Forage Evaluation and Quality in Florida

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Introduction

Warm-season grasses, also called C4, are the predominant forages for ruminant production in Florida. The C4 grasses grow well under high temperatures and generally cultivated between 25^o N and 25^o S of the equator. The C4 grasses are more efficient in fixing carbon dioxide than other grasses; however, they have a specialized thick-walled parenchyma bundle sheath around each vascular bundle, and much smaller proportion of more compact thin-walled mesophyll tissue than C3 grasses (Wilson, 1993). These anatomical characteristics results in plants with less concentration of crude protein (CP) and soluble carbohydrates, and greater concentrations of cell wall components such as cellulose and hemicelluloses than C3 grasses. The importance of the nutritional value of forages can have different implications depending on the production systems. For confined animals with greater concentrate supplementation, forage has been used as a source of fiber to maintain rumen activity, while for grazing animals forages may represent the only source of nutrients in the diet. The validity of a particular nutritive value entity is highly dependable on the forage use. Several methods to estimate nutritive value and quality of warm-season grasses have been published in the literature and the objectives of this paper are to: 1) describe the C4 forage species and cultivars used in Florida, and 2) discuss the methods used to estimate nutritive value of C4 plants.

C4 forages species and cultivars used in Florida

Grasslands cover about 4.5 million hectares (ha) in Florida. Depending on soil type and climatic conditions, different C4 grasses species and cultivars are adapted to the various regions of the State. South Florida has warmer winter and poorly drained soils, whereas North Florida has better drained soils with more frequent freezing events during the winter. Bahiagrass (*Paspalum notatum* Flügge) is the most planted forage in Florida because of its adaptability to low-input systems and persistence under grazing; however, it has limited use as conserved forage because of its limited productivity and nutritive value.

According to the number of forage samples submitted to the Forage Extension Laboratory in Ona, Bermudagrass (*Cynodon dactylon* L.) is the most used forage for hay, haylage, and silage in Florida. The number of Bermudagrass samples received by the laboratory in 2008 and 2009 is three fold greater than any other C4 grass species. Bermudagrasses are more adapted to regions with well-drained soils (North Florida)

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and the most planted cultivars are Coastal and Tifton 85. However, Jiggs Bermudagrass is a cultivar with greater tolerance to poorly drained soils and have been extensively used in South Florida.

Stargrass (*Cynodon nlemfuensis* Vanderyst), Limpograss [*Hemarthria altissima* (Poir.) Stapf & C.E. Hubb.], and Mulato (*Brachiaria* sp.) are important C4 forage species used for grazing and conserved forage in South Florida, but they have limited use in northern regions of the State, primarily because of limited cold tolerance.

Nutritive value of C4 grasses

The nutritive value of C4 grasses can be excellent early in the growing season, but because their rapid growth and maturity, nutritive value can decrease significantly as the growing season progresses (Coleman et al., 2004). The C4 mechanism of photosynthesis allows high CO_2 fixation at relatively low leaf-N concentrations and low concentrations of rubisco (Moore et al., 2004), which results in plants with smaller CP concentrations than C3 species. Averaged across a large number of species, CP concentrations of C4 forage grasses ranged from 4 to 6 % less than that of C3 species and the occurrence of CP deficiency in livestock fed C4 grasses was greater (Minson, 1990). In addition, high temperatures at which C4 plants typically grow also promote lignification and reduce plant tissue and cell wall degradability.

Morphology, growth habit, herbage accumulation, and nutritive value vary widely among C4 grasses. Vendramini et al. (2010) compared herbage accumulation and nutritive value of nine species of warm-season grasses in South Florida and found difference among species and cultivars of the same species (Table 1). Several factors may contribute to the difference in nutritive value in C4 grasses, including species, cultivars within species, maturity, fertilization, conservation practices, etc.

The difference in nutritive value of C4 grasses species is primarily result of differences in anatomy and morphology of the plants. Flores et al. (1993) compared the anatomy of Bahiagrass and Mott Elephantgrass leaf blades and observed that Mott had thicker epidermis and smaller sclerenkyma proportions in the leaf blades. Thus, the leaf epidermis of Mott was more digestible than Bahiagrass. Differences in nutritive value of cultivars within the Bermudagrass species are also evident. Hill et al. (2002) reported that increased digestibility of organic matter, acid detergent (ADF) and neutral detergent (NDF) fiber of Tifton 85 compared with Coastal Bermudagrass hay should determine cultivar priority for enhanced animal performance. Vendramini et al. (2010) observed greater NDF digestibility and in vitro true digestibility (IVTD) of Tifton 85 compared with Florakirk, Coastcross II, and Jiggs in South Florida (Table 1). According to Hill et al. (2001), Tifton 85 has lower concentrations of ether-linked ferulic acid in the cell wall than other Bermudagrass cultivars and this explains the greater NDFD and IVTD of Tifton 85.

Another difference among forage types is that C4 grasses often exhibit greater bulk density in the lower strata of the canopy compared to the upper section (Coleman et al., 2004). Holderbaum et al. (1992) observed that total bulk density of the bottom half of the Limpograsss canopy was over twice that of the top half. However, total and leaf CP and in vitro digestible organic matter (IVDOM) concentrations were greater in the top strata. Conversely, Newman et al. (2002) studying limpograss pastures grazed at three grazing heights, 20, 40, and 60 cm observed that taller canopies had less total bulk density and there was a quadratic response in CP and IVDOM concentrations from 20 to 60 cm grazing heights. In addition, there was linear decrease in average daily gain (ADG) of heifers grazing the 20 to 60 cm grazing heights.

In general, the quality of C4 grasses declines with maturity. The decrease in leaf:stem ratio caused by the onset of reproductive stems elongation often decreases nutritive value. Burn et al., (1997) indicated that the proportion of NDF increased, whereas the digestibility of Switchgrass (*Panicum virgatum* L.) declined markedly during the 28-d period in which plants advanced from vegetative culm elongation to nearly early boot stage. However, the rate of decline in nutritive value at various maturities is highly variable among species. Sollenberger et al. (1988) used steers to graze ‘Pensacola’ Bahiagrass and ‘Floralta’ Limpograss pastures during the summer and early-fall. At all sampling dates, IVDOM of Limpograss pasture (whole plant samples) was approximately 10 units greater than that of Bahiagrass pasture.

Fertilization is another management factor that may impact nutritive value of C4 grasses; however, fertilization has shown no consistent effects on C4 grasses digestibility. Vendramini et al. (2008) observed linear increase in IVDOM concentrations of Tifton 85 with increasing N fertilization levels from 0 to 80 kg/ha. The appearance of new tissues and probable decreased senescence were the probable causes for the increase in IVDOM concentrations. Conversely, Minson (1990) observed no consistent pattern in digestibility of a wide range of grasses due to N fertilization. Despite of the conflicting reports relative to the effect of N fertilization on C4 forages digestibility, N fertilization often results in greater forage CP concentrations (Vendramini et. al., 2008; Stewart Jr. et al., 2007; Lima et al., 1999).

Methods to estimate digestibility of C4 grasses

Forage nutritive value is determined according to the nutrient concentration, nutrient digestibility, and nature of the digestion of the end products (Moot an Moore, 1970). Nutritive value should refer to inherent characteristics of consumed forage, which determine its energy concentration.

The differences in C4 grasses along with the effects of management practices makes difficult to accurately estimate energy concentration in C4 plants. Cell walls (NDF) and their derivatives (ADF) have been used either alone or with other chemical entities, to predict both intake and digestibility (Moore et al, 1996). Van Soest (1967) developed the NDF analysis to estimate total cell wall and showed that cell wall contents met the criteria of a nutritive entity, but NDF did not because its highly variable digestibility (Moore, 1994). In addition, Van Soest (1967) proposed a summative equation for predicting digestible DM concentration of forages. Digestible NDF was determined from NDF concentration and the empirical prediction of NDF digestibility from ADF and lignin. Duble et al. (1971) found that the summative equation of Van Soest (1967) was not acceptable for tropical grasses.

Acid detergent fiber is used most frequently by U.S. feed testing laboratories to estimate digestibility. Reported coefficients of correlation (r) between concentrations of ADF and digestibility of OM and DM varied between -0.5 to -0.95 (Minson, 1982). According to Moore et al. (1999), published r values have ranged from -0.39 and -0.93 between digestible dry matter (DDM) and ADF. Greater coefficients of correlation between ADF and digestibility are generally found in cool-season forages or total mixed rations (TMR) but not in C4 grasses (Table 2). According to Moore et al. (1999), routine forage testing programs only using ADF and NDF may often provides unacceptable of DM intake (DMI) and DDM, for both grasses and legumes. Several laboratories in the country developed their own equations to convert ADF in digestible dry matter; however, the results cannot be consistent. The DDM concentration of Stargrass and Mulato samples with known in vivo apparent DM digestibility (51 and 64%, respectively) were calculated based on its ADF concentration using equations from different commercial laboratories. There was a large variation in the estimated DDM between laboratories (Table 3).

There is a consensus in the scientific community that no other single laboratory technique predicts digestibility as effective as the in vitro procedure. The in vitro procedure is widely used because it measures two nutritive entities: cell contents and digestible cell walls. The in vitro procedure has large capability and it is considered a precise method. The major advance in the in vitro technique came from the two-stage procedure proposed by Tilley and Terry (1963), and the method had many derivations since then. Many studies have shown a strong correlation between in vivo and in vitro digestibility data (Weiss, 1994) when ruminants were fed all forage diets. However, when using the in vitro technique it is still necessary to develop a calibration equation to convert IVDMD to in vivo digestibility. The equations present in the literature should not be directly used by commercial laboratories because of many factors may affect the relationship between IVDMD and in vivo digestibility. Instead, each laboratory should generate its own equation. To maintain the consistency of the results and ensure quality control, internal standards should be included in each run. Ayres (1991) stated that when the IVDMD of the standard is outside 95% confidence interval, the run can be corrected based on the deviation of the standards.

The main source of variation in the in vitro procedure is the rumen fluid collected from the donor animal; therefore, it is not realistic to expect similar results from in vitro analysis conducted by different laboratories because of the variation in the diets of the donor animal. Nelson et al. (1972) reported that when Bermudagrass was fed to donor animals, IVDMD values for a variety of forages were higher than when perennial Ryegrass was fed; but when another warm-season grass (Bahiagrass) was fed, the IVDMD values were less than when perennial Ryegrass as fed. The laboratory needs to identify the type of samples that will be analyzed and adapt the diet of the donor animal, but no single donor diet will produce accurate results for all possible test forages (Weiss 1994).

Neutral detergent fiber digestibility (NDFD) represents another predictor of forage digestibility that has been used for research purposes and routine forage analysis. Vendramini et al. (2010) noted a correlation of NDFD and IVTD in nine species and cultivars of warm-season grasses (r = 0.88). Mertens (2009) proposed that DMD = 85.1 – (0.98 – NDFD) x NDF for animals receiving TMR. Reported NDFD values are only relevant within procedures, and even then, have questionable relationship to animal models (Ward, 2009). There are no standard procedures for NDF or NDFD, which results in a large variation in values reported by commercial laboratories.

The near infrared spectroscopy (NIRS) system has been used widely to provide estimates of CP, ADF, NDF, and in vitro digestion. Norris et al., (1976) demonstrated that NIRS could also be used to estimate animal intake. The differences among C4 grasses species and cultivars, in addition to the effects of management practices on forage nutritive value, pose a challenge for commercial laboratories to develop calibration equations that can provide accurate results for a wide range of C4 grasses under different management. Brown and Moore (1987) developed NIRS calibration equations to determine IVDOM concentration for C4 grasses in different studies. In addition, the authors developed a general equation containing the pool of information from the specific studies. The validation results from the general IVDOM equation were not as acceptable as those from equations developed for each experiment.

C4 grass quality

Mott (1959) suggested that differences in forage quality are expressed in animal performance (weight gain, milk production, wool production, or work) under the conditions that 1) animals used to compare forage have potential for production and are uniform among treatments, 2) forages are available in quantities adequate for maximum intake, and 3) no supplemental energy and protein are provided. According to Moore (1994), the major limitation to practical application of forage quality information is the lack of uniform quantitative definition or expression of forage quality.

Forage quality is a function of nutritive value and intake. According to Mertens (2009) forage quality is affected by intake (50 to 70%), digestibility (24 to 40%) and metabolism (5 to 15%). A predictor of forage quality is a quality-related characteristic of forage, which can be measured by traditional laboratory analyses (Moore, 1994).

Mertens (1987) proposed that daily NDF intake was 1.2% of body weight (BW) per day in diets that produced maximum daily 4% fat-corrected milk. However, this concept is limited because NDF is a poor predictor of intake across many forage types, particularly C4 perennial grasses (Moore and Undersander, 2002). Moore et al. (1999) demonstrate that DM intake is not well correlated (r^2 = 0.30) with the NDF concentration across a variety of forages (Fig 1). Because of the complexity associated with forage composition, structure, and degradation, and voluntary intake control, it is unrealistic to expect that one single measurement of nutritive value will be a universal predictor of intake (Moore, 1994).

Intake prediction equations that include a measure of digestibility may have potential to provide more acceptable predictions than chemical analyses alone. Neutral detergent fiber digestibility has been used as an index of DMI by lactating cows. Cows fed diets based on forages with lower NDFD usually have lower DMI than cows fed forages with higher NDFD. However, this relationship has only been shown to exist when comparisons are made within the same forage type (Weiss, 2009). Oba and Allen (1999) concluded that one-unit increase in NDF digestibility in vitro or in situ was associated with a 0.17-kg increase in DMI and a 0.25-kg increase in 4% fat-corrected milk. These authors concluded that enhanced NDF digestibility of forage improves DMI and milk yield of dairy cows and digestibility of NDF should be measured more routinely to assess forage quality.

However, most of the research using measurements of forage nutritive value to predict intake have been conducted using confined animals that received great proportions of concentrate in the diet. Considering forage quality for ruminants grazing C4 grasses, several factors may affect intake.

The vertical heterogeneity in sward canopy structure and composition and the amount and accessibility of leaf are major canopy characteristics associated with intake. Green herbage mass or green leaf proportion in grazed horizon usually shows positive relationship with bite weight and intake is a function of bite weight and bite rate (Table 4). Leaf density, plant-part composition and nutritive value of the upper canopy are also important to explain the variations in intake. In addition to the the plant intrinsic characteristics, animal and environmental factors may affect intake.

Hernandes-Garay et al. (2002) showed a quadratic relationship between ADG of steers grazing Stargrass pastures and herbage allowance (Figure 2). Increasing average herbage allowance up to approximately 4 kg DM/kg of animal BW resulted in a linear increase in ADG, but as average herbage allowance increased above 4, the rate of increase in ADG slowed. It is well understood that greater herbage availability allows ruminants to maximize intake and intake is the main factor affecting forage quality. However, nutritive value also may impact forage quality. Duble et al. (1971) tested different cultivars of Bermudagrass and concluded that IVDMD explained 56% of the variation in ADG. Sollenberger and Vanzant (2009) stated that forage nutritive value may explain more than 50% of the variation in ADG but only when forage quantity is not limiting. The same authors used meta-analysis to explain the effects of herbage mass and nutritive value on animal performance grazing warm-season pastures. They observed that increasing stocking rate (decreasing herbage mass) had a greater negative impact on ADG of cattle grazing forage with greater nutritive value, but the main factor affecting ADG was herbage quantity. Inyang et al. (2010) found that on heifers grazing Bahiagrass and Mulato pastures, ADG increased with increasing herbage allowance up to 1.4 kg DM/kg of BW, and remained constant at ADG of approximately 0.28 kg/d when herbage allowance was above 1.4 kg DM/kg of BW

(Figure 3). The close relationship between herbage allowance and ADG supports the hypothesis that the major factor affecting gains at high stocking rate was herbage quantity. However, average herbage nutritive value of Mulato was approximately 64% IVDOM and 14% CP and it was expected that heifers would have greater ADG at greater herbage allowance levels. The environmental conditions during the summer in South Florida such as frequent rainfall and flooding conditions impacted grazing time thereby reducing DM intake (Butris and Phillips, 1987). Therefore, environmental conditions may impact forage intake and consequently forage quality in tropical and subtropical areas.

Conclusions

Warm-season grasses are the predominant forages for livestock in Florida. Warm-season grasses differ significantly in nutritive value among species and even among cultivars of the same species. There is relatively limited information on nutritive value and quality of warm-season forage species primarily because of the restricted significance of those for the US ruminant production. Most of the predictors of digestibility and intake used for TMR and cool-season forages have not been accurate to determine those parameters in C4 grasses. The in vitro procedure has been the most accepted procedure to determine digestibility of C4 grasses. Forage quantity and nutritive value are the main factors influencing C4 grasses quality, however, additional variables, such as temperature, humidity, canopy structure, and management practices may affect C4 forage quality in subtropical areas.

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Table 1. Herbage accumulation and nutritive value of warm-season grasses harvested in the summer in South FL

	Forage										
Response Variable[1]	Elephantgrass	Bahiagrass	Stargrass	Mulato	Limpograss	Jiggs	Coastcross 2	Tifton 85	Florakirk	*P* value	SE
HA, kg/ha	13,050[a2]	2,600[d]	3,670[c]	3,200[c]	3,870[c]	4,600[b]	3,090[c]	2,970[c]	3,800[c]	0.04	400
CP, %	9.6	14.9	12.0	12.6	12.5	11.6	12.9	10.2	11.6	0.24	1.9
ADF, %	45.2	37.3	40.5	39.1	36.3	40.5	37.8	27.0	40.1	0.33	4.6
NDF, %	68.8	63.6	71.7	63.2	65.7	72.2	67.5	58.0	71.4	0.65	6.2
IVTD, %	59.1[b]	56.3[b]	61.7[ab]	67.0[a]	60.1[b]	58.4[b]	63.2[a]	63.9[a]	58.0[b]	0.03	2.2
NDFD, %	46.1[c]	53.2[b]	50.0[b]	52.9[b]	44.1[c]	43.3[c]	50.8[b]	57.0[a]	45.2[c]	0.02	1.7

[1] HA = herbage accumulation; CP = crude protein; ADF = acid detergent fiber; NDF = neutral detergent fiber; IVTD = in vitro true digestibility; NDFD = neutral detergent fiber digestibility.

[2] Means followed by the same letter within rows are not different ($P > 0.05$).

Table 2. Correlation between digestibility and ADF

Source	Forage	r
Van Soest, 1965	Alfalfa (11)	-0.74
	C3 Grass (9 to 20)	-0.73, -0.74
	All (83)	-0.74
Van Soest et al., 1978	Diverse (187)	-0.75
Moore et al., 1998	C4 grasses	-0.39

Adapted from Moore et al. (1996).

Table 3. Apparent dry matter digestibility of Stargrass and Mulato samples compared with the estimated digestible dry matter (DDM) calculated from ADF concentration obtained by different commercial laboratories (Lab)

Forage species			Lab 1†	Lab 2	Lab 3	Lab 4	Lab 5	Lab 6	NFTA
	ADF	Apparent DDM				Estimate DDM			
	%	%				%			
Stargrass	45.0	51.0	44.2	48.6	53.8	51.2	56.7	48.6	53.8
Mulato	39.0	64.0	53.5	53.1	58.5	58.1	61.5	53.1	58.5

† Lab 1 = (6.107 + 3.994 * ADF - 0.066 * ADF * ADF) - 8
Lab 2 = 82.38 - (0.7515*ADF)
Lab 3 = 88.9 - (0.779*ADF)
Lab 4 = 4.898 + (89.796 * (1.0876 - (0.0127 * ADF)))
Lab 5 = 34.9 + (53.1 * (1.085 - (0.015 * ADF)))
Lab 6 = 82.38 - 0.7515 * ADF
National forage testing association (NFTA) = 88.9 - 0.779 * ADF

Table 4. Correlation between canopy attribute and intake

Canopy attribute	*Brachiaria* sp.	*Panicum maximum*
	r	
Green HM	0.55-0.61	0.64
Leaf mass	0.51-0.59	0.60
Leaf %	0.46-0.65	---

Euclides et al., 1993 and 2000.

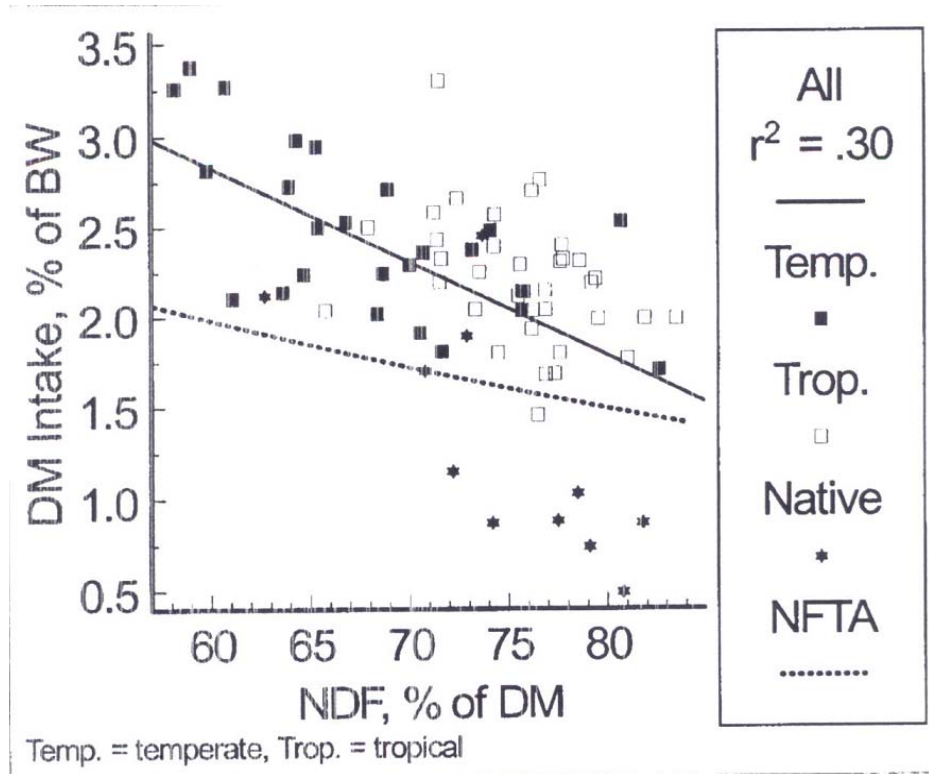

Figure 1. Observed DM intake vs. NDF concentration for 73 grass hays, and NFTA estimates of DM intake (Moore et al., 1999)

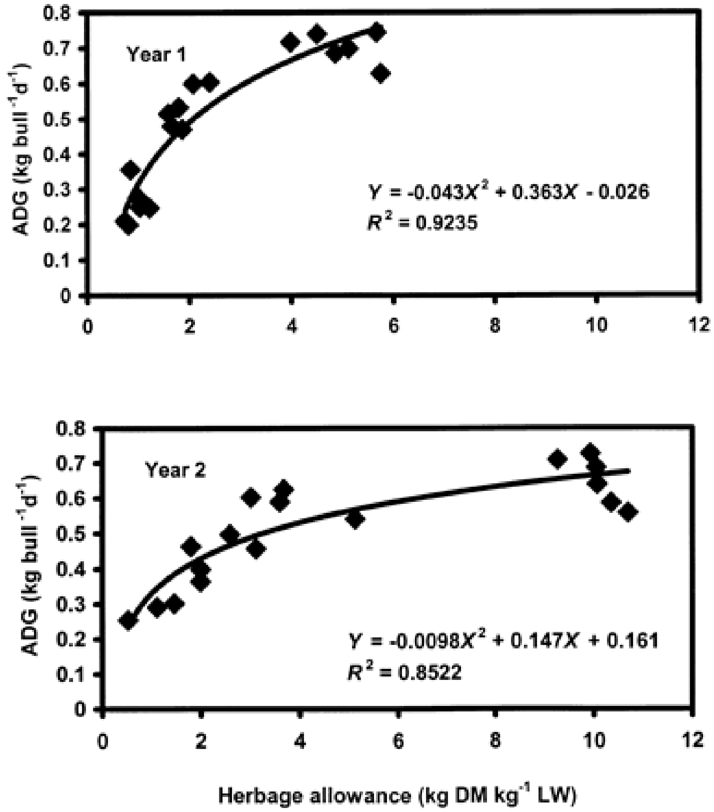

Figure 2. Weanling bull average daily gain (ADG) response to average herbage allowance on Stargrass pastures (Hernadez-Garay et al., 2004).

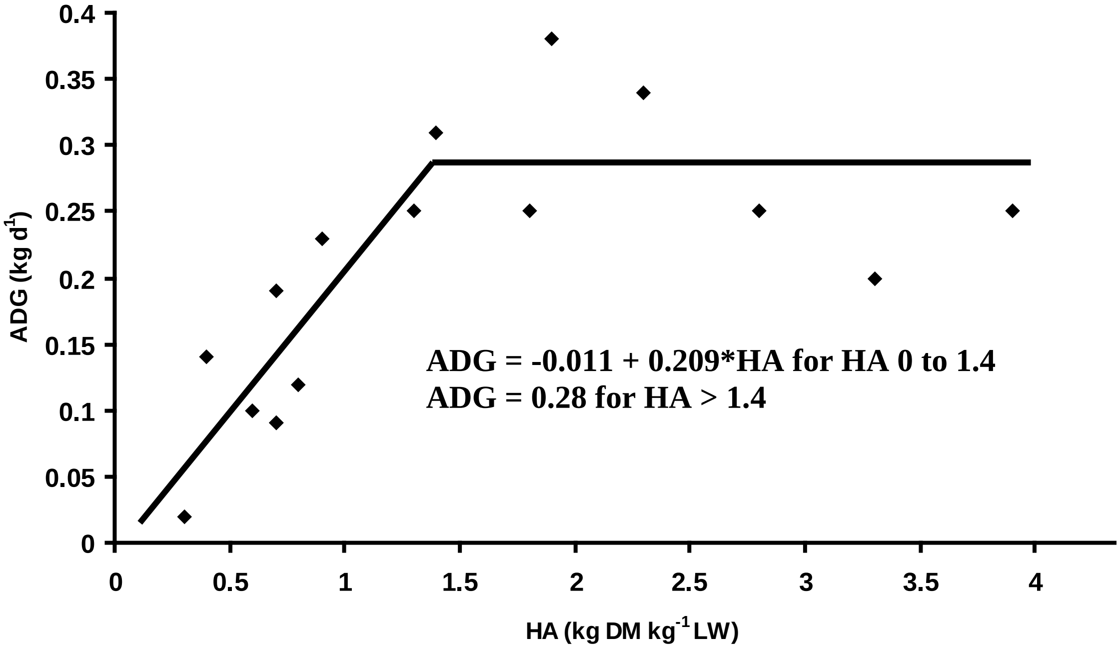

Figure 3. Nonlinear correlation between herbage allowance (HA; kg dry matter/kg of liveweight) and average daily gain (ADG) for Mulato and Bahiagrass pastures stocked at 4, 8, and 12 heifers ha^{-1}.

SESSION NOTES