Herbage and Animal Responses to Management Intensity of Continuously Stocked Bahiagrass Pastures

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ABSTRACT

There are about 1 million ha of bahiagrass (*Paspalum notatum* Flügge) pasture in Florida. Rapid population growth is reducing grassland area and may force beef cattle (*Bos taurus*) producers to achieve economic livelihood on less land. One alternative is to increase management intensity of existing pasture. This research evaluated management intensity effects on beef heifer and bahiagrass pasture performance. Management intensities were low (40 kg N ha^{-1} yr^{-1}, 1.4 animal units [AU, one AU = 500 kg live weight] ha^{-1} stocking rate [SR]), moderate (120 kg N ha^{-1} yr^{-1}, 2.8 AU ha^{-1} SR), and high (360 kg N ha^{-1} yr^{-1}, 4.2 AU ha^{-1} SR). Across 4 yr, herbage mass (3.42 vs. 2.95 Mg ha^{-1}) and allowance (4.8 vs. 1.4 kg forage kg^{-1} animal weight) were greater for low than high intensity. Herbage accumulation (41 vs. 17 kg ha^{-1} d^{-1}), crude protein (140 vs. 99 g kg^{-1}), and in vitro digestible organic matter (505 vs. 459 g kg^{-1}) were greater for high than low intensity. Heifer average daily gain was greater for low than high intensity (0.34 vs. 0.28 kg), but gain per hectare (GHA) increased from low to high intensity (101 to 252 kg). Nitrogen fertilizer cost per additional kilogram of GHA above low intensity was $0.76 for moderate and $2.01 for high intensity. Increasing management intensity increased bahiagrass herbage accumulation and nutritive value, but GHA did not increase sufficiently to compensate for the additional fertilizer cost, especially for high intensity. Therefore, if land limitations for cattle production become acute, use of more management-responsive species than bahiagrass probably will be required.

Bahiagrass is adapted to a wide range of soil drainage and fertility environments and tolerates heavy grazing. It is the most widely planted warm-season grass in Florida, occupying >1 million ha (Chambliss, 1999), and is important throughout the U.S. Gulf Coast.

During the past 35 yr, the population of Florida has grown from 6.8 to >17 million people and is projected to reach 26 million by the year 2030 (Office of Economic and Demographic Research, 2005). Should this occur, it is likely that land area for agricultural uses will decrease, resulting in declining production of many agricultural commodities.

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In forage–livestock systems, one approach to addressing this problem may be to increase management intensity to achieve greater levels of animal production per unit land area. Management intensity within the context of grass pastures is most often a function of N fertilizer rate, animal SR, and grazing management. Bahiagrass was very responsive to N fertilizer in some studies (Burton et al., 1997; Twidwell et al., 1998), but in other experiments it responded to a lesser extent than other C_4 grasses (Stanley and Rhoads, 2000). These studies measured plant responses only, and there is little information in the literature regarding the effect of increasing management intensity on the performance of animals grazing bahiagrass pasture.

The objectives of this research were to quantify the effect of increasing management intensity on pasture and animal productivity and to assess the feasibility of greater management intensity as an approach to increasing animal production per unit land area. Treatments were chosen to encompass and exceed the range in management intensity currently in use by Florida producers. Management intensity was defined in terms of combinations of N fertilizer rate and SR, and response variables measured were herbage mass, accumulation, allowance, and nutritive value, and yearling beef heifer average daily gain (ADG) and GHA.

MATERIALS AND METHODS

The experiment was performed at the University of Florida Beef Research Unit, northeast of Gainesville at 29°43′ N latitude on Pensacola bahiagrass pastures. Pastures used in the study were well established, had been planted within 2 yr of each other, and were at least 10 yr old at the start of the trial. During this 10-yr period, the pastures were similarly managed, with SR ranging from 1 to 2 AU ha^{-1} and N fertilization from 40 to 100 kg N ha^{-1} yr^{-1}. Soils were classified as Spodosols (sandy, siliceous, hyperthermic Ultic Alaquods from the Pomona series or sandy, siliceous, hyperthermic Aeric Alaquods from the Smyrna series). Average soil pH was 5.9, and Mehlich I soil P, K, Ca, and Mg concentrations at the beginning of the experiment were 5.3, 28, 553, and 98 mg kg^{-1}, respectively.

Treatments and Design

Management intensity was the treatment and it was defined as a combination of N fertilizer rate and animal SR. The three management intensity treatments were low (40 kg N ha^{-1} yr^{-1}, 1.2 AU ha^{-1} target SR), moderate (120 kg N ha^{-1} yr^{-1}, 2.4 AU ha^{-1} target SR), and high (360 kg N ha^{-1} yr^{-1}, 3.6 AU ha^{-1} target SR). The actual SR imposed was calculated based on yearling heifer initial and final live weights during the four

Abbreviations: ADG, average daily gain; AU, animal unit; CP, crude protein; DM, dry matter; GHA, gain per hectare; IVDOM, in vitro digestible organic matter; SR, stocking rate.

grazing seasons (2001–2004). Averaged across years, SR were 1.4, 2.8, and 4.2 AU ha^{-1} for low, moderate, and high management intensities, respectively. These values deviated from the targets because initial heifer live weight was greater than anticipated.

Treatments were arranged in two replicates of a randomized block design. Pasture area was varied to achieve the treatment SR: low, moderate, and high treatment pastures were 1, 0.5, and 0.33 ha, respectively. These management intensities were selected because the low intensity approximates average bahiagrass management in Florida cow–calf systems, the moderate intensity represents the upper range of current practice (Chambliss, 1999), and the high intensity 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 SR for the high intensity were based on data from Burton et al. (1997) and Twidwell et al. (1998), who found that bahiagrass forage production was approximately three times greater for N rates near the highest compared with the lowest used in the current study, thus keeping forage mass and SR nearly in balance across these treatments.

Pasture and Animal Management

Two crossbred (Angus × Brahman) yearling beef heifers with average initial live weights of 327 kg were continuously stocked on treatment pastures during 168 d of the 2002, 2003, and 2004 grazing seasons. In 2001, the grazing period was 112 d because April and May drought (45 mm of rainfall vs. the 30-yr average of 175 mm) delayed the start of the trial. Grazing was initiated in the spring or early summer each year when adequate herbage mass was available to support the livestock (26 June 2001, 22 May 2002, 13 May 2003, and 13 May 2004). Heifers remained on treatment the entire grazing season, and no other animals were added at any time. They were provided free-choice access to water and a trace mineral. Artificial shade (3.1 by 3.1 m) was available on all pastures.

Low management intensity pastures received 40 kg N ha^{-1} in one application in late April each year. It is typical for Florida beef producers operating at approximately this management intensity (i.e., low) to apply all N to grazed bahiagrass during spring because forage is in short supply and the breeding season is in progress. Moderate intensity pastures received 40 kg N ha^{-1} at each of three dates (late April, mid-July, and mid-August), while high intensity pastures received 90 kg N ha^{-1} at each of four dates in 2002, 2003, and 2004 (mid-June in addition to those for moderate intensity) and 90 kg N ha^{-1} at only three dates (not in mid-June) in the drought year of 2001. Phosphorus (17 kg ha^{-1} yr^{-1}) and K (66 kg ha^{-1} yr^{-1}) were applied to all management intensities with the initial N application each year. There was a second application of the same amount of P and K in mid-July 2002 for moderate and high intensities only. This reflects recommended P and K fertilization practices in Florida where amounts of these nutrients applied to grazed bahiagrass pasture are based on the amount of N applied (Chambliss and Kidder, 1999). Micronutrients were applied in April 2003 at a rate of 360 g B, 2.7 kg Fe, 3.6 kg Mn, and 1.4 kg Zn ha^{-1} because Fe deficiency chlorosis was observed on some pastures for a limited time during 2002. Sulfur was also applied in April 2002 at a rate of 30 kg S ha^{-1}.

Pasture and Animal Responses

Pastures were sampled just before initiation of grazing and every 14 d thereafter to measure herbage mass, accumulation, and nutritive value. Herbage mass was determined using a 0.25-m^2 Al disk. The disk was calibrated every 28 d by double sampling 20 sites across the six experimental units (three or four sites per pasture). Sites were chosen such that the range of herbage mass was represented. At each site, disk settling height was measured, after which the herbage was clipped to soil level and dried for 48 h at 60°C to determine actual herbage mass. Actual herbage mass was regressed on disk height to develop a calibration equation. The r^2 values for equations used ranged from 0.75 to 0.94. The equations predicted pasture herbage mass from the average of 30 disk settling height measurements per pasture, taken at randomly selected locations.

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, and they were placed in the pasture at the beginning of each 14-d sampling period. Cage placement sites were chosen where the disk settling height was the same (±1 cm) as that of the pasture average. 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 sampling period, cages were moved to new locations on the pasture that approximated the current pasturewide average disk settling height.

Forage allowance was determined for each pasture during each 28-d period. It was calculated as the average herbage mass (mean across three sampling dates in that 28-d period) divided by the average total heifer live weight during that period (Sollenberger et al., 2005).

Herbage crude protein (CP) and in vitro digestible organic matter (IVDOM) concentrations were measured at initiation of grazing and every 14 d thereafter. Hand-plucked samples were taken from each pasture. The objective of sampling was to represent the diet consumed by the grazing animal, and the technique involved removing the top 5 cm of herbage at approximately 30 sites in each pasture. Herbage was composited across sites within a pasture, dried at 60°C, and ground in a Wiley mill (Model 4 Thomas-Wiley Laboratory Mill, Thomas Scientific, Swedeboro, NJ) to pass a 1-mm screen. The micro-Kjeldahl technique was used to determine N concentration (Gallaher et al., 1975), and the two-stage technique was used for IVDOM (Moore and Mott, 1974).

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. Live-weight GHA was calculated for the entire grazing season.

Statistical Analysis

Pasture data are reported as total-season averages and as 28-d period (monthly) averages. Total-season pasture data are the average of all 14-d sampling intervals during that season, while 28-d period data are averages of the three samples taken during that 28 d (Days 0, 14, and 28). Average daily gain is reported for the total season (final weight minus initial weight) and monthly (gain during a given 28-d period).

Data representing annual totals (GHA) or total-season averages (e.g., herbage mass, accumulation rate, allowance, CP and IVDOM, and heifer ADG) were analyzed using analysis of variance in PROC MIXED of SAS (SAS Institute, 1996). Treatment, year, and their interaction were considered fixed effects and replicate the random effect. Year was considered fixed because of the cumulative effects of treatments in studies involving perennial crops. The 28-d period data were analyzed using repeated measures analysis of variance in PROC MIXED of SAS (SAS Institute, 1996) with treatment, year, and their interaction as fixed effects, replicate as the random effect, and month as the repeated variable. The PDIFF test of the LSMEANS procedure was used to compare management intensity, year, and month means. Differences in herbage responses referred to in the text are significant at $P \leq 0.05$, while for animal responses significance was indicated at $P \leq 0.10$. This was done because of the inherently large variability in animal gain responses and the limited number of replicates that could be used in the study.

RESULTS AND DISCUSSION

For total-season data, there were no interactions of year × management intensity ($P \geq 0.30$). There were year effects ($P < 0.001$) for total-season responses except GHA and herbage accumulation ($P = 0.25$ and 0.36, respectively), but in the absence of year × treatment interaction, data are presented as averages across years. For monthly data, there was management intensity × month interaction for all responses ($P < 0.02$), but there were no interactions with year ($P \geq 0.16$). Thus, management intensity effects are compared by month across years.

Herbage Mass and Herbage Accumulation

Average herbage mass across the grazing season was greater for low than high and moderate intensities ($P < 0.01$, Table 1). Generally, bahiagrass herbage mass is expected to increase with increasing N rate (Burton et al., 1997), but in this experiment greater SR accompanied the greater N rates for moderate and high intensities. Their combined effect on moderate and high management intensities was lower herbage mass.

There was management intensity × month interaction for herbage mass. At the beginning of the grazing season, bahiagrass herbage mass was greater for high than either moderate or low intensity (Fig. 1), probably resulting from the greater N application in April and no grazing on any of the pastures until May (2002–2004) or June (2001). As the season progressed, herbage mass in the high intensity treatment began to decrease while that in low and moderate intensities increased. In June, herbage mass for high intensity was greater than moderate intensity, with low intensity intermediate, while during most of the remainder of the grazing season, mass was greater on low than high intensity pastures, and moderate intensity was intermediate.

As management intensity increased from low to moderate, there was an increase in herbage accumulation rate ($P = 0.02$, Table 1), but there was no difference in herbage accumulation rate between moderate and high intensities. Burton et al. (1997) reported bahiagrass annual dry matter (DM) yields of 6010, 8240, 11900, and 15200 kg ha^{-1} for N rates of 56, 112, 224, and 448 kg N ha^{-1}. In contrast, Stanley and Rhoads (2000) found that bahiagrass was not as responsive to higher rates of N; bahiagrass yielded 26 kg DM kg^{-1} N applied for N rates to 168 kg N ha^{-1} but as N increased from 168 to 336 kg ha^{-1} there was little additional herbage produced.

Herbage accumulation rate on all intensities followed a similar trend throughout the grazing season, with lesser accumulation rates in spring, increasing to a maximum during midsummer, and then decreasing in late summer to early autumn (Fig. 1). As grazing began during late spring and early summer, all treatments had similar accumulation rates, probably because of limited rainfall that was typical of May during this study (average of 30 mm across the 4 yr). As the summer rainy season began in June and continued through August, accumulation rates were greater for high than low intensity pastures. Entering autumn, accumulation rates for high intensity pastures remained greater than that of low intensity pastures, and moderate intensity was not different than either of the other treatments. The greater accumulation rate on high and moderate intensity treatments can be explained by the greater N fertilization, while the lack of difference between high and moderate treatments is similar to earlier work showing no additional bahiagrass yield response above 168 kg N ha^{-1} (Stanley and Rhoads, 2000). The decline in growth rate in late summer to early autumn is typical for bahiagrass in this environment (Sumner et al., 1991). It is probably a response to decreasing day length because temperature and soil moisture generally remain conducive for rapid growth through September (Sinclair et al., 2003).

Nutritive Value

Herbage CP increased as management intensity increased from low to moderate and moderate to high (Table 1). Increasing CP with greater N rates is widely reported for bahiagrass and other C_4 grasses (Burton et al., 1997; Twidwell et al., 1998; da Lima et al., 1999; Hernández Garay et al., 2004; Newman et al., 2006). A lesser response to increased N has been observed for

Table 1. Pasture and animal responses to management intensity of continuously stocked bahiagrass pasture. Data are averages across 4 yr of grazing and two replicates ($n = 8$).

Management intensity	Herbage mass	Herbage accumulation rate	Crude protein	In vitro digestibility	Herbage allowance	Avg. daily gain	Gain ha^{-1}
	Mg ha^{-1}	kg ha^{-1} d^{-1}	g kg^{-1}		kg herbage kg^{-1} heifer live wt.	kg	
Low	3.42 a†	17.4 b	99 a	459 b	4.8 a	0.34 a	101 b
Moderate	2.87 b	38.2 a	113 b	473 b	2.0 b	0.35 a	208 a
High	2.95 b	40.9 a	140 c	505 a	1.4 c	0.28 b	252 a
SE	0.4	4.3	5.6	6.3	0.32	0.04	42

† Means within a column followed by the same letter are not significantly different at the 0.05 probability level for herbage responses and the 0.10 level for animal responses.

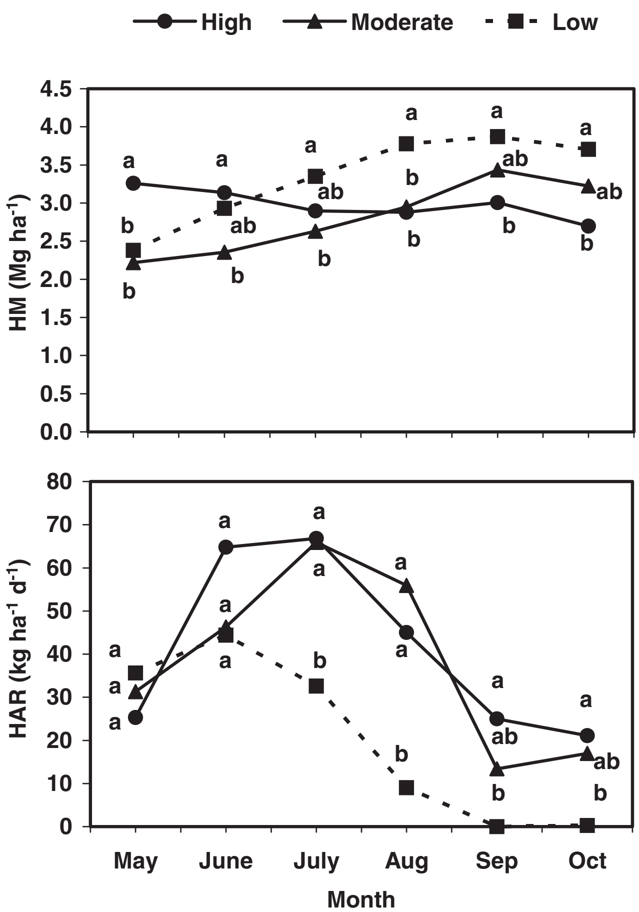

Fig. 1. Effect of management intensity and month on herbage mass (HM, dry matter basis) and herbage accumulation rate (HAR, dry matter basis) of continuously stocked Pensacola bahiagrass pastures during 2001 to 2004. Management intensity means within a month followed by the same letter are not different ($P > 0.05$).

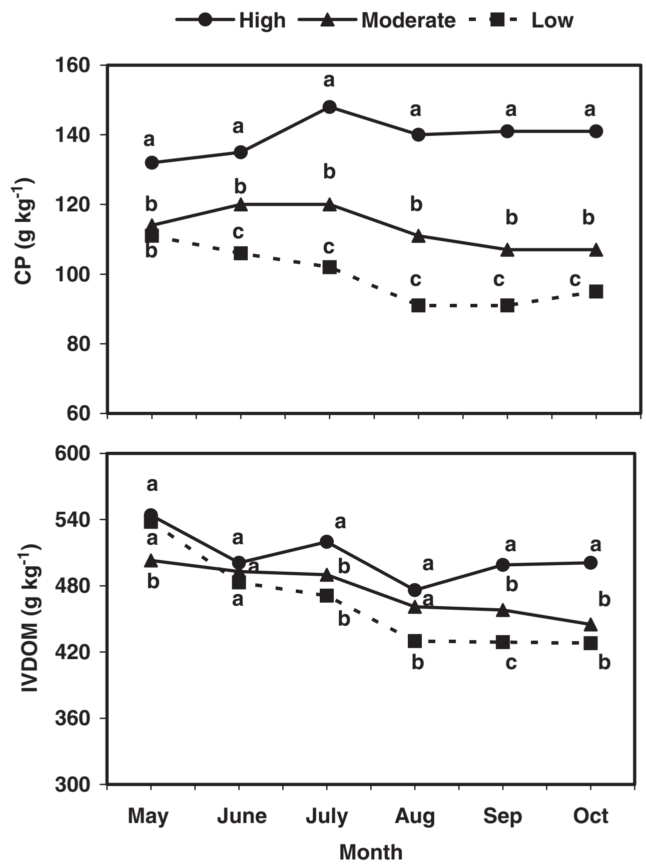

Fig. 2. Effect of management intensity and month on herbage crude protein (CP, in the dry matter) and in vitro digestible organic matter (IVDOM, in the organic matter) concentrations of continuously stocked Pensacola bahiagrass pastures during 2001 to 2004. Management intensity means within a month and followed by the same letter are not different ($P > 0.05$).

bahiagrass forage CP relative to other tropical grasses because of significant N storage in the rhizome and root fractions (Blue et al., 1980). These researchers reported an increase in bahiagrass rhizome and root N of 86 kg ha^{-1} as N rate increased from 0 to 336 kg ha^{-1}, compared with a decrease of 3 kg ha^{-1} for 'Ona' stargrass (*Cynodon nlemfuensis* Vanderyst var. *nlemfuensis*).

There was management intensity × month interaction for herbage CP. In May, herbage CP was greatest for high intensity, while moderate and low intensity CP were similar (Fig. 2). This response was due to the low and moderate treatments having received the same amount of N fertilizer up to that point while the high intensity treatment had received an additional 50 kg ha^{-1}. Throughout the remainder of the grazing season, the treatment ranking for herbage CP was always high > moderate > low. Because of repeated N applications throughout the grazing season, herbage CP in the high and moderate intensity pastures varied less than did the low intensity treatment. Herbage CP in the low intensity pastures decreased about 20 g kg^{-1} from May to August.

In vitro digestible organic matter increased as management intensity increased from low to high ($P < 0.001$, Table 1); however, there were no differences between low and moderate intensities. The response of herbage IVDOM to N rate is not consistent in the literature. There are, however, several recent studies with limpograss [*Hemarthria altissima* (Poir.) Stapf & Hubb; da Lima et al., 1999], stargrass (Hernández Garay et al., 2004), and bahiagrass (Newman et al., 2006) that show a positive response of herbage IVDOM to increasing N rate. In the current experiment, the greater IVDOM for the high management intensity is probably due in part to the greater SR and lesser herbage allowance for that treatment. Greater SR and lesser herbage allowance probably decreased the time period between animal visits to a given grazing patch in the pasture. This would cause the herbage to be less mature and have greater digestibility (Hernández Garay et al., 2004).

Herbage IVDOM was greater for high than for low intensity herbage throughout the grazing season with the exception of June and was greater for high than moderate intensities in July, September, and October (Fig. 2). In most months, herbage IVDOM for the moderate treatment was greater than or equal to the low intensity treatment. Generally, the treatments followed a similar pattern of decreasing IVDOM from May through August, after which IVDOM remained relatively constant. This decrease can be explained in part by high temperatures (Newman et al., 2005) and greater soil moisture (Wilson, 1983) in midsummer than in spring; both factors have been associated with lower herbage digestibility.

Herbage Allowance

Herbage allowance decreased as management intensity increased above low due to decreasing herbage mass and increasing SR. There was management intensity × month interaction for herbage allowance. Allowance on low intensity pastures increased from May to August and remained relatively constant through the end of the grazing season (Fig. 3). Low management intensity herbage allowance was greater than on moderate and high pastures throughout the grazing season. Herbage allowance on the latter two treatments was not different from May through midsummer, after which the moderate treatment increased above the high intensity treatment for the remainder of the season.

Animal Performance

There was a management intensity effect on ADG (P = 0.08), with gains greater for low and moderate intensities

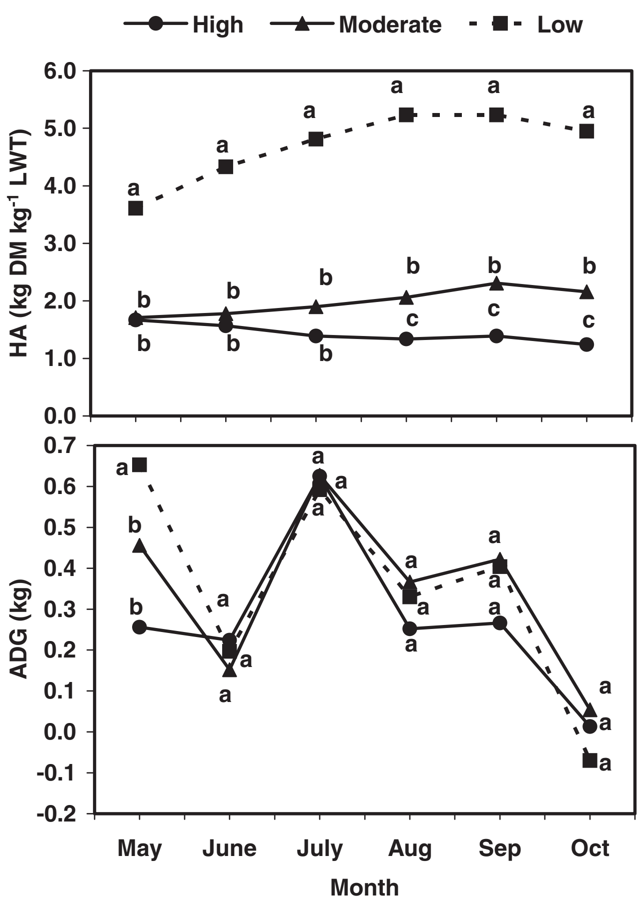

Fig. 3. Effect of management intensity and month on herbage allowance (HA, kg forage dry matter [DM] kg^{-1} animal live weight [LWT]) and heifer average daily gain (ADG) on continuously stocked Pensacola bahiagrass pastures during 2001 to 2004. Management intensity means within a month and followed by the same letter are not different ($P > 0.05$ for HA and $P > 0.10$ for ADG).

than for high (Table 1). The ADG observed in this study was similar to previous reports for bahiagrass in this environment (Sollenberger et al., 1989). Lesser ADG for heifers grazing the high treatment in the current study cannot be explained based on herbage nutritive value because it was greatest for the high treatment. Instead, it appears to be related to quantity of herbage, as herbage allowance was least for the high intensity treatment. Starting with an undergrazed pasture, as herbage allowance decreases, ADG generally remains relatively constant until a breakpoint is reached, after which ADG decreases linearly (Sollenberger et al., 2005). The total-season ADG data from the moderate and high treatments along with total-season herbage allowance responses (Table 1) suggest that for well-fertilized, continuously stocked bahiagrass, the herbage allowance at this breakpoint may be between 1.4 and 2.0 kg forage DM kg^{-1} of animal live weight.

Average daily gain differed ($P < 0.10$) among management intensities only during the late spring when the ADG of heifers on low intensity pasture was greater than for those on moderate and high intensity pastures (Fig. 3). The greater ADG for the low treatment during late spring can be attributed to greater forage allowance and to IVDOM being at its maximum for this management intensity during May. Across the grazing season, all treatments followed a similar trend in ADG, decreasing after May, increasing again in July, and decreasing from July through October.

There was an effect of management intensity (P = 0.04) on GHA; it increased as management intensity increased from the low to moderate treatments, but it was not different between the moderate and high intensities (Table 1). Starting from an underutilized pasture condition, increasing SR increased forage utilization and animal production per unit land area (Mott and Lucas, 1952). Conrad et al. (1981) reported that the increase in production per unit land area can proceed only to a certain SR, after which forage quantity becomes limiting and GHA decreases. Despite the large SR on high intensity pastures, greater N fertilization and forage accumulation rate on these pastures averted the reduction in GHA that might have been expected.

The N fertilizer cost per kilogram of additional GHA above the low treatment was calculated using an average price for NH_4NO_3 during the study of US\$342 Mg^{-1} (does not include the additional cost of P and K applications for the moderate and high intensity treatments during 2002). Gain per hectare increased 107 kg ha^{-1} as management intensity increased from low to moderate at an additional cost of US\$81.67 for N fertilizer. This represents a cost of US\$0.76 of N fertilizer per additional kilogram of GHA above the low intensity treatment. As management intensity increased from low to high, GHA increased 151 kg ha^{-1}. The cost of additional N fertilizer (above the low intensity treatment and accounting for the 270 kg N ha^{-1} rate in 2001) was US\$303.72 ha^{-1} and the cost of N fertilizer per additional kilogram of GHA was US\$2.01. These data suggest that increasing management intensity from low to moderate may increase production enough for producers to benefit; however, increasing management intensity to high is unlikely to be economically viable. In addition, greater SR and N fertilization increase the risk of negative environmental impact.

SUMMARY AND CONCLUSIONS

Greater management intensity resulted in greater herbage accumulation rate, nutritive value, and yearling heifer live weight GHA on continuously stocked bahiagrass pastures. Heifer ADG, pasture herbage mass, and herbage allowance decreased with increasing grazing intensity. Thus, although bahiagrass pastures were responsive to increased management intensity, the limited magnitude of the increase in live weight GHA associated with the high management intensity suggests that large increases in intensity are unlikely to be economical. If the need arises for cattle producers to increase production per unit land area significantly to remain viable, the replacement of bahiagrass with another more management responsive and management demanding species probably will be required.

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