one AU=500 kg live weight] ha^{-1} stocking rate), MODERATE (120 kg N ha^{-1} yr^{-1}, 2.4 AU ha^{-1} stocking rate), and HIGH (360 kg N ha^{-1} yr^{-1}, 3.6 AU ha^{-1} stocking rate), and treatments were arranged in two replicates of a randomized block design.

As management intensity increased, heifer average daily gain, pasture herbage mass, and herbage allowance decreased. However, nutritive value, gain per hectare, herbage accumulation rate, and bahiagrass cover increased as a result of increased management intensity. As management intensity increased above the LOW treatment, production per unit land area increased, but at a large cost in relation to additional N cost. Gain per hectare increased 113 kg ha^{-1} as management intensity increased from LOW to MODERATE at an additional cost of \$60 for N fertilizer (This does not include the additional cost of P and K applications for MODERATE and HIGH during 2002). This equals a cost of \$0.53 of fertilizer per additional kg of gain above LOW. As management intensity increased to HIGH, there was a 173 kg ha^{-1} increase in gain per hectare. With the cost of additional fertilizer (\$206), the cost of fertilizer per additional kg of gain equaled \$1.21.

From the results of this research, it is apparent that very high N rates will not produce gains that will make these strategies economically feasible for beef producers. If the need arises for producers to increase production on decreased land area, the replacement of bahiagrass with another more management responsive species will be required.

CHAPTER 4
GRAZING METHOD EFFECTS ON FORAGE GROWTH AND NUTRITIVE VALUE OF BAHIAGRASS PASTURES

Introduction

High yield of high quality forage is critical for maximizing animal production on pasture. As grassland is converted to non-agricultural uses in increasingly urban states like Florida, maintaining production levels on a decreasing land resource may become difficult. Intensification of management is one option for achieving the desired increase in production per unit land area. Choice of a grazing method is an important management decision that may affect animal production on grazed pasture (Ball et al., 1996).

Changing from continuous to rotational stocking has the potential to increase forage production, reduce amount of forage wasted, and in turn increase stocking rates (Blaser, 1986). This increase in stocking rate may allow for higher animal performance on a per unit land area basis. Potential exists to improve pasture performance by altering the number of pasture subdivisions, i.e., length of the grazing period in rotationally stocked pastures.

Comparisons of bahiagrass pasture performance are limited under a wide range of grazing management practices. The objectives of this experiment were to evaluate the effect of continuous and a range of rotational stocking methods on herbage accumulation, herbage nutritive value, and persistence of bahiagrass.

Methods and Materials

Experiment Site

The experiment was conducted at the Beef Research Unit located northeast of Gainesville, FL (29° 43' N lat.). Pastures used were well-established swards of Pensacola bahiagrass that had been stocked rotationally at similar stocking rates (1.5 animal units [AU, one AU=500 kg live weight] ha^{-1}) during the previous five summer grazing seasons. Soils at the site are predominantly of the Pomona and Smyrna series of sandy Spodisols with average pH of 5.7. Soil P, K, Ca, and Mg concentrations were 3, 33, 450, and 82 mg kg^{-1}, respectively.

Treatments and Design

There were five treatments arranged in a randomized block design with two replicates. Treatments were continuous stocking and four rotationally stocked pastures differing only in length of grazing period (1, 3, 7, and 21 d). Length of rest period between grazings was 21 d for all four rotational stocking treatments. All pastures were fertilized at 270 and 360 kg N ha^{-1} in 2001 and 2002 (Table 4-1), respectively, and had a beginning stocking rate of 4.1 and 4.0 AU per hectare in the 2 yr.

Table 4-1. Nitrogen application dates and rates for bahiagrass pastures.

N application dates (rates in kg ha^{-1})	
2001	2002
13 June (90)	30 Apr (40)
20 July (90)	14 May (50)
24 Aug (90)	12 June (90)
	15 July (90)
	20 Aug (90)

Grazing began in the spring of 2001 and 2002 when quantity of forage was sufficient to support treatment stocking rates. Paddock size for 21-, 7-, 3-, and 1-d residence period treatments were 0.5, 0.25, 0.125, and 0.045 ha, respectively. Comparison of animal performance was not an objective of this experiment, so in effect, the area used for the rotational stocking treatments was that needed for one pasture subunit (paddock) of the complete rotational grazing system. For example, the 21-d residence period treatment would require two paddocks if animal performance was to be measured, one in which grazing would currently be underway, another which was regrowing. In this experiment, we had only one paddock per replicate. Thus during the 21-d rest periods when cattle were not grazing this paddock, they were on other treatments in the experiment. Cattle groups of the appropriate live weight were moved among the rotational stocking treatments whenever a given paddock was scheduled for grazing. In 2001, the 21-, 7-, 3-, and 1-d treatments were grazed 3, 4, 5, and 6 times respectively, while in 2002, they were grazed 4, 6, 6, and 7 times.

The target stocking rate used was that of the HIGH treatment from Experiment 1 (Chapter 3), i.e., 3.6 AU ha^{-1}. Actual rates were somewhat higher due to higher than expected cattle initial weights. Thus, all rotational treatments were stocked with approximately the same number of kg of live weight for the designated length of residence period. This resulted in very different stocking densities (short-term measure of animals per unit land area), but the stocking rate over a complete grazing cycle (time during which each paddock in an actual system would be visited once) was the same for all treatments. This allowed evaluation of the effects of the different grazing strategies on pasture accumulation rate, nutritive value, and percent bahiagrass cover.

Pasture Measurements

For rotationally stocked paddocks, sampling occurred the day prior to the start of each grazing period and the day the grazing period ended. Thirty disk meter measurements were taken throughout each paddock at each sampling to determine herbage mass. The disk meter was calibrated every 28 d as described in Chapter 3. Herbage accumulation was calculated as pregraze herbage mass of the current cycle minus postgraze herbage mass of the previous cycle. Herbage mass, herbage accumulation, and herbage accumulation rate for the continuous treatment were quantified as described in Chapter 3.

Nutritive value for the five treatments was assessed using hand-plucked samples. The approach for the continuous treatment has already been described in Chapter 3. For the rotational stocking treatments, sampling occurred just before the beginning of each grazing period. For these treatments, herbage was sampled to a stubble that approximated what the animals would remove during the grazing period. This was based on the postgraze stubble height of recently defoliated treatments. Samples were dried at 60°C for 48 h, ground to pass a 1-mm screen in a Wiley Mill, and analyzed for crude protein (CP) and in vitro organic matter digestibility (IVOMD) as described in Chapter 3.

Bahiagrass cover was estimated visually at the beginning and end of each grazing season. Five equally spaced line transects were established for each paddock. Percent bahiagrass was estimated visibly at eight locations along each transect for a total of 40 observations per paddock. Data reported are changes in percent bahiagrass cover from before the experiment started through two grazing seasons later.

Statistical Analyses

Data representing annual averages (e.g., average herbage accumulation rate, average herbage CP and IVOMD, and change in bahiagrass cover) were analyzed using analysis of variance in PROC GLM of SAS with treatment as the main plot and year as the subplot. Data representing time trends throughout the season (herbage accumuulation rate, CP, and IVOMD) were analyzed using repeated measures analysis of variance in PROC MIXED of SAS with treatment as a fixed effect and sampling period as the repeated variable. Periods were identified because rotational treatments were grazed at different dates and different numbers of times throughout the year. The periods were early summer (25 June - 11 July 2001 and 15 May - 11 July 2002), mid-summer (12 July - 29 August each year), and late summer (30 August- 21 October each year). Means for a given period represent data from one or two grazing cycles for rotational treatments, depending on treatment.

Results and Discussion

Herbage Accumulation Rate

There was no year or year X management intensity effect on average herbage accumulation rate (P=0.33 and P=0.61), but there was an effect of management intensity (P=0.05). All the rotational treatments had greater herbage accumulation rate than the continuous treatment (Table 4-2). To maximize herbage accumulation requires maximum interception of light by leaf. This is achieved by increasing leaf area index (LAI, ratio of area of leaf in the canopy to the area of ground below) which allows for a greater proportion of radiation to be intercepted by the canopy (Chapman and Lemaire, 1993). Optimal LAI is that which allows 95 to 100% light interception (Donald, 1961), and this is achieved more quickly over time if grazing pressure is reduced. After defoliation, energy for regrowth is derived from mobilization of carbohydrate reserves (Gerrish, 1991). The rest period between defoliations allows swards to accumulate leaf area and restore carbohydrate reserves (Chaparro et al., 1996). Although not quantified in this study, the greater herbage accumulation rates for rotational treatments suggest that average LAI and canopy light interception were greater for rotationally than continuously stocked bahiagrass swards.

Table 4-2. Herbage accumulation rate (HAR†) response to grazing method on bahiagrass pastures.

Treatment‡	2001	2002	Average§
	--------------- $kg\ ha^{-1}\ d^{-1}$	---------------	---------------
Rot.-1	65	60	63 a
Rot.-3	52	84	68 a
Rot.-7	68	75	72 a
Rot.-21	78	80	79 a
Cont.	30	44	36 b
LSD (0.05)			26
S.E.			6.6

† There was no treatment X year interaction for HAR (P=0.61).

‡ Grazing methods are rotational (Rot.) and continuous (Cont.). The number following Rot. is the length of the grazing period in days, while the rest period was a constant 21 d for all rotational treatments.

§ Means within a column followed by the same letter are not significantly different at the 0.05 probability level.

Herbage accumulation rates of rotational treatments followed similar patterns during the 2001 grazing season, increasing from early to mid-summer, and then decreasing in early fall. The continuous treatment decreased accumulation rates throughout the grazing season (Table 4-3). The shorter grazing period treatments (1 and

Table 4-3. Seasonal pasture herbage accumulation rate (HAR[†]) response to grazing method on bahiagrass pastures.

	2001 Season[‡]			2002 Season[§]		
Treatment[¶]	1	2	3	1	2	3
	$kg\ ha^{-1}\ d^{-1}$					
Rot.-1	78 a[#]	87 a	50 ab	69	80	56 a
Rot.-3	60 a	76 ab	28 ab	67	102	93 b
Rot.-7	56 a	75 ab	57 ab	77	105	57 a
Rot.-21	71 a	84 a	74 a	90	79	91 b
Cont.	48 a	32 b	14 b	42	62	44 a
S.E.	20	18	18	25	19	10

[†]There was no treatment X year interaction for HAR (P=0.61).

[‡]2001 Seasons= 1 (25 June- 11 July); 2 (12 July- 29 August); and 3 (30 August- 16 October).

[§]2002 Seasons= 1 (15 May- 11 July); 2 (12 July- 29 August); and 3 (30 August- 21 October).

[¶]Grazing methods are rotational (Rot.) and continuous (Cont.). The number following Rot. is the length of the grazing period, while the rest period was a constant 21 d for all rotational treatments.

[#] Means within a season followed by the same letter are not significantly different ($P \leq 0.05$) by repeated measures ANOVA contrasts.

3 d) experienced a more rapid decline in accumulation rate in early fall, while the longer grazing period treatments (7 and 21 d) had a less pronounced decline. The last sampling

dates of the short grazing period treatments fell in early to mid-October, and herbage accumulation rates ranged from -28.6 to 16.5 kg ha^{-1} d^{-1}, while the longer grazing period treatments ended in mid- to late September and ranged from 50.2 to 83.3 kg ha^{-1} d^{-1}. This partly explains the sharper decrease in herbage accumulation for the 1- and 3-d treatments as well as the overall trend toward lower total-season accumulation rates (Table 4-2). Lower accumulation rates for bahiagrass in fall have been attributed to plant responses to shorter daylength (Sinclair et al., 2003). During the 2002 season, all but the 21-d rotational treatment followed similar trends (Table 4-3), increasing from grazing initiation to mid-summer, and then decreasing to late summer/early fall.

Crude Protein

There was a year effect on herbage CP (P=0.02). The difference between years can be attributed in part to less N being applied in 2001 than in 2002, however, the lower N rate in 2001 was also associated with a shorter grazing season. In addition, during 2001 relatively heavy rainfall occurred the day of, and during the 3 d immediately following N application on 13 June and 20 July (26 and 43 mm, respectively). During the 2002, season rainfall the day of and 3 d following N application was less than 10 mm for all but the last application. The greater rainfall after application in 2001 may have caused N to leach through the soil more quickly making it less available for uptake, and possibly contributing to the lower CP values in 2001. There was no year X treatment or treatment effect on herbage CP (P=0.29 and P=0.24) (Table 4-4). Previous studies with bahiagrass have shown potentially large increases in production and forage N concentration with increasing N rate (Blue, 1998), however, in this trial all treatments received the same N rate and no effect of grazing method was observed. Williams and Hammond (1999) also found no differences in CP when comparing rotational (7 d grazing, 21 d rest) and

Table 4-4. Herbage crude protein (CP) and in vitro organic matter digestibility (IVOMD) responses to stocking method on bahiagrass pastures.

	CP†			IVOMD†		
Treatment ‡	2001	2002	AVG§	2001	2002	AVG§
	------------------g kg^{-1}------------------			------------------g kg^{-1}-----------------		
Rot.-1	132	144	138 a	496	555	526 a
Rot.-3	140	152	146 a	500	572	536 a
Rot.-7	143	148	146 a	508	513	511 a
Rot.-21	148	150	149 a	514	544	529 a
Cont.	133	143	138 a	453	536	493 b
Average	139 b¶	147 a		494 b¶	544 a	
LSD (0.05)			13			18
S.E.			3.5			4.5

† There was no treatment X year interaction for CP (P=0.29) or IVOMD (P=0.12).

‡ Grazing methods are rotational (Rot.) and continuous (Cont.). The number following Rot. is the length of the grazing period in days, while the rest period was a constant 21 d for all rotational treatments.

§ Means within a column followed by the same letter are not significantly different at the 0.05 probability level.

¶ There was a year effect on CP(P=0.02) and IVOMD (P≤0.01).

continuous stocking of bahiagrass when pastures were fertilized and stocked at the same level (70 kg N ha^{-1} and 2.1 to 2.4 head ha^{-1}, respectively). Bermudagrass [*Cynodon dactylon* (L.) Pers.] also showed little difference in CP between rotational (15 paddocks with 1.5- 2.5 d grazing period, and paddocks with 10-14 d grazing periods) and continuous stocking at equal levels of N and stocking rate (210 kg N ha^{-1} and 1.5 AU ha^{-1}) (Matthews et al., 1994).

Seasonal patterns in herbage CP among treatments during the 2001 grazing season followed similar trends (Table 4-5). All treatments decreased from early and mid-summer to late summer and increased in late summer. During the 2002 grazing season, the longer grazing period rotational treatments (7 and 21 d) followed a similar pattern to that in 2001. The short grazing period (1 and 3 d) rotational treatments and the continuous treatment showed little seasonality of response (Table 4-5).

Table 4-5. Seasonal herbage crude protein (CP) response to grazing method on bahiagrass pastures.

	2001 Season†			2002 Season‡		
Treatment§	1	2	3	1	2	3
	-----------------------------------	-----	-----g kg^{-1}-----	-----	-----	-----------------------------------
Rot.-1	166 ab¶	128	138 b	146	155	141
Rot.-3	173 a	134	146 a	155	158	148
Rot.-7	174 a	134	148 a	160	144	150
Rot.-21	167 ab	127	165 a	164	143	149
Cont.	150 b	132	137 b	144	148	146
S.E.	7.8	5.1	4.9	8.0	8.1	8.1

†2001 Seasons= 1 (25 June- 11 July); 2 (12 July- 29 August); and 3 (30 August- 16 October).

‡2002 Seasons= 1 (15 May- 11 July); 2 (12 July- 29 August); and 3 (30 August-21October).

§Grazing methods are rotational (Rot.) and continuous (Cont.). The number following Rot. is the length of the grazing period, while the rest period was a constant 21 d for all rotational treatments.

¶Means within a season followed by the same letter are not significantly different ($P \leq 0.05$) by repeated measures ANOVA contrasts.

In Vitro Organic Matter Digestibility

There was a year effect ($P \leq 0.01$), but there was no year X treatment ($P=0.12$) interaction effect on IVOMD. Greater IVOMD in 2002 than 2001 occurred primarily due to very large differences between years from mid-summer through early fall. Reasons for this difference are not readily apparent. There was a treatment effect on IVOMD ($P=0.01$) because the rotational treatments had greater IVOMD than the continuous treatment (Table 4-4). At the same stocking rate, rotationally stocked animals are restricted to smaller area of pasture at a given point in time than continuously stocked animals causing animals to be less selective and graze lower in the canopy (Bransby, 1991). This may tend to reduce overall diet digestibility or it may increase it over time because it limits the build up of mature or senescent herbage. For these reasons and perhaps because it is difficult to sample a diet comparable to that selected by the animal, the literature does not show a consistent pattern of IVOMD response to grazing method. For example, Williams and Hammond (1999) found IVOMD to be similar in an experiment comparing rotational and continuous stocking on bahiagrass; however, research on bermudagrass suggests a trend toward higher IVOMD for rotational over continuous stocking (Matthews et al., 1994).

During 2001, seasonal changes in IVOMD followed a similar pattern across all treatments, decreasing as the grazing season progressed (Table 4-6). This pattern could possibly be explained by the greater loss of water soluble carbohydrates associated with increased respiration due to increased temperatures associated with mid-summer and early fall (Jones, 1985). Another possible explanation could be the decrease in herbage accumulation rates as the season progressed. With lower accumulation rates, cattle are forced to graze lower in the canopy and this herbage is more mature and includes more senescent material. There were also differences among treatments during each seasonal period. During the early summer, all rotational treatments had significantly higher IVOMD than continuous. However, IVOMD for all rotational treatments, except the 21 d, decreased more severely through the season, so by early fall, only the 21-d rotational was higher than the continuous treatment.

Table 4-6. Seasonal herbage in vitro organic matter digestibility (IVOMD) response to grazing method on bahiagrass pastures.

	2001 Season[†]			2002 Season[‡]		
Treatment[§]	1	2	3	1	2	3
	----------	----------	---------- $g\ kg^{-1}$	----------	----------	----------
Rot.-1	579 a[¶]	510 a	472 ab	569 a	559	543 ab
Rot.-3	599 a	520 a	450 ab	568 a	556	565 a
Rot.-7	616 a	494 ab	468 ab	514 b	513	512 b
Rot.-21	579 a	508 a	494 a	533 ab	544	566 a
Cont.	537 b	442 b	432 b	557 ab	525	525 ab
S.E.	14.5	20.0	16.9	18.5	25.9	16.5

[†]2001 Seasons= 1 (25 June- 11 July); 2 (12 July- 29 August); and 3 (30 August- 16 October).

[‡]2002 Seasons= 1 (15 May- 11 July); 2 (12 July- 29 August); and 3 (30 August- 21October).

[§]Grazing methods are rotational (Rot.) and continuous (Cont.). The number following Rot. is the length of the grazing period, while the rest period was a constant 21 d for all rotational treatments.

[¶]Means within a season followed by the same letter are not significantly different ($P \leq 0.05$) by repeated measures ANOVA contrasts.

During the 2002 season, all treatments decreased or remained relatively constant in IVOMD from late spring/early summer to fall except for the 21-d treatment which increased as the season progressed (Table 4-6). During late spring/early summer, IVOMD for the 1- and 3-d rotational treatments was higher than for the 7-d treatment. During the mid-summer there were no differences among treatments. By the early fall, the 1-d treatment had decreased, and the 21-d treatment had increased so that the 3- and 21-d treatments were higher than the 7-d treatment (Table 4-6).

Bahiagrass Cover

Grazing method affected bahiagrass cover ($P \leq 0.01$). Continuous stocking had a positive effect on bahiagrass cover while all rotational treatments caused bahiagrass cover to decrease, especially the 1-d treatment (Table 4-7). This response was

Table 4-7. Changes in bahiagrass cover in response to grazing method in bahiagrass pastures.

Treatment†	June 2001	December 2002	Change
	--------------------%--------------------		
Rot.-1	96.2	80.6	-15.6 a‡
Rot.-3	84.9	81.2	-3.7 b
Rot.-7	85.1	80.5	-4.6 b
Rot.-21	88.8	80.4	-8.4 b
Cont.	80.6	87.7	7.1 c
LSD (0.05)			6.7
S.E.			1.7

†Grazing methods are rotational (Rot.) and continuous (Cont.). The number following Rot. is the length of the grazing period, while the rest period was a constant 21 d for all rotational treatments.

‡Means followed by the same letter are not significantly different ($P \leq 0.05$) by LSD ANOVA contrast

unexpected, even for a very grazing tolerant species like bahiagrass. Stocking rate was the same across treatments, so it should not have affected the response. Herbage accumulation rate was actually greater on the rotational treatments, so grazing pressure was less than on the continuous treatment. The major change in species composition of the rotational pastures was greater presence of vaseygrass (*Paspalum urvillei* Steud.) and smutgrass [*Sporobolus indicus* (L.) R. Br.]. Both of these species become unpalatable to livestock at relative young growth stages (Newman et al., 2003; Adjei et al., 2003). It can be hypothesized that the more frequent visits by cattle to a particular grazing station under continuous stocking may result in these species being kept in check to a greater degree than under a 21-d rest period rotational system. It is not clear, however, why bahiagrass cover decreased to a greater extent on the 1-d treatment than the other rotational pastures.

Summary and Conclusions

As agricultural land continues to diminish due to conversion to urbanized area by the increasing human population, increasing animal production per unit land area may become more and more important to producers in order to maintain financial stability. Stocking rate decisions greatly affect animal productivity, but stocking method also has the potential to influence animal performance.

The objectives of this experiment were to evaluate the effect of continuous and a range of rotational stocking methods on herbage accumulation rate, herbage nutritive value, and persistence of bahiagrass pastures. Herbage accumulation and herbage IVOMD were greater for rotationally than continuously stocked pastures. Herbage accumulation rate did not differ among rotational treatments, and there was no effect of grazing method on CP. Bahiagrass cover decreased for rotationally stocked pastures (-

8.1% average among rotational treatments) but increased under continuous stocking (7.1%). Among rotational treatments, bahiagrass cover decreased more for the 1-d than the average of the other three treatments (-5.6 to -15.6%).

With the utilization of rotational as opposed to continuous stocking, there is potential to increase herbage growth rates which in turn, could support greater stocking rates. However high N fertilization combined with rotational grazing appears to pose the threat of increased invasion of vaseygrass and smutgrass in bahiagrass pastures, thus necessitating more intensive weed control management as well. These data show no consistent advantage in any production response of very short grazing periods (1 or 3 d) on rotationally stocked bahiagrass pastures.

CHAPTER 5
SUMMARY AND CONCLUSIONS

The beef industry is a critical component of Florida's large agriculture industry. Revenues from the beef cattle industry in Florida totaled 371 million dollars in 2000 and accounted for 5.3% of the total agricultural cash receipts (Florida Agricultural Facts Directory, 2002). Grasslands cover large areas of land in both Florida and the southeastern USA and are an important source of feed to the livestock industry. Bahiagrass serves as an essential resource to the beef industry covering approximately 1 million hectares in Florida (Chambliss, 2000). However, with the large increase in human population over the past 40 yr and projected increases in the next 30 yr, urbanization poses a threat to the amount of land available for agricultural uses. The livestock industry may be forced to maintain economic livelihood on smaller amounts of land. A potential solution to this problem is to increase management intensity on smaller amounts of land to attain equal or greater production.

With this situation in mind, the research conducted focused on animal performance and pasture characteristics of grazed bahiagrass pastures as influenced by increasing management intensity. Management intensity was defined by stocking rate, N fertilization rate, and grazing method, and the research was divided into two experiments.

The first experiment evaluated beef heifer performance and pasture responses to three levels of management intensity of continuously stocked bahiagrass pastures. Intensity levels were defined by N fertilizer rate and stocking rate and included LOW (40 kg N ha^{-1} yr^{-1}, 1.2 animal units [AU, one AU=500 kg live weight] ha^{-1} stocking rate), MODERATE (120 kg N ha^{-1} yr^{-1}, 2.4 AU ha^{-1} stocking rate), and HIGH (360 kg N ha^{-1} yr^{-1}, 3.6 AU ha^{-1} stocking rate), and were intended to represent and extend the current practice of producers in Florida. Animal performance was evaluated on a per animal basis (average daily gain) and a per unit land area basis (gain per hectare). Pasture responses included nutritive value, herbage mass, herbage allowance, and herbage accumulation.

As management intensity increased, heifer average daily gain and pasture herbage mass and allowance decreased. However, gain per hectare, herbage nutritive value, herbage accumulation rate, and bahiagrass cover increased as a result of increased management intensity. Both herbage mass and allowance decreased as management intensity increased above the LOW to the HIGH treatment (3.0 to 2.6 Mg ha^{-1} and 4.0 to 1.1 kg forage kg^{-1} an. wt., respectively) as a result of the greater proportional increase in stocking rates compared to accumulation rate. Heifer ADG and pasture herbage mass and allowance generally followed similar trends throughout the season. Heifer ADG decreased, but the response was relatively small, only decreasing 0.10 kg d^{-1} as management intensity increased from the LOW to HIGH treatment. Both herbage CP and IVOMD increased as management intensity increased. Increases in CP (97 to 138 g kg^{-1}) from the LOW to HIGH treatment were caused in part by the increase in N application. The observed increase in herbage IVOMD from the LOW to HIGH treatment (452 to 495 g kg^{-1}) is not a typical response to increased N fertilization, but it can be explained by the increase in SR which likely increased the frequency of visits per site in the pasture. This prevented underutilization and accumulation of mature herbage.

Production per unit land area increased as management intensity increased above the LOW treatment, but at a large cost in relation to additional N cost. As management intensity increased from the LOW to the MODERATE level, gain per hectare increased 110 kg ha^{-1}. However with the cost of additional N being 60 dollars, the cost of fertilizer per additional kg of gain was \$0.55. As management intensity increased from LOW to HIGH, gain per hectare increased 170 kg ha^{-1}. The cost of additional N was \$206; therefore the cost of fertilizer per additional kg of gain was \$1.21. From this it is apparent that very high N rates on bahiagrass are not likely to be economically feasible for beef producers.

The second experiment evaluated continuous and a range of rotational stocking methods on herbage accumulation rate, herbage nutritive value, and persistence of bahiagrass pastures. In this experiment there were five treatments, including four rotational treatments differing only in length of the grazing period, and one continuous stocking treatment. The rotational treatments had grazing periods of 1, 3, 7, and 21-d, all with a 21 d rest period. All treatments received the same N fertilization and stocking rate of the HIGH treatment from the first experiment.

Changing from continuous to rotational stocking increased herbage accumulation and IVOMD. There were no differences among rotational treatments in herbage accumulation rate; however, there was a trend toward increasing accumulation rate as length of grazing period increased (63 to 79 kg ha^{-1} d^{-1}). Use of rotational compared with continuous stocking decreased bahiagrass cover (-8.1% average among rotational treatments compared to +7.1% for continuous). Among rotational treatments, bahiagrass cover decreased more for the 1-d treatment than for the other grazing periods (-15.6 % vs. -3.7). These treatments had no effect on herbage CP.

These experiments showed that bahiagrass pastures were responsive to increased management intensity, but high levels of N fertilization appear to be associated with significant concerns including insufficient increase in animal production relative to N costs, greater weed invasion with rotational stocking, and, although not an objective of these experiments, greater potential for loss of nutrients to the environment. Rotational stocking increased herbage accumulation rate, which in practice would allow for a greater stocking rate and production per unit land area, but rotational stocking in conjunction with high N fertilizer rates resulted in large increases in cover by vaseygrass and smutgrass. Among rotational stocking treatments, there were no measurable advantages to increasing the number of paddocks (decreasing the grazing time per paddock) per pasture. In conclusion, these data suggest that modest increases in management intensity of bahiagrass pastures may be warranted, specifically rotational stocking (2-4 paddocks) and increasing N rate to approximately 120 kg ha^{-1} yr^{-1}. However, higher rates of N fertilizer do not appear to have merit from either an economic or a pasture-persistence perspective in addition to increase potential for negative environmental impacts. Therefore, if the need for increased production per unit land areas becomes acute in Florida forage-livestock systems, the use of other more management-responsive grasses will likely be required.

This research also points to the need for further research in related areas. There is the possibility of imposing these or similar management practices on one or more forage species that have the potential to respond more favorably than bahiagrass. This research may provide useful data for development of models that can be helpful in assessing sustainability in an increasingly urban society.

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BIOGRAPHICAL SKETCH

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