Pasture Management: Quantity and Quality

Joao Vendramini

Introduction

Warm-season grasses, also called C4, are the predominant forages for ruminant production in the tropics. The C4 grasses grow well under high temperatures and in general occurs between 25^{o} N and 25^{o} S of the equator. The C4 grasses has a more efficient fixation of 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 in C3 grasses (Wilson, 1993). In general, C4 grasses have greater annual herbage accumulation than C3 grasses in the tropics and subtropics, however, lesser concentration of CP and soluble carbohydrates, and greater concentrations of cell wall components such as cellulose and hemicelluloses.

A grazing system is defined as an integrated combination of the soil, plant, and animal, and other environmental components by which the system is managed to achieve specific results (Burns et al., 2004). There is no hierarch of importance among those components and synergism or antagonism may alter the outcomes of the grazing system. Although the concept of grazing system is employed across both the humid and semi-arid regions of the world, sustainable grazing management strategies are site-specific and differ widely among regions (Burns et al., 2004). Regardless of the geographical location, the overall objectives of the grazing management are the optimization of the forage use efficiency, persistence of the desired species, and achievement of acceptable levels of production per animal and per unit of land. These outcomes must be accomplished while providing economic return and maintaining environmental quality (Sollenberger and Newman, 2007).

Grazing management can be defined as the manipulation of livestock grazing to accomplish a desired result. The desired result depends upon the enterprise, but for most producers economic goals are of primary importance. Decisions regarding what grazing management to use are based on the characteristics of the forage being grazed, animal requirements, input costs associated with adopting a particular system, and the probability of return on investment. Grazing management is a powerful tool that strongly influences pasture and animal performance. Choice of grazing management affects pasture yield, nutritive value, and stand longevity. Choice of grazing management also affects weight gain or milk production of an individual animal as well as the amount of milk or meat produced per acre.

In order to implement an effective grazing management program, there are a number of important issues of which we should be aware. These include a) what is required for plants and animals to be productive in a pasture-livestock system, b) what management choices have the greatest impact on success or failure of a grazing system, and c) how can the nutritional requirements of the animal be matched with the ability of the pasture to supply nutrients.

According to Mertens (2009), animal performance, which is a product of forage quality, is affected by intake (50 - 70%), digestibility (24 - 40%) and metabolism (5 – 15%). 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 are many times 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 objective of this review is to describe some factors involved in grazing management and the effects of forage quantity and nutritive value on animal performance.

Herbage Quantity

In recent literature review, Sollenberger and Vanzant (2011) found that forage mass decreased with grazing intensity in 29 of 31 (94%) studies in which it was reported and in most cases, the response of increasing SR or decreasing sward height was linear. Burns et al. (1989)

concluded that the predictable and highly significant relationship of individual animal performance with grazing intensity is due to the profound effect of grazing intensity on forage mass and allowance. The forage mass at which quantity no longer affects ADG will differ for different forages (Guerrero et al. 1984), but will likely occur when animals have opportunity for selection and ad libitum intake (Sollenberger and Vanzant, 2011).

Stocking rate is one of the most important grazing management decisions, and it is defined as the amount of land allotted to each animal during the grazing season. Increasing stocking rates tend to decrease herbage allowance and may limit herbage quantity and intake. Hernandes-Garay et al. (2004) showed a quadratic relationship between ADG of steers grazing stargrass pastures and herbage allowance (Fig. 1).

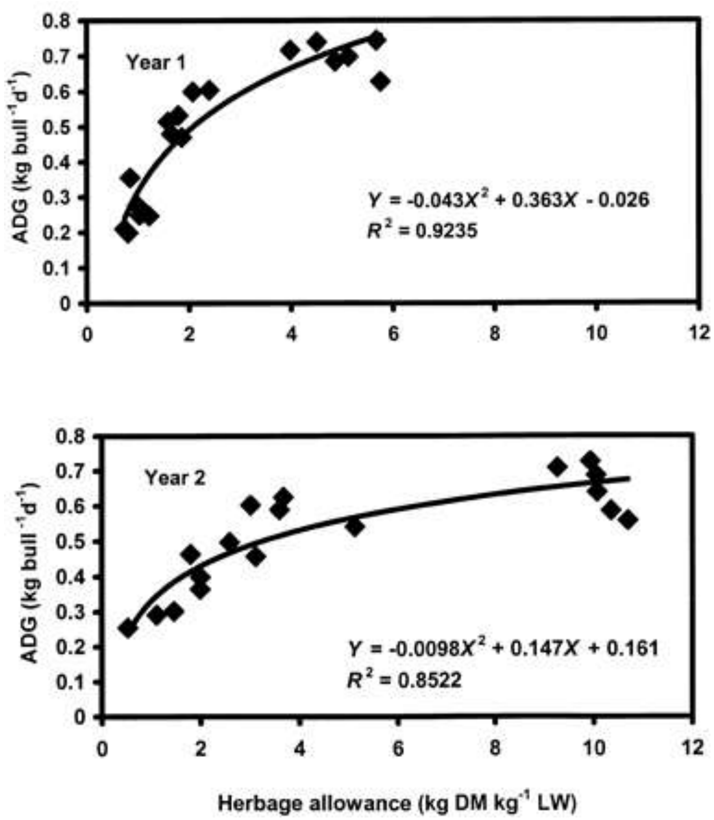

Figure 1. Weanling bull average daily gain (ADG) response to average herbage allowance on stargrass pastures (Hernadez-Garay et al., 2004)

Increasing average herbage allowance up to ≈4 kg DM/kg of animal live weight resulted in a linear increase in ADG, but as average herbage allowance increased above 4 kg DM/kg, the rate of increase in ADG was reduced. In Florida, Inyang et al. (2010) investigated the interaction between herbage accumulation and animal performance of beef heifers grazing bahiagrass and 'Mulato' brachiariagrass (*Brachiaria* sp.) at 3 stocking rates, 4, 8, and 12 heifers (350 kg LW)/ha. The intermediate stocking rates (8 heifers/ha), resulted in the greatest gain per ha and herbage accumulation rates (Fig 2). The adjustment in stocking rates results in changes in grazing height, which impacts the sward structure and plant responses. In addition, there was no effect of increasing herbage allowance above 1.4 kg DM/kg LW on ADG of the heifers (Fig.3).

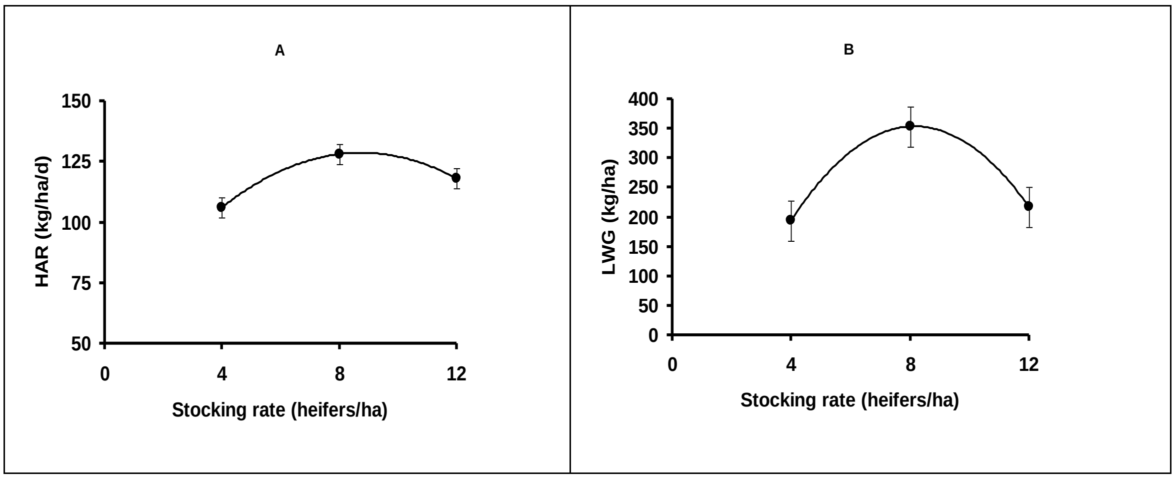

Figure 2. Herbage accumulation rate (A) and gain per ha of heifers grazing bahiagrass and Mulato brachiariagrass at 3 stocking rates, 4, 8, and 12 heifers/ha.

Inyang et al. (2010)

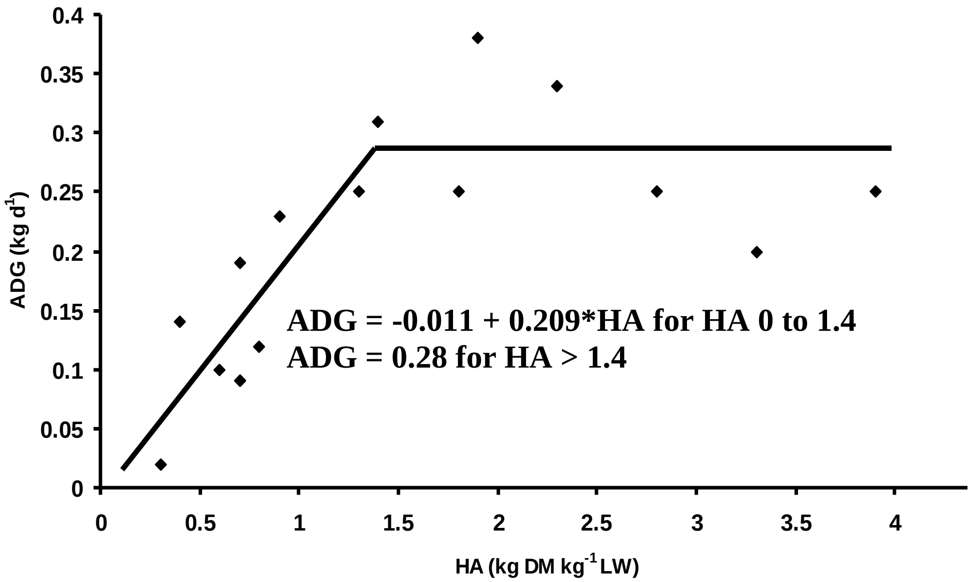

Figure 3. Nonlinear correlation between herbage allowance (HA; kg dry matter/kg liveweight) and average daily gain (ADG) for Mulato and bahiagrass pastures stocked at 4, 8, and 12 heifers ha^{-1}.

Difante et al. (2010) tested the effects of two stubble heights (25 and 50 cm) on herbage mass accumulation and performance of steers grazing ‘Tanzania’ guineagrass (*Panicum maximum* Jacq.). Stubble height of 50 cm resulted in greater herbage accumulation rates and ADG. Conversely, the shorter stubble height resulted in greater stocking rates. According to Coleman and Sollenberger (2007), bite weight and herbage intake increase linearly with sward surface height and herbage mass, but the results of those variables in animal performance are inconsistent.

Besides herbage quantity, the vertical heterogeneity of the sward canopy structure, composition, and accessibility of leaf are major canopy characteristics affecting intake of ruminants grazing warm-season forages. Green herbage mass or green leaf proportion in grazed horizon has shown positive correlation with bite weight, which may also affect intake. Leaf density, plant-part composition and nutritive value of the upper canopy are also important characteristics that affect forage intake. Euclides et al. (1993) observed a positive correlation between green leaf herbage mass, leaf area %, and animal intake (Table 1).

Table 1. 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

Herbage Nutritive Value

The nutritive value of C4 grasses can be excellent early in the growing season, but they grow and mature rapidly, decreasing the nutritive value (Coleman et al., 2004). The C4 mechanism allows high CO_2 fixation at relatively low leaf-N concentrations and with lower concentrations of Rubisco (Moore et al., 1994), which results in plants with decreased CP concentrations. Across a large number of species, CP concentrations of C4 forage grasses averaged 4-6 % less than that of C3 species and the occurrence of CP deficiency among livestock feed C4 grasses was much greater (Minson, 1990). Additionally, the higher temperatures at which C4 plants grow increase lignification and reduce 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 2). There are several factors contributing to the difference in nutritive value in C4 grasses, such as species, cultivars within species, maturity, fertilization, conservation practices, etc.

Table 2. Below

The difference in nutritive value of C4 grasses species is primarily result of differences in anatomy and morphology among the plants. Flores et al. (1993) compared the anatomy of bahiagrass and Mott Elephantgrass leaf blades and Mott had thicker epidermis and smaller sclerenkyma proportions in the leaf blades. Consequently, the leaf epidermis of Mott was more digestible. There is especially evident difference in nutritive value of cultivars within the bermudagrass species. Hill et al. (2001) reported that increased digestibility of organic matter, ADF, NDF of Tifton 85 compared to 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 to 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 canopies often have a greater bulk density in the lower than in the upper strata of the canopy (Coleman et al., 2004). Holderbaum et al. (1992) observed that total bulk density of the bottom half of a limpograsss canopy was over twice that of the top half. However, total and leaf CP and in vitro digestible organic matter (IVDOM) concentrations were all greater in the top strata. Conversely, Newman et al. (2002) studied limpograss pastures grazed at three grazing heights, 20, 40, and 60 cm. 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 ADG of heifers grazing the 20 to 60 cm grazing heights.

In general, quality of C4 declines with maturity. The decrease in leaf:stem ratio caused by the onset of reproductive stems elongation decreasing nutritive value. Burn et al., (1997) noted 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 inconsistent 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).

Herbage 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 - 70%), digestibility (24 - 40%) and metabolism (5 – 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% 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 = .30) to NDF concentration across a variety of forages (Fig. 4). Because of the complexities of forage composition, structure, and degradation, and of voluntary intake control, it is unrealistic to expect that one single measurement of nutritive value will be a universal predictor of intake (Moore, 1994).

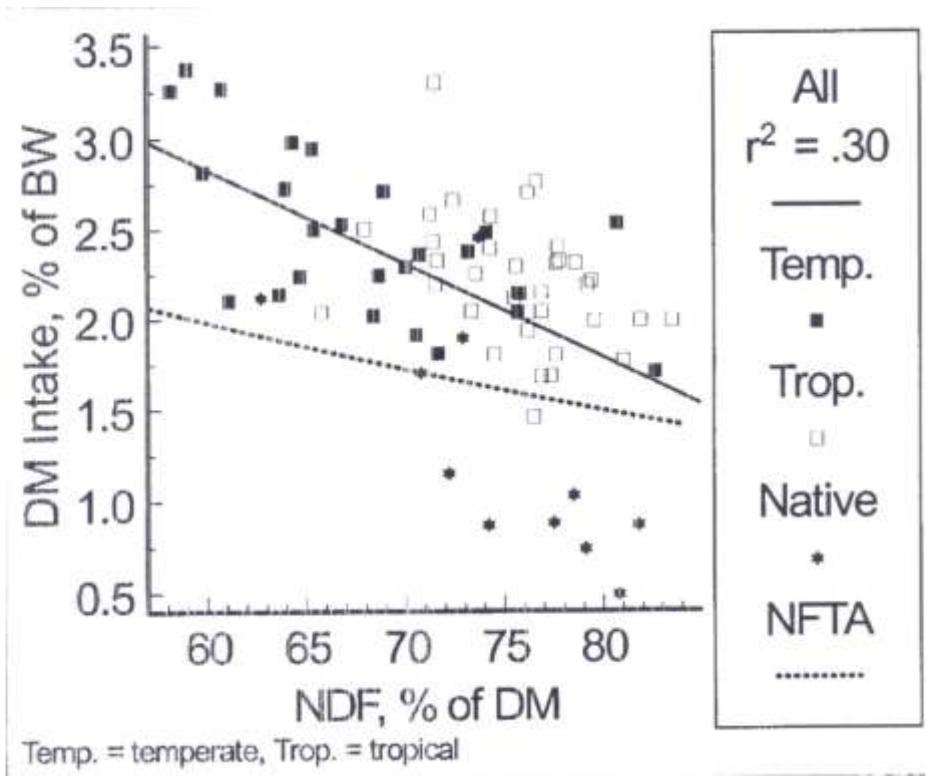

Figure 4. Observed DM intake vs. NDF concentration for 73 grass hays, and NFTA estimates of DM intake (Moore et al., 1999)

Intake predictions 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 forage type (Weiss, 1994). 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 with confined animals receiving greater proportions of concentrate in the diet. Considering forage quality for ruminants grazing C4 grasses, several factors may affect intake.

The interaction of effects of herbage quantity and nutritive value on animal performance was described by Duble et al. (1971) and Guerrero et al. (1984). According to these authors, the in vitro digestible dry matter concentration on the forage sets the upper limit on individual animal performance. In addition, these studies show that NVAL determines the forage mass at which the ADG plateau, with forages with greater digestibility requiring less forage quantity to reach maximum ADG (Fig. 5)

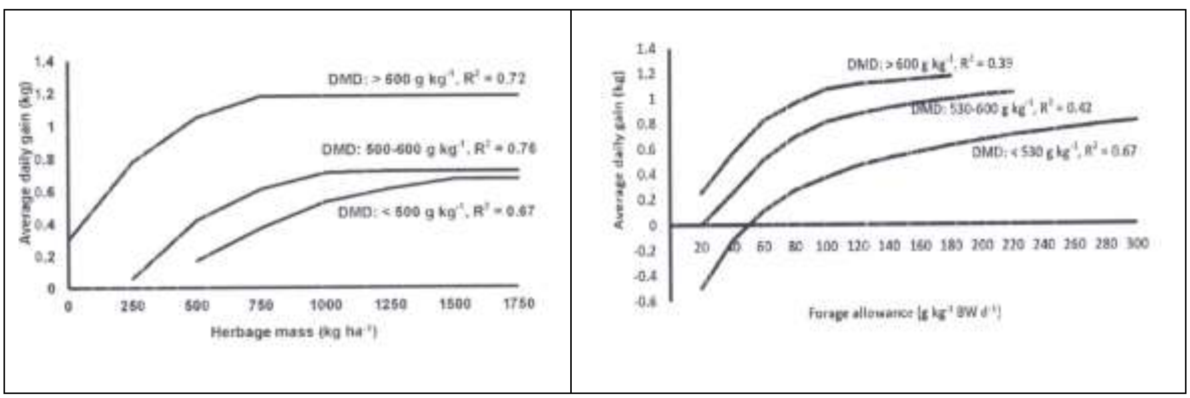

Figure 5. Effects of forage quantity and nutritive value on animal performance (Adapted from Sollenberger and Vanzant 2011).

Conclusions

The pattern of response usually shows linear increases ADG to increasing forage quantity when quantity is low, but as forage quantity reaches greater levels the ADG typically reaches a plateau. The current literature indicate that considering a wide range of herbage mass and allowance, a high proportion of the variation in ADG is explained by forage quantity (Sollenberger and Vanzant 2011). 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.

References

Burns, J.C., J.G. McIvor, V.M. L., R.R. Vera, and D.I. Bransby. 2004. Grazing systems for C4 grasslands: A global perspective. p. 309-354. In L. E. Moser, et al., (ed). Warm-season (C4) grasses. Agron. Monogr. 45. ASA, CSSA, SSSA, Madison, WI.

Burns, J.C., K.R. Pond, D.S. Fisher, and J.M. Luginbuhl. 1997. Changes in forage quality, ingestive mastication, and digesta kinetics resulting from switchgrass maturity. J. Anim. Sci. 75:1368-1379.

Burns, J.C., H. Lippke, and D.S. Fisher. 1989. The relationship of herbage mass and characteristics to animal responses in grazing experiments. p. 7-19. In G.C. Marten (ed.) Grazing research: Design Methodology, and analysis. CSSA Spec. Pub. No. 16. ASA, CSSA, SSSA, Madison, WI.

Coleman, S.W., J.E. Moore, and J.R. Wilson. 2004. Quality and Utilization, p. 267-308., *In* L. E. Moser et al., (eds.) Warm-Season (C4) grasses. Agron. Monog. 45. ASA, CSSA, SSSA, Madison, WI.

Coleman, S.W. and L.E. Sollenberger. 2007. Plant-herbivore interactions. p. 123-136.

In R.F. Barnes et al. (ed.) Forages—The science of grassland agriculture.

Blackwell Publ., Ames, IA.

Difante, G.S., V. P. B. Euclides, D. Nascimento Jr; S. C. da Silva, R. A. Barbosa, R. A. A. Torres Jr. 2010. Performance and feed conversion of beef cattle steers on Tanzania guineagrass under two grazing intensities and rotational stocking. R. Bras. Zootec. 39:33-41.

Duble R L, J.A. Lancaster, and E.C. Holt. 1971. Forage characteristics limiting animal performance on warm-season perennial grasses. Agron. J. 63:795.

Euclides, V. P. B., E. G. Cardoso, M. C. M. Macedo, and M. P. de Oliveira. 2000. Consumo voluntário de B. decumbens cv. Basilisk e B. brizantha cv. Marandu sob pastejo. Rev. Bras. Zootec. 29:2200–2208.

Euclides, V.P.B., M.C.M. Macedo, A. Vieira, and M.P. Oliveira. 1993. Evaluation of

Panicum maximum cultivars under grazing. p. 1999-2000. In Proceedings of the 17th International Grassland Congress, Rockhampton.

Flores J.A., J.E. Moore, and L.E. Sollenberger. 1993. Determinants of forage quality in Peansacola bahiagrass and Mott elephantgrass. J. Anim. Sci. 71:1606-1614.

Guerrero, J.N., B.E. Conrad, E.C. Holt, and H. Wu. 1984. Prediction of animal performance on bermudagrass pasture from available forage. Agron. J. 76:577-580.

Hill, G.M., R.N. Gates, and J.W. West. 2001. Advances in bermudagrass research involving new cultivars for beef and dairy production. J. Anim. Sci. (Suppl.) 79:48–58.

Hernández Garay, A., L.E. Sollenberger, D.C. McDonald, G.J. Ruegsegger, R.S. Kalmbacher, and P. Mislevy. 2004. Nitrogen fertilization and stocking rate affect stargrass pasture and cattle performance. Crop Sci. 44:1348–1354.

Holderbaum, J.F., L.E. Sollenberger, K.H. Quesenberry, J.E. Moore, and C.S. Jones, Jr. 1992. Canopy structure and nutritive value of limpograss pastures during mid-summer to early autumn. Agron. J. 84:11–16.

Inyang, U., J.M.B. Vendramini, L.E. Sollenberger, B. Sellers, A. Adesogan, Paiva, L., and A. Lunpha. Effects of stocking rates on animal performance and herbage responses of Mulato and bahiagrass pastures. Crop Sci. (in press)

Lima, F.G.d.C., L.E. Sollenberger, W.E. Kunkle, J.E. Moore, and A.C. Hammond. 1999b. Nitrogen fertilization and supplementation effects on performance of beef heifers grazing limpograss. Crop Sci. 39:1853-1858.

Mertens, D. R. 1987. Predicting intake and digestibility using mathematical models of rumen function. J. Anim. Sci. 64:1548–1558.

Mertens, D. 2009. Challenges in measuring forage quality. In: 2009 Annual meeting abstracts [CD-ROM]. ASA, CSSA, SSSA, Madison, WI.

Minson, D.J. 1990. Forage in ruminant nutrition, Academic Press, San Diego, CA.

Moore, J.E. 1994. Forage quality indices: development and application. p. 967-998. *In* G. C. Fahey. Jr., (ed.) Forage quality, evaluation, and utilization. ASA, CSSA, SSSA, Madison, WI.

Moore, J.E., M.H. Brant, W.E. Kunkle, and D.I. Hopkins. 1999. Effects of supplementation on voluntary forage intake, diet, digestibility, and animal performance. J. Anim. Sci. 77:122-135.

Moore, J. E. and D. J. Undersander, 2002. Relative Forage Quality: An alternative to relative feed value and quality index. p. 16-31 In: Proc. Florida Ruminant Nutrition Symposium, January 10-11, University of Florida, Gainesville.

Mott, G.0. 1959. Symposium on Forage Evaluation: IV. Animal Variation and Measurement of Forage Quality**.** Agron J. 51: 223–226

Newman, Y.C., L.E. Sollenberger, W.E. Kunkle, and C.G. Chambliss. 2002. Canopy height and nitrogen supplementation effect on performance of heifers grazing limpograss. Agron. J. 94:1375–1380.

Oba, M. and M. S. Allen. 1999. Evaluation of the importance of the digestibility of neutral detergent fiber from forage: effects on dry matter intake and milk yield of dairy cows. J. Dairy Sci. 82:589-596.

Sollenberger, L.E., and E.S. Vanzant. 2011. Interrelationships between forage nutritive value and quantity in affecting animal performance. Crop Sci. 51:420-432.

Sollenberger, L.E., and Y.C. Newman. 2007. Grazing management. p. 651-659.

In R.F. Barnes et al. (ed.) Forages—The science of grassland agriculture.

Blackwell Publ., Ames, IA.

Sollenberger, L.E., W.R. Ocumpaugh, V.P.B. Euclides, J.E. Moore, K.H. Quesenberry, and C.S. Jones, Jr. 1988. Animal performance on continuously stocked 'Pensacola' bahiagrass and 'Floralta' limpograss pastures. J. Prod. Agric. 1:216–220

Stewart, R.L., Jr., L.E. Sollenberger, J.C.B. Dubeux, Jr., J.M.B. Vendramini, S.M. Interrante, and Y.C. Newman. 2007. Herbage and animal responses to management intensity of continuously stocked bahiagrass pastures. Agron. J. 99:107-112.

Vendramini. J.M.B., A.T. Adesogan, M.L.A. Silveira, L.E. Sollenberger, O. C. Queiroz, and W.E. Anderson. Nutritive value and fermentation parameters of warm-season grass silage. Prof. Anim. Sci. 26:193-200.

Vendramini, J.M.B., L.E. Sollenberger, J.C.B. Dubeux, Jr., S.M. Interrante, R.L. Stewart, Jr., and J.D. Arthington. 2008. Sward management effects on forage component responses in a production system for early weaned calves. Agron. J. 100:1781-1786.

Weiss, W.P. 1994.Estimation of digestibility of forages by laboratory methods. p. 644-681. *In* G. C. Fahey. Jr., (ed.) Forage quality, evaluation, and utilization. ASA, CSSA, SSSA, Madison, WI.

Wilson, J.R. 1993. 1993. Organisation of forage plant tissues. p. 1-32. In H.G. Jung et al. (ed.) Forage Cell wall structure and digestibility, ASA, CSSA, and SSSA, Madison, WI.

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

Item[1]	Forage Name									*P* value	SE
	Elephantgrass	Bahiagrass	Stargrass	Mulato	Limpograss	Jiggs	Coastcross 2	Tifton 85	Florakirk		
HA, kg/ha	13,050a[2]	2600d	3670c	3200c	3870c	4600b	3090c	2970c	3800c	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, %	59.1b	56.3b	61.7ab	67.0a	60.1b	58.4b	63.2a	63.9a	58.0b	0.03	2.2
NDFD, %	46.1c	53.2b	50.0b	52.9b	44.1c	43.3c	50.8b	57.0a	45.2c	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 ($P > 0.05$)