MANAGEMENT OF *BRACHIARIA* CULTIVAR MULATO IN SOUTH FLORIDA

By

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To my father, Ime Sampson Inyang
For being an inspiration in pursuit of excellence and greatness all through the years

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Bahiagrass (*Paspalum notatum* Flügge) is the most planted forage in Florida covering approximately 2.5 million acres. Nonetheless, loss of stands due to mole crickets indicates a need for other grass species adapted to south Florida. Brachiariagrasses are the most widely grown warm-season forage in tropical America. Mulato is the first hybrid in the *Brachiaria* genus and results from crossing ruzigrass (*Brachiaria ruziziensis* clone 44-6) and palisadegrass (*Brachiaria brizantha* CIAT 6297). This new cultivar is known for its tolerance of prolonged drought and superior nutritive value, but its response to defoliation is unknown. Two field experiments were conducted to determine the yield, animal performance, and nutritive value of Mulato under varied management intensities and in comparison with bahiagrass. The experiments were conducted at the Range Cattle Research and Education Center, Ona, FL. The first experiment tested the effect of three stocking rates [4, 8, and 12 heifers (LW = 350 ± 21 kg) ha^{-1}] on animal performance and herbage production of Mulato and bahiagrass pastures. There was an increase in herbage yield but a decrease in herbage allowance with increasing stocking rates. Mulato had greater herbage accumulation, crude protein, and digestibility than bahiagrass. Heifers grazing bahiagrass and Mulato pastures had lower daily gain at 12 heifers ha^{-1} but there was no difference between grasses at stocking rates of 4 and 8 heifers ha^{-1}. Gain per hectare (GHA) and

herbage accumulation (HMA) were greatest for Mulato pastures stocked at 8 heifers ha^{-1}. The second experiment determined the effects of regrowth interval (2 and 4 wk) and three stubble heights (2.5, 7.5, and 12.5 cm) under hay harvest management on the growth, nutritive value, and persistence of Mulato. When harvested every 2 wk at 2.5 cm, Mulato was less persistent but was greater in herbage accumulation and crude protein. Persistence of Mulato increased when harvested every 4 wk at a stubble height of 7.5 cm. It is concluded that Mulato is a feasible forage option for livestock producers in south Florida, but additional research assessing long-term persistence is needed.

CHAPTER 1
INTRODUCTION

Florida is the 13th state in the USA in number of beef cows with approximately one million head (USDA Census of Agriculture, 2002). Beef cattle produced cash receipts of 293 million US dollars in 1998 (Hodges et al., 2004) which increased to 430 million US dollars in 2007. In Florida, most beef cattle operations rely on warm-season grasses as the primary source of nutrients.

Bahiagrass is an essential resource to the beef industry in Florida. It is the most widely planted warm-season grass in the state, covering approximately one million hectares. Of this area, 90% is grazed by beef cattle (Chambliss, 2000). Bahiagrass is relatively tolerant to 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). Since 1996 through 2000, more than 150,000 ha of bahiagrass pastures were damaged by mole cricket (*Scapteriscus* spp.) in Florida (Adjei et al., 2001). Damage to bahiagrass pastures by armyworms (*Pseudaletia unipuncta*), grasshoppers (*Melanoplus differentialis*), and loss of stands due to mole crickets stimulated a search for other grasses adapted to the South Florida environment.

Brachiaria species are well adapted to low-fertility acid soils of the tropics because they are tolerant of high Al, low P, and low Ca concentrations (Rao et al., 1995; Rao et al., 1996; Wenzl et al., 2002). *Brachiaria* cv. Mulato shares many of the desirable characteristics of bahiagrass, establishes from seed, tolerates low fertility and requires minimal pest control inputs, and is persistent when defoliated. Although, Mulato does not tolerate variations in edaphic and climatic conditions as well as bahiagrass does, it is adapted to infertile soils of Central and South

America (Argel et al., 2005). Mulato is known for its tolerance of prolonged drought and recovery after sporadic frost. Some Brachiaria cultivars are being offered for sale in South Florida but little scientific information is available on these new entries.

Stocking rate is the relationship between the number of animals and the area of pasture to which they are assigned over an extended period of time. Increasing stocking rate implies increasing animals consuming available herbage a given area of grassland, but this often leads to a decrease in individual animal production. The effect of increasing management intensity on plant persistence and animal performance must be determined before recommending plants for use by producers. The stocking rate and method adopted plays an important role in affecting cost of production, and utilizing available herbage (Matches, 1992).

It is important to understand the effects of defoliation frequency and intensity on plant persistence, productivity and nutritive value in order to develop harvest management recommendations (Chaparro et al., 1995, 1996). Frequent removal of forage may decrease non-structural carbohydrate reserves, decreasing the plant's ability to produce DM; however, as interval between defoliation increases, CP and IVDOM may decrease. Frequent defoliation prevents plants from reaching maturity, thus increasing the proportion of young, lush herbage. Defoliation by grazing or clipping to a short stubble height may reduce persistence and cause encroachment by other grasses (Newman et al., 2002).

The objective of this research was to assess the adaptation of Mulato to South Florida and develop basic management practices for this newly introduced warm-season grass cultivar. The research was divided into two experiments. The first experiment evaluated animal performance and forage response of bahiagrass and Mulato pastures to three stocking rates. Animal performance was measured as average daily gain (ADG) and gain per hectare (GHA) of beef heifers grazing Mulato and bahiagrass pastures. Forage responses included nutritive value, herbage mass (HM), herbage allowance (HA), and herbage mass accumulation (HMA). Results from this study will provide information to producers considering the use of Mulato as an alternative warm-season grass species for bahiagrass. In addition, information provided by this study will allow producers to make better decisions regarding stocking rates for Mulato and bahiagrass pastures and ultimately increase the profitability of their agriculture enterprise.

The second experiment evaluated forage responses of two regrowth intervals and three stubble heights of Mulato. Forage responses measured included nutritive value, HMA, and Mulato percent cover over time. These data will allow conclusions to be drawn about the harvest management practices of Mulato hay fields that favor herbage production and persistence. Data from both experiments will help producers understand management strategies to optimize the utilization of Mulato as a complement or alternative to bahiagrass in South Florida.

CHAPTER 2
LITERATURE REVIEW

Brachiaria: Origin, Introduction, and Economic Importance

Center of Origin

Brachiaria species are native from Africa. The commercially exploited brachiariagrasses species are: *Brachiaria brizantha* (palisadegrass); *B. ruziziensis* (ruzigrass); *B. decumbens* (signalgrass); and *B. humidicola* (koroniviagrass) (Miles, 2004). Apart from palisadegrass, which is found throughout tropical Africa, the other three *Brachiaria* species are found around the latitude of the Equator in eastern Africa (Keller-Grein et al., 1996).

Brachiaria belongs to a small group of genera that includes *Urochloa, Eriochloa, and Panicum.* All have the PEP-CK (phosphoenol pyruvate carboxykinase) type of C4 photosynthetic pathway (Clayton and Renvoize, 1986) and, although they have been recognized for over 100 yr, the precise separation of these genera is still in doubt. *Urochloa* is scarcely separable from *Brachiaria*, differing in little but the orientation of the spikelet (Renvoize et al., 1996). Some *Brachiaria* are difficult to separate from *Panicum* based on the inflorescence characteristics. A phylogenetic analysis based on nucleotide base sequence polymorphisms of the internal transcribed DNA did not separate *Brachiaria* from *Urochloa*. It was concluded that neither genus is monophyletic (Torres-Gonzalez, 1998).

Introduction to the Americas

The existing *Brachiaria* cultivars were direct selections of germplasm collected from Africa (Kenya, Ethiopia, Uganda, Tanzania, Zimbabwe, Rwanda, and Burundi). *Brachiaria* was first introduced in tropical Australia in the early 1960s and subsequently in tropical South America, beginning with Brazil in early 1970s (Parsons, 1972; Sendulsky, 1978). The *Brachiaria* cultivars were developed by several institutions and released in one or more tropical American countries – Brazil, Colombia, Mexico, Cuba, etc. (Miles and Lapointe, 1992).

Importance

Brachiariagrasses are the most widely grown forages in tropical America, occupying over 80 million ha (Boddey et al., 2004). *Brachiaria* species are extensively used as pasture grasses. They are not commonly harvested and stored, although hay is sometimes made from signalgrass and other species (Boonman, 1993; Stur et al., 1996). They are planted primarily for fattening and breeding beef cattle, but are not popular for dairying because of their relatively low forage quality **(**Stur et al., 1996). They are used often in rotation with annual crops such as rice [*Oryza sativa* L. (Sanz et al., 1999)]. *Brachiaria* species are popular among producers because they show rapid regrowth and good persistence under heavy or frequent defoliation (Rika et al., 1991).

The Important Brachiaria Species and Their Characteristics

Brachiaria decumbens

Signalgrass is a vigorous stoloniferous perennial, established by seed, either broadcast or planted in rows (Gil et al., 1991). Once established, this species tolerates temporarily waterlogged soils, although it grows better on well-drained ones. According to the Centro International de Agricultura Tropicale (CIAT), signalgrass can tolerate up to 6 mo of drought (CIAT, 1998). It is highly susceptible to spittlebug but tolerates leaf-eating insects. The temperature for optimal growth of signalgrass is 30 to 35°C. It is readily frosted. Values of *in vitro* dry matter digestibility (IVDMD) in signalgrass have ranged from 600 to 700 g kg^{-1} in immature forage, and from 500 to 600 g kg^{-1} in mature forage, greater than the average (550 g kg^{-1}) for tropical forage grasses (Lascano and Euclides, 1996).

Brachiaria brizantha

Palisadegrass is a highly productive grass that is propagated by seed and vegetatively by clumps and stems. It can spread slowly by seed as the seed ages to break its dormancy (Ellis, 1988). It requires more fertile and better drained soils than other species of *Brachiaria* and has a higher tolerance to drought. Palisadegrass persists under severe grazing and frequent harvesting (Granier and Lahore, 1966; Urio et al., 1988). It has the ability to spread and suppress weeds and is highly resistant to rust, leaf cutting ants (*Atta cephalotes)*, and spittlebugs (*Deois* sp. and *Notozulia entreriana*), but is highly susceptible to *Rhizoctonia* foliar blight (CIAT, 1998; Urriola et al., 1988). *Rhizoctonia* foliar blight is a disease that can be very destructive when environmental conditions are particularly conducive (high relative humidity, dense foliar growth, high nitrogen fertilization, and extended wet periods). Palisadegrass is one of the most cultivated forage grasses in Central Brazil, due mainly to spittlebug resistance and high yield potential. In the Zona da Mata of the state of Pernambuco, northeastern Brazil, the total herbage accumulation in palisadegrass pastures can reach 28 Mg dry matter (DM) ha^{-1} during the grazing season (from September 1998 through April 1999, Santos et al., 2003). About 10.5 million ha (21% of total improved grassland areas) are cultivated with palisadegrass in Central Brazil, supporting 56 million head of cattle (*Bos sp*., Vilela et al., 2004). Released by the Empresa Brasileira de Pesquisa Agropecuaria (EMBRAPA) in 1984 'Marandu' palisadegrass currently ranks first in the Brazilian forage seed market: 44% of the total amount of seed commercialized (Valle et al., 2004).

Brachiaria humidicola

Koroniviagrass is a stoloniferous perennial grass. Though established by seeds, farmers in the humid tropics favor vegetative propagation using mature stolons. It tolerates waterlogged or intermittently flooded soils such as chromic Vertisols (Amaya Hernandez and Carmona Munoz, 1988). Although it can withstand dry periods (Urriola et al., 1988), DM yield was reduced by 40% (Tergas, 1981). Koroniviagrass has high DM yield with IVDDM ranging from 480 to 620 g kg^{-1}, and CP from 50 to 120 g kg^{-1} (Hoyos and Lascano, 1985; Munoz, 1985), although N fertilization improves these parameters (Botrel et al., 1990). Koroniviagrass is highly resistant to leaf cutting ants, and tolerates, but is not truly resistant to spittlebugs (Lapointe and Miles, 1992).

Brachiaria ruziziensis

Ruzigrass has high nutritive value and is propagated by seeds. It is fast growing early in the wet season and compatible with legumes. It has high seed production potential but low competitiveness with weeds. It requires more fertile and well drained soils than palisadegrass**.** It has good drought tolerance but is highly susceptible to spittlebugs. When harvested every 6 wk, ruzigrass had a CP of 140 g kg^{-1} and IVDMD from 670 to 710 g kg^{-1} (Vallejos, 1988; do Valle et al., 1988).

Description of the Mulato Hybrid

Breeding and Genetics

A hybridization program was initiated at the CIAT, conducted in collaboration with EMBRAPA with the objective to produce improved brachiariagrass cultivars with outstanding agronomic characteristics, greater range of adaptation, higher biomass production and nutritional quality, and resistance to *Rhizoctonia* and multiple spittlebug species. This effort generated Mulato, an apomictic hybrid (CIAT, 2000), which is the first commercial hybrid in the *Brachiaria* genus.

Mulato resulted from crossing *Brachiaria ruziziensis* clone 44-6 X *Brachiaria brizantha* CIAT 6297, and this was carried out in 1988 (CIAT, 2001). A series of agronomic tests in Mexico, Colombia, and Central America has proved Mulato to be high in vigor and with good production potential (Miles, 1999).

Agronomic Characteristics and Nutritive Value

Mulato is a semi-erect perennial apomictic grass that can grow up to 1.0 m tall. It is established by seed, although it could be propagated vegetatively by rooted stem stocks. It produces vigorous cylindrical stems, some with a semi-prostrate habit, capable of rooting at the nodes when they come in close contact with soil. Mulato has lanceolate and highly pubescent leaves of 40 to 60 cm in length and 2.5 to 3.5 cm width (Guiot and Melendez, 2003). Mulato grows well in humid tropical areas with high rainfall and short dry periods, and in sub-humid conditions with 5 to 6 dry months and annual rainfall of 700 mm. It has been reported by Argel et al., 2005 that Mulato grows well in subtropical conditions where periodic frost occurs, such as southern Florida in the USA. It grows in acid to alkaline soils (pH 4.2-8.0), but it requires medium to high fertility and good drainage. Mulato is drought tolerant and has the capacity to regrow again during critical times of the year. It has CP concentration fluctuating between 90 to 170 g kg^{-1} and digestibility of 550 to 620 g kg^{-1} (CIAT, 2005; CIAT, 2006). It produces 25% more DM yield than palisadegrass and signalgrass, increasing animal productivity from 1 to 2 kg milk cow^{-1} d^{-1} over that achieved on palisadegrass cv. Marandu or palisadegrass cv. Toledo (Peters et al., 2003).

Bahiagrass

Origin

Scott (1920), cited by Gates et al. (2004), reported that bahiagrass was first introduced into the USA by the Bureau of Plant Industry and grown by the Florida Agricultural Experiment Station in 1913. After its introduction into Florida, it soon escaped from cultivation and rapidly became naturalized throughout Florida. Bahiagrass is particularly tolerant of poor soil drainage, close continuous grazing, and marginal fertility. Currently, bahiagrass is widespread throughout the southern USA and Central and South America (Chambliss and Adjei, 2006). It is used extensively as pasture and utility turf on highway rights-of-way (Gates et al., 2004).

Agronomic Characteristics

Bahiagrass is a low-growing perennial spreading by short, stout rhizomes and can grow up to 30 cm tall. It is primarily established by seed. It produces vigorous leaf growth and has a prostrate growth habit. It has many large, fibrous roots and forms dense, tough sods, even on drought-prone sandy soils. It has pubescent basal leaves, with a purple glabrous sheath. The culms (stems) of bahiagrass are ascending, usually ranging from 20- to 75-cm tall, and the dark green leaves are 4- to 10-mm wide and linear-elongate in shape. The leaf blades are typically 6 to 25 cm long and the leaf sheaths are generally 4 to 20 cm long. Bahiagrass grows well in humid tropical areas with high rainfall and short dry periods but requires a minimum annual rainfall of 750 mm. It grows in acid soils (pH 5.0 – 6.5). Bahiagrass is drought tolerant but it produces less biomass during critical times of the year, particularly in winter. It has CP concentration fluctuating between 70 to 100 g kg^{-1} and a digestibility from 490 to 510 g kg^{-1}. Bahiagrass is one of the most important cultivated grasses in Florida and the southern part of the Gulf States of the USA.

Pensacola Bahiagrass

'Pensacola' bahiagrass belongs to the botanical variety *Paspalum notatum var. saurae* Parodi. It is a sod-forming perennial grass of tropical origin which concentrates its forage production near the soil surface. It is taller, spreads faster, has longer narrower leaves, smaller spikelets, and can have more racemes per inflorescence than common bahiagrass (Gates et al., 2004). Pensacola bahiagrass was introduced into North America in 1936 (Burton, 1967), its widespread proliferation throughout the lower southeastern USA demonstrates excellent adaptation by this species to regional environmental conditions. It is fairly frost tolerant and growth starts early in the spring. In Florida, DM yields of Pensacola bahiagrass during the growing season ranged from 3000 to 4000 kg ha^{-1} (Blue, 1970). Nonetheless, most production occurs during spring and summer (April - September). Plant response to short days appears to account for at least some of the seasonality of production. Mislevy et al. (2001) reported a 167% increase in total cool-season herbage accumulation of Pensacola bahiagrass when day length was extended from 10.4 to 15 h.

Defoliation Frequency and Intensity Effect

The principal function of green plants is to intercept enough solar radiation in the foliage to guarantee the energy supply for their growth and development (Hodgson, 1990). Plants in pastures that are continuously stocked at a high stocking rate will be defoliated frequently, so there is little shading of leaves in the lower part of the canopy due to constant leaf removal. Forage plants must have adaptation mechanisms to survive frequent and severe grazing or harvests. The immediate effect of a harvest is the reduction of leaf area, and therefore, the quantity of intercepted light, carbohydrate reserves, and root growth (Richards, 1993). The ability to rapidly re-establish the photosynthetic capacity of the canopy after defoliation is an important characteristic of defoliation-tolerant plants, and the presence of active shoot meristems allows for rapid leaf expansion from existing cells (Mott and Lucas, 1952). Swards sown to warm- or cool-season perennial forages often change with time into mixtures that vary in botanical composition, herbage productivity, and nutritive value. Cool-season swards clipped or grazed intensively can be invaded by warm-season species, such as crabgrass (*Digitaria* spp.), and warm-season swards can be invaded by a number of cool-season species adapted to a site, especially in spring and late summer.

When established brachiariagrass pastures are defoliated, the regrowth curve is roughly sigmoid. After an initial lag in recovery of growth, the exponential growth phase begins but its extent and duration depends on the intensity of grazing and the species (Lascano and Euclides, 1996). The accumulation of DM in forage plants ensues from complex interactions of genetic attributes, environment, and their effects on physiological processes and the morphologic characteristics of the plants (Da Silva and Quarry, 1997). Different grazing frequencies generate changes in the structure of the canopy, modifying the light environment and resulting in canopies with different photosynthetic potentials. The photosynthetic rate of individual leaves is reduced when there is diminished grazing frequency. This compromises the photosynthetic potential of the canopy while also generating a delay in regrowth. A lesser frequency of defoliation generates competition for light and reduces values of foliar photosynthesis and canopy. Braga, et al. (2006) recommended optimum management practices for *Xaraés* palisadegrass to include grazing intervals shorter than 28 d, so that higher photosynthetic rates are achieved during the regrowth period.

Effect on Productivity

The influence of grazing frequency on ruzigrass, palisadegrass, and signalgrass fertilized with 170 kg ha^{-1} N and clipped to a 7.5-cm stubble height was found to be the opposite of effects observed for most grasses, showing highest persistence when grazing frequency was 2 or 3 wk. Delaying grazing frequency of these three *Brachiaria* grasses to 5 or 7 weeks may allow plants to develop an oversupply of forage, which shades the stem bases and regenerative buds (Mislevy et al., 1996). The decrease in stand persistence of signalgrass and palisadegrass at each harvest frequency indicates that these grasses may not be adapted to clipping to a 7.5-cm stubble height. Koroniviagrass showed the highest DM yield at 7-wk regrowth intervals (Mislevy et al., 2002).

Palisadegrass can be heavily grazed if regularly fertilized with N (Sivalingam, 1964). If grown with a legume, the grazing system must favor the legume, and adequate P must be provided. In Sri Lanka, Sivalingam (1964) recommended a cutting interval of 30 d when palisadegrass was fertilized with N at 0, 45, 132, and 396 kg ha^{-1}. Cumulative DM yield of palisadegrass increased with increasing N rates from 0 to 400 kg ha^{-1} when cut every 40 d (Mtengeti and Lwoga, 1989, unpublished report). Mulato had greater DM yield when cut every 28 (4.0 Mg ha^{-1}) compared to 21 (2.6 Mg ha^{-1}) and 35 d (4.6 Mg ha^{-1}; Hidalgo, 2004).

Cuomo et al. (1996) compared three grazing frequencies, 20, 30, and 40 d, of bahiagrass across two growing seasons. At these frequencies, total forage DM production was 10.6, 11.8, and 12.3 Mg ha^{-1}, respectively. Herbage CP was significantly greater at 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 (590 g kg^{-1}).

Stanley (1994) compared bahiagrass at harvest intervals of 1, 2, 4, 8, and 16 wk, with N fertilization 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.

Beaty et al. (1970) evaluated bahiagrass across six harvest frequencies, 1, 2, 3, 4, 5, and 6 wk. At these frequencies, average DM production 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. Without fertilization, as much as 67% of total Pensacola herbage mass was found in the bottom layers (0-2.5 cm) of the canopy. This indicated that close defoliation may improve forage nutritive value by reducing the amount of dead material that accumulates under lax defoliation methods.

Gates et al. (1999) compared 2-, 4-, and 8-wk-old regrowth of Pensacola, Tifton 9, and RRPS Cycle 14. Depletion of reserves available for growth was evident in the reduction of etiolated spring growth of bahiagrass plots harvested biweekly (74 g DM m^{-2}) for 2 yr in comparison with 4-wk (81g DM m^{-2}) or 8-wk (105 g DM m^{-2}) harvest intervals.

Effect on Nutritive Value

According to Gates et al. (2001), Pensacola bahiagrass exceeded Tifton 9 in CP concentrations on five different harvest dates. This was consistent with previous findings of Mislevy et al. (1990), who demonstrated that CP concentrations were higher in Pensacola than in Tifton 9 bahiagrass. The CP concentration of all bahiagrass cultivars at 2- to 5- wk grazing frequencies was more than adequate to meet the requirements of lactating beef cows (90 to 100 g kg^{-1}) and lactating heifers (100 to 120 g kg^{-1}, National Research Council, 1984). However, when grazing frequency (GF) was delayed to 7 wk, forage CP concentration of all grasses was just adequate to meet requirements of lactating beef cows.

In Araçatuba, São Paulo, Vendramini et al. (1999) evaluated Tifton 9 bahiagrass harvested at six regrowth intervals (20, 27, 34, 41, 48, and 55 d after staging). Plots received 60 kg ha^{-1} of N for the period of January to March 1997. Dry matter yield ranged from 188 to 593 g m^{-2}. Crude protein was found to decrease linearly from 121 to 69 g kg^{-1}as regrowth interval increased.

In a 3-yr clipping study, Mislevy et al. (2005) reported greatest bahiagrass forage CP and IVDOM in April (157 and 534 g kg^{-1}respectively), October (157 and 542 g kg^{-1}, respectively), and December (177 and 587 g kg^{-1}, respectively), while lowest CP and IVDOM were always found in June (113 and 467 g kg^{-1}, respectively) and August (122 and 482 g kg^{-1}, respectively). Stewart et al. (2007) reported that Pensacola bahiagrass herbage CP and IVDOM in continuously stocked pastures generally decreased from May through August.

Hirata (1993) reported greatest annual IVDDM of Pensacola when harvested at 2-cm stubble height (570 g kg^{-1}) and lowest IVDDM at 22-cm stubble (460 g kg^{-1}). This author also reported IVDDM was greater in the spring (580 g kg^{-1} at 2-cm stubble and 540 g kg^{-1}at 22-cm stubble) than autumn (530 g kg^{-1} at 2-cm stubble and 430 g kg^{-1}at 22-cm stubble).

Haddad et al. (1999) evaluated the production characteristics and nutritive value of Pensacola bahiagrass at six regrowth intervals (20, 35, 50, 65, 80 and 95 d after staging) from December 1987 to March 1988 in Brazil. They found DM production increased quadratically (from 161 to 418 g m^{-2}) while IVDDM decreased quadratically (from 678 to 373 g kg^{-1}) with increased regrowth intervals. Haddad et al. (1999) reported a decline in nutritive value of Pensacola bahiagrass from 20 to 50 d of regrowth after cutting [678 to 448 g kg^{-1} (IVDDM) and 145 to 97 g kg^{-1} (CP)]. Results showed that the recommended harvest should be performed approximately at 30-d intervals in order to balance forage production and nutritive value.

The CP and IVDOM of signalgrass, ruzigrass, palisadegrass, and koronviagrass fertilized with 170 kg ha^{-1} N and clipped to a 7.5-cm stubble height decreased after 5 wk. Regardless of the grazing frequency, koronviagrass was the lowest in IVDOM (Mislevy et al., 1996; Mislevy et al., 2003). Crude protein concentration of palisadegrass declined with longer cutting intervals, but increased from 69 to 129 g kg^{-1} when N was increased from 0 to 400 kg ha^{-1}.

According to Mislevy et al. (1996), koronviagrass holds a distinct advantage over bahiagrass in digestibility. Koronviagrass had 77 (June–July) and 80 g kg^{-1} (August–September) greater IVDOM than Pensacola bahiagrass when grazed at a 21-d frequency. In a clipping trial, average IVDOM of koronviagrass from April to September was 120 g kg^{-1} higher than Pensacola (Mislevy and Everett, 1981). Koronviagrass and bahiagrass contained CP of 119 and 139 g kg^{-1} and IVDOM of 550 and 499 g kg^{-1}, respectively, early in June.

Stocking Rates

Stocking rate is a fundamental variable for management that affects vegetation, livestock, and economic responses (Gillen and McCollum, 1992; McCollum et al., 1999). When stocking rate is imposed across a relatively wide range, it has a profound effect on the forage, especially forage mass and subsequent animal performance (Burns et al., 1989). It has been established that stocking rate affects ADG (Guerrero et al., 1984; Bransby et al., 1988; Gillen et al., 1992). At low stocking rates, ADG is maximized, but a heavier stocking rate maximizes gain per hectare. Maximum net return per hectare usually occurs between 55 to 60% of the stocking rate that produces maximum gain per hectare (Hart et al., 1988). Bransby et al. (1988) proposed that the function describing the relationship between stocking rate and animal performance is unique for each forage type.

Effect on Herbage Production and Nutritive Value

Stewart et al. (2007) evaluated the effects of three management intensity treatments low (40 kg N ha^{-1} yr^{-1}, 1.4 AU ha^{-1} target SR), moderate (120 kg N ha^{-1} yr^{-1}, 2.8 AU ha^{-1} target SR), and high (360 kg N ha^{-1} yr^{-1}, 4.2 AU ha^{-1} target SR) on beef heifer performance and bahiagrass production and nutritive value. Herbage accumulation (41 vs. 17 kg ha^{-1} d^{-1}), CP (140 vs. 99 g kg^{-1}), and IVDOM (505 vs. 459 g kg^{-1}) of bahiagrass pastures were greater for High than Low intensity. Herbage allowance was 1.4 kg DM kg^{-1} liveweight (LW) for high compared to 4.8 kg DM kg^{-1} LW for low management intensity.

Utley et al. (1974) reported greater animal performance on continuously stocked Coastcross-1-bermudagrass (0.68 kg d^{-1}) than on Pensacola bahiagrass and Coastal bermudagrass (average 0.46 kg d^{-1}), when pastures were grazed for 4 yr and fertilized with 168 kg N ha^{-1} yr^{-1} in Tifton, GA.

Sollenberger et al. (1988) showed that total season ADG of bahiagrass seldom exceeds 0.5 kg d^{-1}. They showed ADG of 0.38 and 0.33 kg d^{-1}, and carrying capacities of 5.2 and 5.4 steers (320 kg ha^{-1}) for Pensacola bahiagrass and 'Floralta' limpograss [*Hemarthria altissima* (Poir.) Stapf and C.E. Hubbard], respectively. Pastures were continuously stocked for 2 yr in Florida.

Gain per hectare was 370 and 344 kg for bahiagrass and limpograss respectively, when pastures received N fertilization of 190 kg ha^{-1} each year. However, this was because stocking rate was higher on limpograss than on bahiagrass.

Dubeux et al., (2006) conducted a 3-yr study to evaluate the effects of a wide range of management intensities on patterns of herbage and soil nutrient responses in Pensacola bahiagrass pastures. The three management intensities were: low (40 kg N ha^{-1} yr^{-1} and 1.4 AU ha^{-1} stocking rate [SR]), moderate (120 kg N ha^{-1} yr^{-1} and 2.8 AU ha^{-1} SR), and high (360 kg N ha^{-1} yr^{-1} and 4.2 AU ha^{-1} SR). It was reported that herbage N was greatest at the high SR, within the range of 20 to 23.5 g kg^{-1} DM, but it showed lower values for low SR within the range of 14 to 15.7 g kg^{-1} DM. At high SR, IVDOM varied from 436 to 558 g kg^{-1} but showed lower values for low SR of 419 to 496 g kg^{-1}.

In Florida, herbage mass accumulation (HMA) of Tifton 85 bermudagrass at SR 11.1, 11.2, and 13.7 AU ha^{-1} varied throughout the grazing season ranging from 45 to 121 kg DM ha^{-1} d^{-1} in 2003 and from 56 to 133 kg DM ha^{-1} d^{-1} in 2004 (Vendramini et al, 2007).

Effect on Animal Performance

Stocking rate of pastures is a key determinant of pasture and animal production, and for most responses has a much greater impact than N fertilizer rate. Stewart et al. (2007) studied the effects of three management intensities (include stocking rates and N fertilization levels) on performance of beef heifers grazing bahiagrass pastures in Florida. Averages across 4 yr of grazing continuously stocked bahiagrass showed an ADG and gain per hectare of 0.34 kg and 101 kg ha^{-1}, and 0.28 kg and 252 kg ha^{-1} for Low and High, respectively. Stewart et al. (2007) reported greater heifer ADG (0.34 and 0.28 kg d^{-1}, respectively) for Pensacola bahiagrass under low intensity management (40 kg N ha^{-1} yr^{-1}, 1.4 AU ha^{-1} SR) than high intensity (360 kg N ha^{-1} yr^{-1}, 4.2 AU ha^{-1} SR), but gain per hectare increased from low to high intensity (101 to 252 kg ha^{-1}). Greater CP (140 vs. 99 g kg-1) and IVDOM (505 vs. 459 g kg-1) were observed at high than at low intensity management for bahiagrass.

Animut et al. (2005) studied stocking rates of 4, 6, and 8 animals per 0.4-ha pasture, with equal numbers of sheep and goats stocked rotationally. Average daily gain tended to decrease linearly as SR increased (61, 51, and 47 g d^{-1}), and gain per hectare increased linearly to 610, 759, and 933 g d^{-1} for SR4, SR6, and SR8, respectively.

Hernández Garay et al. **(**2004) reported a quadratic decrease in ADG of weanling bulls grazing stargrass (*Cynodon nlemfuensis* Vanderyst) pastures as stocking rate increased from 2.5 to 7.5 bulls ha^{-1}. Average daily gain decreased from 0.70 to 0.26 kg d^{-1} in Year 1 and 0.65 to 0.35 kg d^{-1} in Year 2 as stocking rate increased from 2.5 to 7.5 head ha^{-1}. Salazar-Diaz (1977) reported a relationship of 1.05, 1.02, and 1.36 kg of LW per kg N applied, with low, medium, and high SR, respectively, for digitgrass (*Digitaria eriantha* Steud.) pastures. Increased SR increases consumption of herbage ha^{-1}, but there is a shift in use of consumed energy from maximum daily animal growth at low SR, toward maintenance of the animals at moderate to high SR.

Adjei et al. (1980) conducted grazing trials to study the effects of three SR (7.5, low; 10, medium; and 15 steers ha^{-1}, high) on forage yield, nutritive value, and utilization, and animal performance of three stargrasses: 'UF-5' and 'McCaleb' (*Cynodon aethiopicus* Clayton and Harlan) and 'UF-4' (*Cynodon nlemfuensis* Vanderyst var. *nlemfuensis*). Additionally, the medium SR was imposed on 'Transvala' digitgrass (*Digitaria eriantha* Steud) and Pensacola bahiagrass. The average annual DM yields of stargrasses at low, medium, and high SR and of digitgrass and bahiagass at medium SR were 17.0, 18.3, 20.1, 15.0, and 10.0 Mg ha^{-1}, respectively. The ADG and gain per hectare at the medium SR on stargrass, digitgrass, and bahiagrass averaged 0.35, 0.28, 0.22, kg d^{-1}, and 580, 461, and 396 kg ha^{-1}, respectively. During 168-d experimental period in Florida, ADG of yearling beef steers grazing stargrass (average of three cultivars and 2 yr) was 0.47, 0.38, and 0.21 kg d^{-1} for SR treatments of 7.5, 10, and 15 steers ha^{-1} (initial weight of 230–250 kg).

Gunter et al. (2005) reported that the ADG of beef steers was decreased by increasing the stocking rate on dallisgrass pasture fertilized with 112 kg N ha^{-1}, Stocking rates of 3.7, 6.2, 8.6 and 11.1 steers ha^{-1} resulted in an ADG of 0.63, 0.61, 0.51 and 0.34 kg d^{-1}, respectively. Increasing stocking rate resulted in quadratic decreases in the total BW gain per steer.

Aiken et al. (2006) studied the influence of stocking rate and steroidal implants on growth rate of steers grazing pasture of tall fescue (*Festuca arundinacea* Schreb.). Forage mass declined linearly from 4000 to 3600 kg of DM ha^{-1}as stocking rate increased. There was no ADG response to stocking rate but there was a linear decrease in gain per hectare as stocking rate increased. Trends in gain per hectare showed that 6.0 steers ha^{-1}, with or without implantation, provided approximately a 75% increase in gain per hectare over the 3.0 steer ha^{-1}.

CHAPTER 3
EFFECT OF STOCKING RATES ON ANIMAL PERFORMANCE AND HERBAGE RESPONSES OF MULATO AND PENSACOLA BAHIAGRASS PASTURES

Introduction

Bahiagrass (*Paspalum notatum* Flügge) is the main forage used for the beef cattle industry in Florida because of its reliability and persistence under adverse climatic conditions and management practices. It is the most widely planted warm-season grass in Florida, covering approximately 1 million hectares. Nonetheless, overdependence on bahiagrass pastures has made the industry vulnerable to potential losses of bahiagrass stands to pests and diseases infestations. There is a need to identify alternative warm-season grasses adapted to Florida. Although, *Brachiaria* cv. Mulato does not tolerate variations in edaphic and climatic conditions as well as bahiagrass does, it is adapted to infertile soils is known for its tolerance of prolonged drought and recovery after sporadic frost (Argel et al., 2005). These attributes suggest potential for use in South Florida forage livestock systems.

Mulato, the first hybrid in the *Brachiaria* genus, has been proven to be high in vigor and with good production potential in South and Central America (Miles, 1999). Brachiariagrasses are the most widely grown forages in tropical America, occupying over 80 million ha (Boddey et al., 2004). *Brachiaria* species are popular among producers because they show rapid regrowth and good persistence under heavy or frequent defoliation (Rika et al., 1991). Mulato is drought tolerant and has the capacity to regrow during critical times of the year. It has crude protein (CP) concentrations fluctuating between 90 to 170 g kg^{-1} with digestibility of 550 to 620 g kg^{-1} (CIAT, 2005; 2006). It produced 25% more yield than palisadegrass and signalgrass, increasing animal productivity from 1 to 2 kg milk cow^{-1} d^{-1} over that achieved on palisadegrass cv. Marandu or palisadegrass cv. Toledo (Peters et al., 2003).

There are no data available in the literature comparing Mulato and bahiagrass forage characteristics in Florida. However, Mislevy et al. (1996) stated that koronviagrass (Brachiaria humidicola) holds a distinct advantage over bahiagrass in digestibility. Koronviagrass had 77 (June–July) and 80 g kg–1 (August–September) greater in vitro digestible organic matter (IVDOM) than Pensacola bahiagrass when grazed at a 21-d frequency. In a clipping trial, mean IVDOM of koronviagrass from April to September was 120 g kg–1 greater than Pensacola (Mislevy and Everett, 1981). Koronviagrass and bahiagrass CP were 119 and 139 g kg–1 and IVDOM 550 and 499 g kg–1, respectively, early in June.

Stocking rate (SR) is the most critical grazing management decision (Vendramini and Sollenberger, 2007). Stocking rate has profound effects on forage and animal production. Animut et al., (2005) studied three SR (4, 6, and 8 animals) per 0.4-ha pasture, with equal numbers of sheep and goats using rotational grazing in 2-wk grazing periods. Average daily gain decreased linearly as SR increased (61, 51, and 47 g d^{-1}), and total live weight gain (LWG) increased linearly to 610, 759, and 933 g d^{-1} for 4, 6, and 8 animals per 0.4 ha, respectively. Hernández Garay et al. **(**2004) reported a quadratic decrease in average daily gain (ADG) of weanling bulls grazing stargrass (*Cynodon nlemfuensis* Vanderyst) pastures as increased from 2.5 to 7.5 bulls ha^{-1}. Average daily gain decreased from 0.70 to 0.26 kg d^{-1} in Year 1 and 0.65 to 0.35 kg d^{-1} in Year 2 as SR increased from 2.5 to 7.5 head ha^{-1}.

It is necessary to evaluate and develop management practices to optimize the utilization of Mulato in grazing systems in South Florida. The objective of this study was to evaluate the effects of SR on herbage mass (HM), accumulation rate (HMA), and nutritive value and performance of beef heifers grazing Mulato and bahiagrass pastures.

Materials and Methods

Experimental Site

This experiment was conducted at the University of Florida Range Cattle Research and Education Center (RCREC), Ona, FL (27.4^{o} N) in 2007 and 2008. The soil at the research site was classified as a sandy siliceous, hyperthermic Alfic Alaquod (EauGallie sand). These sandy soils are poorly drained with slow permeability. Prior to initiation of the grazing trial, mean soil pH (in water) was 6.0. Mehlich-I (0.05-*M* HCl + 0.0125-*M* H_2SO_4) extractable P, K, Mg, and Ca in the Ap1 horizon (0- to 15-cm depth) were 34, 72, 234, and 1600 mg kg^{-1}.

Treatments and Design

Treatments were the factorial arrangement of three SR [4, 8, and 12 heifers ha^{-1}] and two forage species (Mulato and bahiagrass) in a randomized incomplete block design with three replicates for 4 and 12 heifers ha^{-1} and two replicates for the 8 heifers ha^{-1} treatment. Pastures (0.25 ha) were stocked continuously.

Pasture Management

Grazing was initiated in May of each year when adequate forage was available to support the livestock (18 May 2007 and 19 May 2008). Pastures received 150 kg N ha^{-1} split in three equal applications (April, June, and August). The periods of the grazing trial were from 18 May through 10 Sept. 2007 (116 d) and 19 May through 9 Sept. 2008 (114 d).

Plant and Animal Response Variables

Pastures were sampled just prior to initiation of grazing and every 14 d during the grazing period. Herbage mass, HMA, and nutritive value (CP and IVDOM) were measured. Double sampling was used to determine HM. The indirect measure was the settling height of a 0.25-m^2 aluminum disk, and the direct measure involved hand clipping all herbage from 2 cm above soil level to the top of the canopy using an electric clipper. Every 28 d, one or two double samples were taken from each of the sixteen experimental units for a total of 20 per species. Sites were chosen that represented the range of herbage mass present on the pastures. At each site, the disk settling height was measured and the forage clipped. Clipped forage were dried for 72 h and weighed. At sampling every 14 d, 20 sites for disk measures were chosen by walking a fixed number of steps between each drop of the disk to ensure that all sections of the pasture were represented. The average disk height of the 20 sites were entered into the equation to predict actual herbage mass.

Because these pastures were stocked continuously, a cage technique was used to measure herbage accumulation. Three 1-m^2 cages were placed in the pasture at the initial sampling date. Placement sites were chosen where the disk settling height was the same (±1cm) 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 period, cages were moved to new locations on the pasture with a current average disk settling height. Herbage allowance was calculated for each pasture as the average herbage mass (mean across two sampling dates within each 28-d period) divided by the average total heifer live weight during that period (Sollenberger et al., 2005).

Herbage CP and IVDOM concentration was measured at the initiation of grazing and at every 14 d thereafter. Hand-plucked samples were taken from each pasture. The objective 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 randomly chosen in each experimental unit. Herbage was composited across sites, dried at 60°C for 48 h in a forced-air oven to constant weight and ground in a Wiley mill (Model 4, Thomas-Wiley Laboratory Mill, Thomas Scientific, Swedesboro, NJ) to pass a 1-mm stainless steel screen. Analyses were conducted at the University of Florida Forage Evaluation Support Laboratory using the micro-Kjeldahl technique for N (Gallaher et al., 1975) and the two-stage technique for IVDOM (Moore and Mott, 1974).

The heifers were Angus-sired (crossbred cows sired by Angus bulls) with initial LW of 386±38 kg. 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 each 28-d period through the entire grazing season. Gain per hectare (GHA) was calculated for each pasture over the entire grazing season.

Statistical Analysis

Response variables were ADG, GHA, HM, HMA, HA, CP and IVDOM. The data were analyzed using PROC MIXED of SAS (SAS Institute Inc., 2006) with forage species, stocking rate, species **x** stocking rate (main plot), year (subplot), and month as fixed effects. Month was a repeated measure. Replicate and its interactions were considered random effects.

For pasture variables, the model used was:

$$Y_{ijkl} = \mu + A_i + R_j + S_k + P_l + (AR)_{ij} + (AS)_{ik} + (AP)_{il} + (RS)_{jk} + (RP)_{jl} + (ARS)_{ijk} + (ARP)_{ijl} + (RSP)_{jkl} + (ARSP)_{ijkl} + e_{ijk}$$

Where Y_{ijk} is the dependent variable
μ is the overall mean
R_j is the stocking rate effect (main plot)
S_k is the specie effect (main plot)
A_i is the year effect (sub-plot)
P_l is the month effect (sub-sub-plot)
$(AR)_{ij}$ is the year*stocking rate interaction
$(AS)_{ik}$ is the year*specie interaction
$(AP)_{il}$ is the year*month interaction
$(RS)_{jk}$ is the stocking rate*specie interaction
$(RP)_{jl}$ is the stocking rate *month interaction
$(ARS)_{ijk}$ is the year*stocking rate*species interaction
$(ARP)_{ijl}$ is the year*stocking rate*month interaction
$(RSP)_{jkl}$ is the stocking rate*species*month interaction
$(ARSP)_{ijkl}$ is the year*stocking rate*species*month interaction
e_{ijkl} is the error

Single degree of freedom orthogonal polynomial contrasts were used to test stocking rate effects. Treatments were considered different when $P < 0.05$. Interactions not discussed in the Results and Discussion section were not significant when $P > 0.05$. The means reported are least squares means and were compared using PDIFF (SAS Institute Inc., 2006). The correlation of HA and ADG was determined by a nonlinear minimization procedure using the PROC NLP of SAS (SAS Institute Inc., 1999).

Results and Discussion

Herbage Mass

There was a linear decrease in HM from 5.8 to 3.2 Mg ha^{-1} as SR increased from 4 to 12 heifers ha^{-1}. There was a SR x species x month interaction for HM (Table 3-1).

Table 3-1. Stocking rate x species x month interaction effects on herbage mass of bahiagrass and Mulato pastures.

Species/Stocking rate‡	Month†					SE
	May	June	July	August	September	
heifers ha^{-1}	---------------- Mg ha^{-1} ----------------					
Mulato						
4	5.6 c†	7.3 b	8.2 a	4.9 d	5.2 cd	0.3
8	4.7 a	5.2 a	5.0 a	3.4 b	3.2 b	0.4
12	4.7 a	4.4 a	3.3 b	2.6 c	2.5 c	0.3
Contrast‡	L	L	L	L	L	
Bahiagrass						
4	5.3 cd	4.3 d	5.2 cd	5.9 c	5.9 c	0.3
8	4.0 ab	3.3 b	3.7 b	4.4 ab	4.4 ab	0.4
12	3.8 ab	2.7 cd	2.6 bc	2.8 bc	3.0 bc	0.3
Contrast‡	L	L	L	L	L	

† Monthly means within stocking rate followed by the same lower case letter are not different ($P > 0.05$)
‡ Stocking rate effect within month and grass species. L = Linear ($P < 0.05$)

The interaction occurred because Mulato had similar or greater HM than bahiagrass in May, June, and July but lower HM in August and September at 4 and 8 heifers ha^{-1}, respectively. The less HM of Mulato in August and September was observed because of the above average rainfall in August (Table 1, Appendix A), which resulted in soils with excessive moisture. It was observed that HM of Mulato was negatively impacted by poorly drained soils conditions to a greater degree than bahiagrass. Mulato had greater HM at 12 heifers ha^{-1} SR for May, June, and July but there was no difference in the subsequent months. There were no effects of SR on HM of Mulato in May. This occurred because the experimental period started in May with similar HM across experimental units and there was not enough time for the different treatments to impact HM.

There was a year × month interaction for HM (Table 3-2). Herbage mass was greater in 2008 than 2007 for May, June, and July but there was no difference in August and September. This was attributed to greater rainfall in those months in 2008 (Table 1, Appendix A). In 2007, HM was the least in June and similar on May, July, August, and September.

Table 3-2. Year x month interaction effects on herbage mass of bahiagrass and Mulato pastures.

Year‡	Month					SE
	May	June	July	August	September	
	-------------------------Mg ha^{-1}---------------------------					
2007	3.8 a†	2.7 b	3.5 a	4.1 a	4.1 a	0.2
2008	5.6 b	6.4 a	5.8 b	3.9 c	4.0 c	0.2
P‡	< 0.01	< 0.01	< 0.01	0.23	0.49	
SE			0.2			

† Monthly means within year followed by the same lower case letter are not different (P>0.05)
‡ P value of year effect within month

However, in 2008, HM increased in June and decreased in August and September. Greater HM was expected in June because of the greater rainfall. The decrease in HM in August and September 2008 happened because of above average rainfall and excessive soil moisture. The greatest HM was observed in June of 2008 with an average of 6.4 Mg ha^{-1} while least HM was observed in June of 2007 with an average of 2.7 Mg ha^{-1}.

Herbage Mass Accumulation Rate

There was a quadratic increase in HMA as SR increased. Herbage mass accumulation was 106, 128, and 118 kg ha^{-1} d^{-1} for stocking rate 4, 8, and 12 heifers ha^{-1}, respectively. Pastures grazed at 8 heifers ha^{-1} SR had stubble height of approximately 15 cm with sufficient leaf area to optimize light interception that resulted in greater HMA. Pastures stocked at 12 heifers ha^{-1} had stubble heights of approximately 5 cm and the reduced leaf area remaining compromised HMA.

Table 3-3. Stocking rate x month interaction effects on herbage mass accumulation rate of bahiagrass and Mulato pastures.

Stocking rate†	Month‡				SE
	May	June	July	August	
heifers ha^{-1}	----------------kg ha^{-1} d^{-1} ------------				
4	127 b	156 a	70 c	72 c	8
8	124 b	179 a	117 bc	91 c	9
12	104 bc	168 a	115 b	86 c	9
Contrast‡	L	Q	Q	Q	
SE	8	7	7	9	

†Monthly means within stocking rate followed by the same lower case letter are not different ($P > 0.05$)
‡ Stocking rates effects within month. L = Linear; and Q = Quadratic ($P < 0.05$).

Conversely, pastures stocked at 4 heifers ha^{-1} had excessive HM which probably resulted in self-shading, increased senescence rates, and finally decreased HMA. There was a stocking rate × month interaction for HMA (Table 3-3). Herbage mass accumulation increased from May to June and subsequently decreased in July and August, however, the decrease was greatest in the 4 heifers ha^{-1} SR.

There was a year × species x month interaction for HMA (Table 3-4). In 2007, HMA of Mulato and bahiagrass increased from May to June, decreased in July in bahiagrass, and increased in July in Mulato pastures. This increase in HM from May to June was observed because of the limited rainfall in May 2007 followed by adequate moisture conditions from June to August. In 2008, HMA of Mulato decreased linearly from June to August because of the excessive soil moisture, which limited plant growth. On the other hand, bahiagrass HMA increased from May to June and subsequently decreased in July and August for the same reason mentioned previously.

Table 3-4. Year x species x month interaction effects on herbage mass accumulation rate of bahiagrass and Mulato pastures.

Year/Species	Month				SE
	May	June	July	August	
	---------------- $kg\ ha^{-1}d^{-1}$	---------------			
2007					
Mulato	111 b	164 a	121 b	143 a	10
Bahiagrass	38 c	69 b	108 a	71 b	10
$P^{‡}$	< 0.01	< 0.01	0.36	< 0.01	
2008					
Mulato	119 a	114 a	47 b	34 b	10
Bahiagrass	87 b	158 a	106b	65c	10
$P^{‡}$	< 0.01	< 0.01	< 0.01	0.48	

† Monthly means within year and species followed by the same lower case letter are not different ($P > 0.05$)

‡ P value for species effect within month and year.

Bahiagrass is known for its tolerance to poorly drained soils conditions, and the decrease in HMA in July was not as great as the decrease in Mulato HMA. Mislevy (1985) described Pensacola bahiagrass as warm-season grass tolerant to short periods of flooding conditions. Excessive soil moisture decreases oxygen replenishment around the root system, respiration, energy production, and consequently plant growth (Salisbury and Ross, 1992). This may have caused low HMA in those months in addition to the likelihood of N leaching from the rooting zone.

Nutritive Value

There was a linear increase in CP (from 125 to 136 g kg^{-1}) and IVDOM (591 to 611 g kg^{-1}) concentrations as SR increased from 4 to 12 heifers ha^{-1}. The increased in nutritive value occurred because of the most frequent appearance of new tissues and the greater leaf: stem ratio in the greater SR treatments.

Stewart et al. (2007) reported that CP (140 vs. 99 g kg^{-1}) and IVDOM (505 vs. 459 g kg^{-1}) of bahiagrass pastures were greater for High SR (4.2 AU ha^{-1}) than Low SR (1.2 AU). Hernadez-Garay et al., (2004) also reported increase in CP and IVDOM of stargrass pastures as stocking rates increased from 2.5 to 7.5 bulls ha^{-1}. There was a stocking rate × month interaction on herbage CP and IVDOM of bahiagrass and Mulato. Herbage CP was greater for 8 and 12 heifer ha^{-1} treatments in all months but May. The lack of difference in May was likely because of the short period for detecting treatments differences after the start of the experiment. Herbage nutritive value increased from May to June in all treatments, likely because of the regrowth promoted by the greater rainfall in June. The effect of the N fertilization from April was delayed by the decreased rainfall in May and the plants likely responded to the N fertilizer in June, resulting in plants with greater CP concentrations. Positive IVDOM response to N fertilization of warm-season grasses is not consistently reported in the literature; however there are many examples of this occurring (Newman et al, 2002; Vendramini et al., 2008).

Table 3-5. Stocking rate x month interaction effects on crude protein of bahiagrass and Mulato pastures.

Stocking rate	Month					SE
	May	June	July	August	September	
heifers ha^{-1}	----------------------------	g kg^{-1}	----------------------------			
4	115 b[†]	144 a	137 a	112 b	118 b	5
8	115 c	159 a	154 a	133 b	128 b	6
12	102 c	152 a	159 a	134 b	134 b	5
Contrast[‡]	L	Q	L	L	L	
SE			6			

[†]Monthly means within stocking rate followed by the same lower case letter are not different (*P* > 0.05)

‡ Stocking rate effect within month. NS = Not significant, $P > 0.05$; L = Linear; and Q = Quadratic.

Vendramini et al. (2008) reported increases in IVDOM concentrations of Tifton 85 bermudagrass with increasing N fertilization levels from zero to 80 kg ha^{-1}harvest^{-1}). The greater IVDOM of Mulato and bahiagrass in June and July may be due to increased proportion of new leaves caused by the delayed effects of the N fertilization. There was no difference in forage CP and IVDOM concentrations between the 8 and 12 heifers ha^{-1} SR but there was a consistent decrease in nutritive value in August and September. The reduction in nutritive value in August and September is likely due to higher temperature which resulted in rapid growth and increased HMA.

Table 3-6. Stocking rate x month interaction effects on *in vitro* digestible organic matter of bahiagrass and Mulato pastures.

Stocking Rate	Month					SE
	May	June	July	August	September	
heifers ha^{-1}			--------------------g kg^{-1} --------------------			
4	589 b†	608 a	623 a	569 c	567 c	8
8	579 b	638 a	648 a	596 b	594 b	10
12	555 d	628 b	657 a	612 bc	607 c	8
Contrast‡	L	Q	L	L	L	
SE	10	10	10	9	9	

† Monthly means within stocking rate followed by the same lower case letter are not different ($P > 0.05$)
‡ Stocking rate effect within month. L = Linear; and Q = Quadratic ($P < 0.05$).

There was a year × species x month interaction on herbage CP and IVDOM concentrations (Tables 3-7 and 3-8). In 2007, there were no differences in herbage CP between species from May to August; however, Mulato had greater CP concentration in September. In 2008, Mulato had greater CP concentration than bahiagrass in May, June, and September but no differences were detected in other months. In 2007 and 2008, bahiagrass CP concentration increased from May to June with a subsequent decrease from July to September. The CP concentration of Mulato also increased from May to June, followed by a decrease in August and subsequent increase in September 2007 and 2008. The last N fertilization occurred in August and the increase in CP concentration in September was expected. The reason for the continued decrease in CP concentration in bahiagrass from July to September is not known.

Table 3-7. Year x species x month interaction effect on crude protein concentration of bahiagrass and Mulato pastures.

Year/Species	Month					SE
	May	June	July	August	September	
	------------------- g kg^{-1} -------------------					
2007						
Mulato	108 c[†]	172 a	163 a	143 b	158 a	5
Bahiagrass	104 d	165 a	154 b	130 c	111 d	5
P[‡]	0.48	0.27	0.21	0.06	<0.01	
2008						
Mulato	121 b	144 a	139 a	112 c	123 b	5
Bahiagrass	108 d	125 b	142 a	119 c	112 cd	5
P[‡]	0.05	<0.01	0.71	0.29	0.10	
SE			5			

[†]Monthly means within species followed by the same lower case letter are not different ($P > 0.05$)
[‡]*P* value for species effect within month and year

In vitro digestible organic matter concentrations were greater in Mulato than in bahiagrass pastures during the entire experimental period. An increase in IVDOM was observed from May to July with a subsequent decrease in August and September. The reason for the consistent reduction in IVDOM concentration in August and September is likely due to higher temperature which resulted in rapid growth and increased deposition of lignin which reduces digestibility (Mislevy et al. 2001; Ezenwa et al., 2006). Mulato IVDOM concentrations were greater in July, August, and September 2007 than in the same months in 2008, however, the same trend was not observed in bahiagrass. The greater IVDOM concentrations in Mulato in 2007 may be due to reduced rainfall during the experimental period (Table A, Appendix). It was observed that bahiagrass IVDOM concentration were less affected by climatic variation between years than

Mulato. Climatic factors, primarily rainfall and temperature can have significant impact on forage nutritive value (Adesogan et al., 2006).

Table 3-8. Year x species x month interaction effect on *in vitro* digestible organic matter concentration of bahiagrass and Mulato pastures.

Year/Species	Month					SE
	May	June	July	August	September	
		---------------- g kg^{-1}--------------				
2007						
Mulato	635 c†	704 b	726 a	689 b	686 b	10
Bahiagrass	487 bc	578 a	578 a	508 b	482 c	10
P‡	<0.01	<0.01	<0.01	<0.01	<0.01	
2008						
Mulato	635 d	674 b	699 a	640 c	657 c	10
Bahiagrass	538 b	541 b	567 a	530 b	529 b	10
P‡	<0.01	<0.01	<0.01	<0.01	<0.01	
SE			10			

†Monthly means within species followed by the same lower case letter are not different ($P >$ 0.05)

‡*P* value for species effect within month and year

Forage nutritive value tends to decline as forages regrow due to accumulation of stems and deposition of lignin in leaves and stems. Forage regrowth in the summer may have lower nutritive value due to increased lignin deposition associated with high temperatures, and in Florida due to increased growth rates and maturation associated with high rainfall (Adesogan et al., 2006).

Herbage Allowance

There was a quadratic effect of SR on HA of Mulato and bahiagrass pastures. Herbage allowances were 2.4, 1.0, and 0.5 kg DM kg^{-1} LW for 4, 8, and 12 heifers ha^{-1}, respectively. According to Sollenberger and Moore (1997), HA below 1.0 kg DM kg^{-1} LW is an indicator of lack of sufficient forage for ad libitum consumption. It was observed that stocking rate above 8 heifers ha^{-1} had decreased HA and likely compromised animal performance.

Table 3-9. Stocking rate x species x month interaction effect on herbage allowance of bahiagrass and Mulato pastures.

Species/Stocking rate‡	Month					SE
	May	June	July	August	September	
heifers ha^{-1}	-----------------kg DM kg^{-1} LW---------------					
Mulato						
4	2.4 c†	3.0 b	3.5 a	2.3 c	2.6 c	0.2
8	1.0 a	1.0 a	1.0 a	0.8 a	1.2 a	0.2
12	0.7 a	0.6 a	0.5 a	0.5 a	0.5 a	0.2
Contrast‡	L	L	L	L	L	
Bahiagrass						
4	2.5 a	1.5 c	2.0 b	2.6 a	1.9 bc	0.2
8	1.0 a	0.6 a	0.8 a	1.0 a	0.9 a	0.2
12	0.7 a	0.3 a	0.3 a	0.4 a	0.4 a	0.2
Contrast‡	L	L	L	L	L	
SE			0.2			

†Monthly means within stocking rate followed by the same lower case letter are not different ($P > 0.05$)

‡ Stocking rate effect within month and grass species. L = Linear ($P < 0.05$)

There was a stocking rate x species x month interaction effect on HA. The interaction occurred because there was a declined in HA of bahiagrass at 4 heifers ha^{-1} from May to June with a subsequent increase from June to August. At the same stocking rate, Mulato HA increased from May to July and declined subsequently. The increase in HA of Mulato pastures from May to July may be due to increased HMA that resulted in greater HM and consequently greater HA. The same trend was not observed in bahiagrass likely due to a smaller increase in HMA and HM. It was observed that HA was below the desirable levels (1.0 kg DM kg^{-1} LW) during the entire experimental period, on both forage species, for the 12 heifers ha^{-1} SR treatment. Herbage allowance of Mulato pastures stocked at 8 heifers ha^{-1} was below 1.0 kg DM kg^{-1} LW in August and in bahiagrass pastures in June, July, and September. This is an indication that greater HMA and HM observed in Mulato pastures correlated with greater HA levels throughout the experimental period for the 8 heifers ha^{-1} SR .

Table 3-10. Year x month interaction effects on herbage allowance of bahiagrass and Mulato pastures.

Year	Month					SE
	May	June	July	August	September	
	----------- kg DM kg $^{-1}$LW --------------					
2007	1.8 a†	1.2 b	1.6 a	1.8 a	1.6 a	0.1
2008	1.0 ab	1.2 a	1.1 ab	0.7 c	0.9 bc	0.1
P‡	<0.01	0.68	<0.01	<0.01	<0.01	
SE			0.1			

† Monthly means within year followed by the same lower case letter are not different (P>0.05)
‡ P value for year effect within month

There was a year x month interaction on HA of Mulato and bahiagrass pastures (Table 3-10). Herbage allowance was greater in 2007 than in 2008 for May, July, August, and September except in the month of June when HA was the same in 2008. The decreased HA in 2008 occurred because of the decreased HMA caused by above average rainfall. The interaction occurred because there was a decrease in HA in 2008 from July to August and in 2007, the HA was constant from July to September.

Average Daily Gain

There was no effect of grass species on ADG (P = 0.32) nor was there species x SR interaction (P = 0.83). There was a nonlinear correlation between HA and ADG (Fig. 3-1). Average daily gain increased with increasing HA up to 1.2 kg DM kg^{-1}LW, and remained constant at ADG at ~ 0.28 kg d^{-1} when HA was above 1.2 kg DM kg^{-1}LW. The close relationship between HA and ADG supports the conclusion that the major factor affecting gains at high SR was herbage quantity. Parkin and Boultwood (1981) also observed that HA was the main

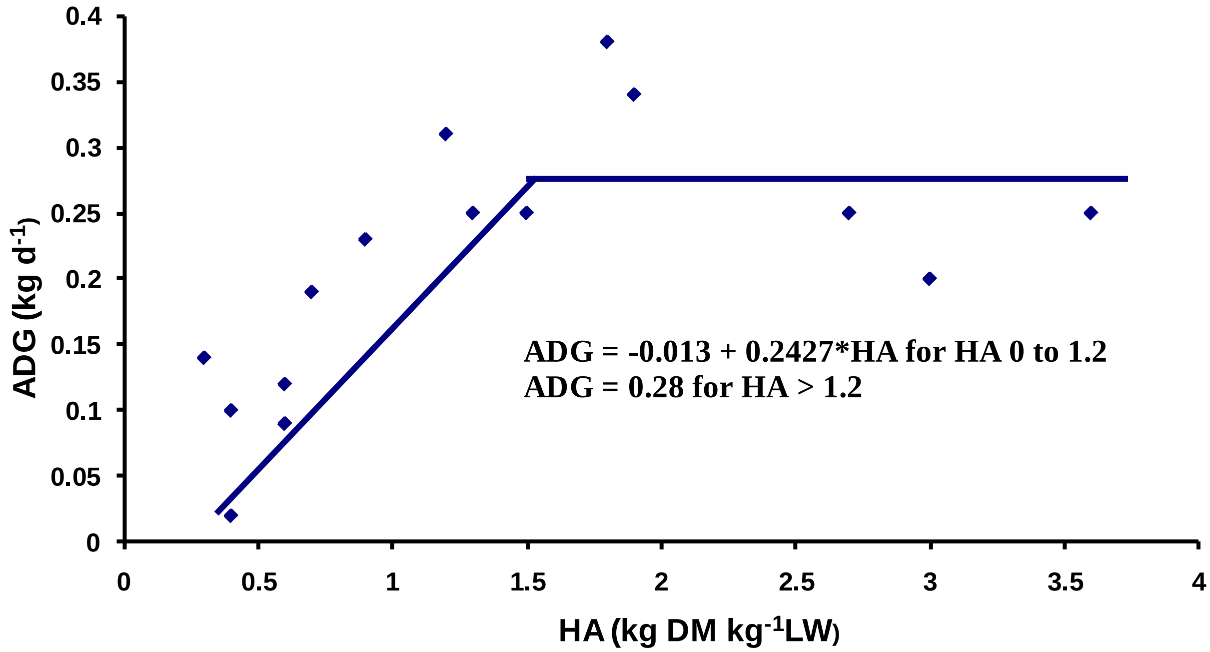

Figure 3-1. Nonlinear correlation between HA and ADG for Mulato and bahiagrass pastures stocked at 4, 8, and 12 heifers ha^{-1}.

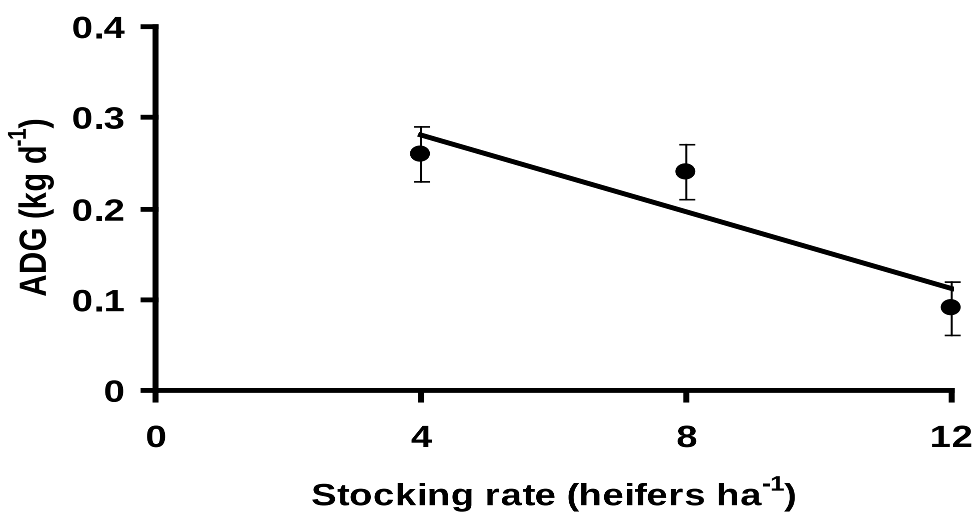

Figure 3-2. Average daily gain of heifers Mulato and bahiagrass pastures stocked at 4, 8, and 12 heifers ha^{-1}.

factor determining animal production on stargrass pastures. For continuously stocked pearl millet [*Pennisetum glaucum* (L.) R. Br.], no increase in ADG above an HA of 3.3 was observed (McCartor and Rouquette, 1977).

There was a decrease in ADG from May to August for the heifers stocked at 4 and 8 heifers ha^{-1} treatments on bahiagrass and Mulato pasture, however, the decrease was greater for heifers grazing bahiagrass pastures. The decrease in ADG later in the experimental period is likely due to a combination of water standing on the pasture, which caused discomfort of the animals, and decreasing nutritive value of the forage. During periods with frequent rainfall, animals reduce grazing time thereby reducing DM intake (Butris and Phillips, 1987).

A year x month interaction effect was observed on ADG of heifers grazing bahiagrass and Mulato pastures (Table 3-11). The interaction occurred because heifers grazing bahiagrass pastures had greater ADG in May 2008 but a more rapid decrease in ADG in 2008 than 2007. The reason for the greater decrease in ADG in 2008 was likely because of excessive rainfall (Table A-1) and water standing in the pastures that likely caused discomfort of the animals. Despite greater HM, ADG was consistently lower in 2008.

Table 3-11. Year x month interaction effects on ADG of Mulato and bahiagrass pastures.

Year‡	Month†				SE
	May	June	July	August	
	------------------kg d^{-1}----------------				
2007	0.66 a	0.09 b	0.13 b	-0.12 c	0.05
2008	1.03 a	0.12 b	-0.23 c	-0.07 c	0.05
P‡	<0.01	0.75	<0.01	0.55	
SE		0.05			

† Monthly means within year followed by the same lower case letter are not different (P>0.05)
‡ *P* value for year effect within month

There was a species × SR × month interaction on ADG of heifers grazing Mulato and bahiagrass pastures (Table 3-12). It was observed that animals grazing pastures stocked at the 12 heifers ha^{-1} SR presented decreased performance throughout the experimental period compared to 4 and 8 heifers ha^{-1}, primarily because of the limited forage quantity mentioned previously. The only exceptions were observed in May and August. The animals had greater ADG in May was possibly due in part to residual of gut fill effects resulting from the transition of the animals from cool-season annual pasture to warm-season grass pasture.

Table 3-12. Stocking rate x species x month interaction effects on ADG of Mulato and bahiagrass pastures.

Species/Stocking rate‡	Month				SE
	May	June	July	August	
heifers ha^{-1}	---------------- kg d^{-1}------------				
Mulato					
4	0.79 a†	0.18 b	0.22 c	-0.05 d	0.08
8	0.83 a	0.23 b	0.18 b	-0.15 c	0.1
12	0.74 a	-0.07 b	-0.33 c	0.07 b	0.08
Contrast‡	Q	Q	L	L	
Bahiagrass					
4	1.05 a	0.20 b	-0.33 d	-0.02 c	0.08
8	0.85 a	0.15 b	0.02 bc	-0.11 c	0.1
12	0.83 a	-0.06 b	-0.09 bc	-0.32 c	0.08
Contrast‡	L	L	Q	L	
SE	0.08	0.08	0.09	0.09	

†Monthly means within stocking rate followed by the same lower case letter are not different (*P* > 0.05)

‡ Stocking rate effect within month and grass species. L = Linear; and Q = Quadratic (*P* > 0.05).

Gain per Hectare

There was a quadratic effect of SR on GHA for bahiagrass and Mulato with means of 190, 353, and 218 kg ha^{-1} for 4, 8, and 12 heifers ha^{-1} respectively. The SR of 8 heifers ha^{-1} resulted in the greatest GHA. Understocked pastures accumulate excess forage that becomes lower in nutritive value resulting in low gain per unit land area (Mott and Lucas, 1952).

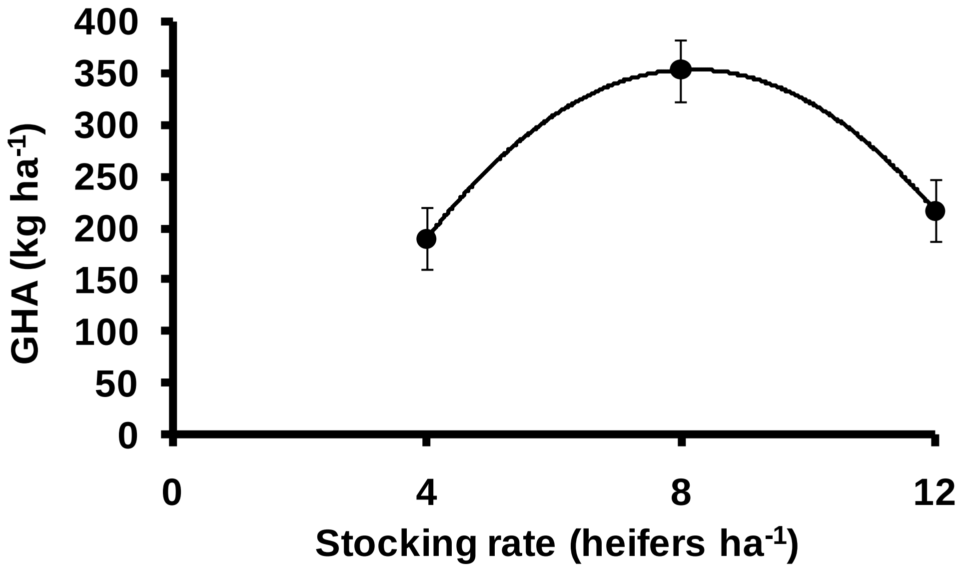

Figure 3-3. Gain per ha of heifers grazing Mulato and bahiagrass pastures stocked at 4, 8, and 12 heifers ha-1.

Hernandez Garay et al. (2004) studied the effect of stocking rate on weanling bulls grazing stargrass. Animal ADG decreased quadratically with increasing stocking rate from 1.3 to 3.8 AU (500 kg LW) ha^{-1}. The GHA was maximized at stocking rates of ~ 2.5 AU ha^{-1}.

Summary and Conclusions

Mulato had greater HM at all SR than bahiagrass. Herbage mass accumulation was the greatest at 8 heifers ha^{-1}for both grasses. Mulato showed greater HMA than bahiagrass in May, June, and August. In September, the greater HMA resulted in decreased CP and IVDOM concentrations. In general, CP and IVDOM of Mulato were greater in August and September than in May.

Herbage CP concentration of Mulato was not affected by SR in May, July and August, but was greater at 8 than 4 heifers ha^{-1} in June and September. In vitro digestible organic matter concentrations were greater at 8 than 4 heifers ha^{-1} across the grazing period except in May. Mulato had greater IVDOM than bahiagrass throughout the experimental period.

Stocking rate was the most influential factor in GHA and ADG. Increasing SR from 4 to 12 heifers ha^{-1} linearly decreased ADG. Gain per hectare was the greatest at 8 heifers ha^{-1}. There were no conclusive differences on ADG and GHA among species. Year and month significantly impacted ADG.

In general, Mulato had superior HM, HMA, and nutritive value than bahiagrass; however, it was observed that Mulato was more negatively impacted by flooded soils than bahiagrass. The slightly superior forage HMA and nutritive value of Mulato did not result in greater animal performance. Stocking rate was the primary determinant of animal performance on Mulato and bahiagrass pastures.

There is potential of using Mulato as an alternative forage for bahiagrass pastures in South Florida, however, Mulato should be planted in areas with well-drained soils and grazed at SR which allow HA of 1.2 kg DM kg^{-1} LW or greater.

CHAPTER 4
EFFECT OF STUBBLE HEIGHT AND HARVEST FREQUENCY ON FORAGE PRODUCTION AND NUTRITIVE VALUE OF *BRACHIARIA* CV. MULATO

Introduction

Bahiagrass (*Paspalum notatum* Flügge) has been the primary forage species used for beef cattle producers in Florida due to its wide environmental adaptation and tolerance to minimal management inputs. However, more than 150,000 ha of bahiagrass pastures were damaged by mole cricket (*Scapteriscus* spp.) in Florida between 1996 and 2000 (Adjei et al. 2001). Damage to bahiagrass pastures by armyworms (*Pseudaletia unipuncta*), grasshoppers (*Melanoplus differentialis*), and loss of stands due to mole crickets has stimulated a search for other grasses adapted to the South Florida environment.

Brachiaria species are popular among producers in tropical areas of the world because they show rapid regrowth and good persistence under heavy or frequent defoliation (Rika et al., 1991). A hybridization program was initiated at the Centro Internacional de Agricultura Tropicale (CIAT) with the objective to produce improved brachiariagrass cultivars with outstanding agronomic characteristics, greater range of adaptation, higher biomass production and nutritional quality, and resistance to *Rhizoctonia* and multiple spittlebug species. This effort generated an apomictic hybrid, Mulato (CIAT, 2000) which is the first hybrid in the *Brachiaria* genus.

Although, Mulato does not tolerate variations in edaphic and climatic conditions as well as bahiagrass does, it is adapted to the infertile soils of Central and South America. According to Peters et al. (2003), Mulato produced 25% more dry matter yield (DMY) than palisadegrass (*Brachiaria brizantha*) and signalgrass (*Brachiaria humidicola*), increasing animal productivity from 1 to 2 kg milk cow^{-1} d^{-1} over that achieved on 'Marandu' or 'Toledo' palisadegrass. Moreover, Mulato has shown superior nutritive value when compared to other brachiarias

(CIAT, 2006). Mulato is known for its tolerance of prolonged drought and rapid recovery after sporadic frost (Argel et al., 2005). Because of these desirable characteristics, Mulato may be a potential warm-season grass for use in South Florida forage livestock systems.

Production and nutritive value of warm-season grasses are greatly affected by management practices, including regrowth interval and stubble height. Forage quality tends to decline as forages mature due to accumulation of stems and deposition of lignin in leaves and stems (Adesogan et al., 2006). Arthington and Brown (2003) reported that increasing Pensacola bahiagrass regrowth interval from 4 to 10 wk resulted in decreased CP and digestibility. Additionally, forage regrowth in the summer may have lower quality due to increased lignin deposition associated with high temperatures, and in Florida due to increased growth rates and maturation associated with high rainfall (Adesogan et al., 2006). Brown and Mislevy (1988) reported summer yields of Pensacola were greater than spring yields, but crude protein (CP) and in vitro digestible organic matter (IVDOM) concentrations were lower.

Chaparro and Sollenberger (1997) reported frequent defoliation to short stubble height resulted in greatest IVDOM of ‘Mott’ elephantgrass (*Pennisetum purpureum* Schum.), while herbage harvested infrequently to short stubble was least digestible. When defoliated frequently, most of the harvested material of elephantgrass consisted of leaf blade and less leaf sheath and stem (Chaparro et al., 1995). Beaty et al. (1970) indicated that close clipping (0 to 2.5 cm) of ‘Pensacola’ bahiagrass produced highest DMY; however, stand deterioration was evident with frequent harvests. Mislevy and Everett (1981) found that total DMY of Pensacola and ‘Argentine’ bahiagrasses were greater at a 5- than a 10-cm stubble height, while Beaty et al. (1968) reported total DMY of Pensacola generally increased as stubble height decreased across six stubble heights. Similarly, Pedreira and Brown (1996) reported that annual yields of Pensacola and 'Tifton 9' were greater at 3.5 than 10 cm.

Frequent defoliation may have negative effects on plant persistence. Stem base, rhizome, stolon, and root mass are generally depleted under conditions of frequent and severe defoliation (Chambliss, 1999; 2000; and 2006). According to Youngner (1972), root growth is generally reduced by defoliation as results of the reduction of photosynthetically active tissue and shortage of carbohydrates for root growth.

Therefore, it is important to establish warm-season perennial grass pastures that tolerate different defoliation regimens while maintaining forage production, persistence, and nutritive value. The general objective of this study was to evaluate the effect of harvest management strategies on Mulato. The specific objectives of this study were to evaluate the effects of stubble height and regrowth interval on nutritive value, herbage mass accumulation, and persistence of Mulato.

Materials and Methods

Experimental Site

This experiment was conducted at the University of Florida Range Cattle Research and Education Center (RCREC), Ona, FL ($27^{o}26'$N, $82^{o}55'$W) from 17 Aug. to 9 Nov. 2007. The soil at the research site was classified as sandy siliceous, hyperthermic Alfic Alaquod (EauGallie sand). These sandy soils are poorly drained with slow permeability. Prior to initiation of the clipping study, mean soil pH (in water) was 6.3. Mehlich-I (0.05-*M* HCl + 0.0125-*M* H_2SO_4) extractable P, K, Mg, and Ca in the Ap1 horizon (0- to 15-cm depth) were 22, 63, 128, and 980 mg kg^{-1}.

Treatments and Experimental Design

Treatments were the factorial arrangement of three stubble heights (2.5, 7.5, and 12.5 cm) and two harvest frequencies (2 and 4 wk) in a randomized complete block design with four replicates. Mulato plots were planted in May 2007 using the seeding rate of 10 kg ha^{-1}. In July 2007, the plots received 40 kg N ha^{-1}, 17 kg P ha^{-1}, and 66 kg K ha^{-1} to stimulate growth and provide maintenance P and K. An additional 40 kg N ha^{-1} was applied after every 28-d harvest. Total-season N fertilization was 120 kg N ha^{-1}.

Forage Measurements

Plot size was 3 x 2 m with 1-m alley between plots. Plots were staged to the treatment stubble heights on 17 Aug. 2007. At harvest dates, herbage was clipped to the target stubble height from two representative 0.25-m^2 quadrats per plot. Remaining herbage was clipped to the same stubble height using a sickle bar mower and removed.

Herbage accumulation data are presented by month and data from a given month are the total of one harvest of 4-wk treatments or 2 harvests of the 2-wk treatment. Forage samples were dried at 60^{o}C to a constant weight, weighed, and ground in a Wiley mill (Model 4 Thomas-Wiley Laboratory Mill, Thomas Scientific, Swedesboro, NJ). Herbage N concentration was determined by combustion using a N analyzer (Flash EA 1112 Series) and CP calculated as N x 6.25. The in vitro digestible dry matter concentration (IVDDM) was determined using the ANKOM (2005) adaptation of the Van Soest et al. (1966) method in an ANKOM Daisy ^{II} Incubator and ANKOM 200 Fiber Analyzer (ANKOM Technology, Macedon, NY) .

Mulato cover was determined visually by two observers at the end of the experimental period using a 1-m^2 quadrat divided into 10-cm x 10-cm squares.

Statistical Analysis

Response variables were proportion of Mulato coverage, HMA, CP, and IVDDM concentration. The data were analyzed using PROC MIXED of SAS (SAS Institute Inc., 2006) with stubble height, regrowth interval, month, and their interactions were fixed effects. Month was considered a repeated measure. Block and its interactions were random effects. Single degree of freedom orthogonal polynomial contrast was used to test stubble height effects. Treatments were considered different when $P < 0.05$. Interactions not mentioned in the text were not significant ($P > 0.05$). The means reported are least squares means and were compared using PDIFF (SAS Institute Inc., 2006).

For plot variables, the model used was:

$$Y_{ijkl} = \mu + P_i + S_j + H_k + B_m + (PS)_{ij} + (PH)_{ik} + (SH)_{jk} + (PSH)_{ijk} + e_{ijk}$$

Where Y_{ijkl} is the dependent variable
μ is the overall mean
S_j is the stubble height effect (main plot)
H_k is the regrowth interval effect (main plot)
P_i is the month effect (sub-plot)
B_m is the block effect
$(SH)_{jk}$ is the stubble height x regrowth interval interaction
$(PS)_{ij}$ is the month x stubble height interaction
$(PH)_{ik}$ is the month x regrowth interval interaction
$(PSH)_{ijk}$ is the month x stubble height x regrowth interval interaction
e_{ijkm} is the error

Results and Discussion

Herbage Mass Accumulation

There was a decrease in HMA from 2.6 to 1.9 Mg ha^{-1} as stubble height increased from 2.5 to 12.5 cm. The quadratic effect occurred because HMA decreased from 2.5 to 7.5 cm but then remained relatively constant. Hidalgo (2004) found similar trends in the effects of stubble height on HMA of Mulato in South America. There was no difference in Mulato HMA when harvested above 7.5 cm stubble height (0.13 Mg ha^{-1} d^{-1} at 10- cm and 0.14 Mg ha^{-1} d^{-1} at 20- cm stubble).

Gates et al. (1999) reported that lower cutting stubble heights resulted in greater HMA in bahiagrass plots. Herbage mass accumulation was maximized by cutting at lower stubble height and 8-wk regrowth interval (7.0 Mg ha^{-1}) in the first year, however, the 4-wk regrowth interval and low cutting height produced the greatest yield (11.2 Mg ha^{-1}) in the second year. Corroborating with the current study, the authors concluded that stubble height consistently affected HMA.

There was a regrowth interval × month interaction for HMA. The interaction occurred because HMA declined from 3.0 to 0.8 Mg ha^{-1} from August to October when harvested at 2 wk, however, HMA increased from August to September and subsequently decreased in October in the 4-wk treatment. The 4-wk regrowth interval had greater HMA than the 2-wk in September, less in August, and similar in October (Table 4-1). Shorter daylengths and lower temperatures (Table 1, Appendix A) likely decreased Mulato growth from August to October (Sinclair et al., 2003). Hidalgo (2004) reported that Mulato had greater HMA when cut every 35 d (4.6 Mg ha^{-1}) compared to 28 d (4.0 Mg ha^{-1}) and 21 d (2.6 Mg ha^{-1}) regrowth intervals. In addition, below–average rainfall (more than 25.7 mm less than normal) may have contributed to decreased HMA in October.

Table 4-1. Regrowth interval x month interaction effects on herbage mass of Mulato forage.

Regrowth interval	Month† August	September	October	SE
wk	----------------Mg ha^{-1}------------			
2	3.0 a†	2.6 b	0.8 c	0.1
4	2.5 b	3.2 a	1.0 c	0.1
P‡	<0.01	<0.01	0.28	
SE		0.1		

† Monthly means within regrowth interval followed by the same lower case letter are not different ($P > 0.05$).
‡ *P* value for effect of regrowth interval within month.

Mislevy and Everett (1981) found that total DM yields of Pensacola bahiagrass and koroniviagrass (*Brachiaria humidicola*) were greater at 5- than 10-cm stubble when clipped every 30 d. Koroniviagrass showed no difference in yield (2.9 Mg ha^{-1}) than Pensacola (2.5 Mg ha^{-1}) at the 5- cm stubble height. There was also no difference in DM yield (1.8 Mg ha^{-1}) at 10 cm between both grasses.

Forage Nutritive Value

There was a regrowth interval × stubble height and regrowth interval x month interactions on herbage CP concentration. Herbage CP of Mulato was the greatest when cut to 2.5 cm at 2-wk regrowth interval and the least when cut to 12.5 cm at 4- wk regrowth interval (Table 4-2). The regrowth interval x stubble height interaction occurred because there was a linear decline in CP concentration from 200 to 160 g kg^{-1} as stubble height increased from 2.5 to 12.5 cm at the 2-wk regrowth interval. Stubble height did not affect CP concentrations at the 4- wk regrowth interval. Herbage CP was greater at 2- wk compared with 4- wk regrowth interval at all stubble heights. The more frequent harvest at shorter stubble heights resulted in a greater proportion of new leaf tissue and decreased appearance of stems, resulting in plant material with greater CP concentration.

Table 4-2. Regrowth interval x stubble height interaction effects on crude protein of Mulato forage

Regrowth interval	Stubble height (cm)			Contrast
	2.5	7.5	12.5	
wk		g kg^{-1}		
2	200	180	160	L
4	130	130	120	NS
$P^{‡}$	<0.01	<0.01	<0.01	
SE		6		

† Effect of stubble height within regrowth interval; NS = Not significant ($P > 0.05$); L = Linear, ($P < 0.05$).

‡ P value for regrowth interval effect within a stubble height.

Crude protein concentration of Mulato decreased as regrowth interval increased. This response was similar to that reported by Hidalgo (2004) who found that CP decreased from 100 to 92 g kg^{-1} as harvest interval of Mulato was delayed from 21 to 35 d. Vendramini et al. (2008) found that there was a linear increase in CP concentration of Tifton 85 bermudagrass (*Cynodon* sp.) with increasing N fertilization, but the rate of increase was greater for the 2- than the 4-wk regrowth interval.

Herbage CP was affected by a regrowth interval × month interaction (Table 4-3). When harvested at 2 wk, herbage CP was greater across all months compared to harvests at 4 wk. The interaction occurred because there was no difference in herbage CP between harvests in August and October at the 2- wk regrowth interval. However, herbage CP concentration increased from August to October when forage was harvested at a 4- wk regrowth interval. Herbage CP was lowest at both 2 and 4 wk in September. The greater CP concentration in October may be due to decreased HMA and less of a N dilution effect. Similar results were reported by Vendramini et al. (2008) with Tifton 85 bermudagrass. Tifton 85 had greater CP concentration when harvested at a 2- wk than a 4- wk regrowth interval (160 vs. 120 g kg^{-1} for 2 and 4 wk, respectively).

Table 4-3. Regrowth interval x month interaction effects on crude protein of Mulato forage.

Regrowth interval	Month† August	September	October	SE
wk	------------g kg^{-1}------------			
2	190 a†	170Ab	190 a	4
4	130 b	110 c	150 a	4
P‡	<0.01	<0.01	<0.01	
SE		4		

† Monthly means within regrowth interval followed by the same lower case letter are not different ($P > 0.05$).
‡ *P* value for effect of regrowth interval within month.

Arthington and Brown (2005) found that increased forage maturity (10-wk regrowth) was associated with 38% lower CP concentration compared with harvesting at 4-wk regrowth, when averaged across several different species of warm-season grasses. Arthington and Brown (2003) also reported that increases in Pensacola maturity from 4- to 10-wk regrowth resulted in decreased CP and digestibility. Haddad et al. (1999) reported a decline in CP of Pensacola bahiagrass from 20 to 50 d of regrowth after cutting (from 145 to 97 g kg^{-1}). The decrease in CP concentration at longer regrowth intervals in warm-season grasses is attributed to N dilution effects caused by greater HMA and associated deposition of cell wall.

There was a linear decrease in CP concentration from 170 to 140 g kg^{-1} as stubble height increased from 2.5 to 12.5 cm. There was a stubble height × month interaction on herbage CP of Mulato. The CP of Mulato was greatest when cut in October at 2.5 cm and least when cut in September at 12.5 cm. There was a linear decline in CP concentration as stubble height increased from 2.5 to 12.5 cm in all months. The reason for consistent reduction in CP in September is due to higher temperature which resulted in rapid growth and increased HMA.

Table 4-4. Stubble height x month interaction effects on crude protein concentration of Mulato forage.

Stubble height	Month			SE
	August	September	October	
cm	------------------g kg^{-1}----------------			
2.5	170 b[†]	150 c	190 a	5
7.5	160 b	140 c	170 a	5
12.5	140 b	130 c	150 a	5
Contrast[‡]	L	L	L	
SE		5		

[†] Monthly means within stubble height followed by the same lower case letter are not different ($P > 0.05$).

[‡] Effect of stubble height on CP concentration within month; L = Linear ($P < 0.05$).

A similar trend in nutritive value was reported by Mislevy et al. (2005) on bahiagrass plots. The greatest bahiagrass CP concentrations were reported in the fall, October (157 g kg-1) and

December (177 g kg-1), while lowest CP was always found in the summer (June, 113 g kg-1; August, 122 g kg-1).

There was a regrowth interval × month interaction on IVDDM. Herbage digestibility of Mulato was the greatest in October and the least in September at the 4- wk regrowth interval (Table 4-5). Mulato had the greatest IVDDM concentrations in October due to slower growth rates, lower growth temperature and less mature herbage. The presence of a higher proportion of young, less mature leaf and stems resulted in greater IVDDM for the 2- wk than 4- wk regrowth interval in August and September, but in October the response was reversed, likely associated with slower forage growth rates that month. There was an increase in IVDDM as time progressed from August to October at 2- wk regrowth interval (Table 4-5). A quadratic trend was observed for IVDDM harvested at 4-wk regrowth interval. The digestibility was 690 g kg^{-1} in August, decreased to 660 g kg^{-1} in September and increased to 780 g kg^{-1} in October.

Table 4-5. Regrowth interval x month interaction effects on *in vitro* digestible dry matter concentration of Mulato forage.

Regrowth interval	Month			SE
	August	September	October	
wk	----------------g kg^{-1}----------------			
2	710 b†	740 a	740 a	8
4	690 b	660 c	780 a	8
P‡	0.04	<0.01	<0.01	
SE		8		

† Monthly means within a regrowth interval followed by the same lower case letter are not different ($P > 0.05$).
‡ *P* value for effect of regrowth interval within month.

Arthington and Brown (2005) reported decreased IVDOM when harvest was delayed from 4 to 10 wk (average IVDOM decrease = 11, 9, and 62 g kg^{-1} for bahiagrass, bermudagrass, and stargrass, respectively. Haddad et al. (1999) reported a decline in IVDDM of Pensacola bahiagrass from 20 to 50 d of regrowth after cutting from 678 to 448 g kg^{-1}. Gates et al. (1999)

reported that forage IVDMD ranged from more than 600 g kg^{-1} early in the season to 400 g kg^{-1} or less by the end of the growing season for Pensacola, Tifton 9, and RRPS cycle 14. Cuomo et al. (1988) observed a quadratic trend in IVDDM response to harvest frequency of three cultivars of bahiagrass. Digestibility declined from 595 (20 d) to 587 (30 d) and increased slightly to 592 g kg^{-1} (40 d) when harvest at 5 cm stubble height.

There was a stubble height × month interaction on IVDDM concentrations of Mulato (Table 4-6). For all stubble heights, IVDDM concentration increased from August to October, but the increase was greater for the 2.5 cm stubble height treatment than the others. The decreased HMA in October and cooler weather resulted in less mature, more digestible material.

Table 4-6. Stubble height x month interaction effects on *in vitro* digestible dry matter concentration of Mulato forage.

Stubble height	Month			SE
	August	September	October	
cm	--------------g kg^{-1}----------------			
2.5	660 b†	660 b	750 a	10
7.5	710 b	710 b	780 a	10
12.5	720 b	720 b	750 a	10
Contrast‡	L	L	Q	
SE		10		

† Monthly means within stubble height followed by the same lower case letter are not different ($P > 0.05$).

‡ Stubble height effect within month; L = Linear ($P < 0.05$); and Q = Quadratic ($P < 0.05$).

These results agree with Mislevy et al. (2005) who reported greatest bahiagrass IVDOM in October (542 g kg-1) and December (587 g kg-1), while lowest IVDOM was always found in July (467 g kg-1) and August (482 g kg-1).

There was regrowth interval × stubble height interaction for Mulato ground cover (Table 4-7). Continuous clipping of Mulato at a 2- wk interval at 2.5- cm stubble height tended to decrease persistence and increase bare ground. There was no difference in Mulato cover associated with clipping every 2 to 4 wk at 2.5 cm, but there was an increase in Mulato ground cover when harvested at 4 wk compared to 2 wk at 7.5 cm stubble height. Increasing stubble height from 7.5 to 12.5 increased the ground cover of Mulato at 2 wk regrowth interval, but there was no difference in ground cover between 7.5 to 12.5 cm stubble heights at 4 wk regrowth interval.

According to Beaty et al. (1970), Pensacola bahiagrass stands were gradually reduced after frequent clipping due to a reduction in root and stolon mass and subsequent reduction in nonstructural carbohydrates available for regrowth.

Table 4-7. Regrowth interval x stubble height interaction effects on percentage cover of Mulato.

Regrowth interval	Stubble height (cm)			SE
	2.5	7.5	12.5	
Wk	------------- % -------------			
2	63 b†	67 b	91 a	4
4	70 b	86 a	84 a	4
P‡	0.20	<0.01	0.15	
SE		4		

† Stubble height means within a regrowth interval followed by the same lower case letter are not different ($P > 0.05$).
‡ *P* value for effect of regrowth interval within stubble height.

Mislevy and Everett (1981) reported Pensacola and Argentine stands harvested to 10 cm every 30 d had superior stand persistence and minimal weed encroachment than plants harvested to 5 cm. Mislevy at al. (1989) studied the responses of three stargrasses to treatment combinations of grazing intensity (stubble heights of 5-25 cm) and frequency (pastures grazed at plant heights above stubble ranging from 0-60 cm). The authors concluded that stubble height was the primary factor that affected persistence of stargrass. Allowing a postgraze stubble height of 15-25 cm resulted in lowest weed cover for all cultivars.

Summary and Conclusions

Mulato had greater HMA when harvested at shorter stubble. The effects of regrowth interval on HMA were not conclusive in the first year of defoliation. Monthly HMA of Mulato was greater at 2 than 4 wk regrowth interval.

In general, CP and IVDDM of Mulato were greater in October than August and September. Herbage CP concentration of Mulato was greater at 2 than 4 wk regrowth interval, regardless of stubble height. In vitro digestible dry matter concentrations were greater at 2 than the 4 wk regrowth interval through the experimental period except in October.

Stubble height was the most influential factor in Mulato persistence. The 2.5- cm stubble height treatment resulted in the least Mulato cover, regardless of the regrowth interval. When harvested at 7.5- cm stubble height, the 4- wk regrowth showed superior cover than the 2- wk regrowth interval.

The results from this study imply that harvesting Mulato in August and September at 7.5 cm stubble every 4 wk regrowth interval enhances HMA while maintaining the Mulato stand. Conversely, harvesting Mulato at 2.5- cm stubble height increases its HMA but decreases Mulato stands. The 2- wk regrowth interval resulted in forage with greater nutritive value. The decision of the regrowth interval to harvest Mulato is dependent on the nutrient requirements of the animals that will consume the forage.

CHAPTER 5
SUMMARY AND CONCLUSIONS

Bahiagrass has been the primary warm-season pasture grass used in cow-calf production systems in Florida due to its wide environmental adaptation and tolerance to minimal management inputs. However, there is a necessity to evaluate warm-season grasses with potential to complement bahiagrass forage systems. Brachiaria cv. Mulato does not tolerate variations in edaphic and climatic conditions as well as bahiagrass, but it is adapted to the infertile soils of Central and South America and merits evaluation in Florida.

Production and nutritive value of warm-season grasses are greatly affected by management practices, such as regrowth interval and stubble height. Regrowth interval and season of year play major roles in determining forage nutritive value. Forage nutritive value tends to decline as forages regrow due to accumulation of stems and deposition of lignin in the cell wall of leaves and stems (Adesogan et al., 2006). Warm-season grasses decrease crude protein (CP) and in vitro digestible organic matter (IVDOM) concentrations with advancing maturity (Ball et al., 2001), primarily due to reproductive stem elongation (Coleman et al., 2004). Forage regrowth in the summer may have lower quality due to increased lignin deposition associated with high temperatures, and in Florida due to increased growth rates and maturation associated with high rainfall (Adesogan et al., 2006).

On grazed pasture, stocking rate has a profound effect on forage characteristics and animal performance (Burns et al., 1989). It is important to understand the effects of defoliation intensity on plant persistence, productivity, and nutritive value in order to develop best management recommendations for grazing systems (Chaparro et al., 1995, 1996).

The objectives of this study were i) to determine forage characteristics and animal performance of heifers grazing Mulato and bahiagrass pastures (Chapter 3); and ii) to determine the effects of defoliation management on herbage production, nutritive value, and persistence of Mulato (Chapter 4). The overall goal of the research effort was to assess the potential of using Mulato in grazing systems and develop a range of management practices to optimize the utilization of Mulato in South Florida.

Mulato and Bahiagrass Grazing Study

Herbage Yield and Nutritive Value

The periods of the grazing trial were from 18 May through 10 Sept. 2007 (116 d) and 19 May through 9 Sept. 2008 (114 d). Treatments were the factorial arrangement of three stocking rates [4, 8, and 12 heifers (LW = 350 ± 21 kg) ha^{-1}] and two forage species (Mulato and bahiagrass) in a randomized incomplete block design with three replicates for 4 and 12 heifers ha^{-1} and two replicates for the 8 heifers ha^{-1} treatment. Pastures were 0.25 ha and were stocked continuously.

Double sampling was used to determine herbage mass (HM). For laboratory analyses, harvested samples collected every 14 d were analyzed for IVDOM and N concentration. Because these pastures were stocked continuously, a cage technique was used to measure herbage accumulation. Three 1-m^2 cages were used per pasture, and disk settling height was recorded at specific sites where cages were placed. Herbage allowance (HA) was calculated for each pasture as the average herbage mass (mean across two sampling dates within each 28-d period) divided by the average total heifer live weight during that period (Sollenberger et al., 2005). Cattle were weighed at the initiation of the experiment and every 28 d thereafter. Average daily gain and gain per hectare was calculated each 28-d period through the entire grazing season.

There was a linear decrease in HM as stocking rate increased. Mulato and bahiagrass HM were affected by climatic variation during experimental period. Mulato had greater HM than bahiagrass in the early months of the experimental period but presented similar HM in August and September. It was observed that Mulato decreased HM in greater magnitude than bahiagrass in conditions of excessive soil moisture. In addition, pastures stocked at 12 heifers ha^{-1} had a more pronounced decrease in HM from May to September than the other stocking rate treatments. In 2008, pastures had greater HM in May, June, and July than in 2007. This occurred because of more favorable rainfall conditions in 2008. On the other hand, HM increased from July to September in 2007, but a decrease was observed during the same period in 2008.

There was a quadratic effect of stocking rate on HMA. Herbage mass accumulation was greatest at the 8 heifer ha^{-1} stocking rate treatment. Mulato had greater HMA than bahiagrass during the experimental period. Bahiagrass increased HMA from May to June and July with a subsequent decrease in August. There was no difference in monthly HMA of Mulato in 2007. However, there was a significant decrease from June to August in 2008. The decreased occurred because of the excessive soil moisture conditions mentioned previously. Mulato showed greater HMA than bahiagrass in May, June, and August. In 2008, HMA of Mulato decreased linearly from June to August because of the excessive soil water concentration that limited plant growth.

There was a linear decrease in CP and IVDOM concentrations of Mulato and bahiagrass as stocking rates increased from 4 to 12 heifers ha^{-1}. Herbage CP concentration of Mulato and bahiagrass was greater in the first year than in the second year. Mulato showed greater herbage CP concentration than bahiagrass in September in both years. Mulato had greater IVDOM than bahiagrass throughout the entire experimental period.

Animal Performance

Herbage allowance (HA) decreased below 1.0 kg dry matter (DM) kg^{-1} liveweight (LW) when stocking rate was raised above 8 heifers ha$^{-1.}$ This likely compromised animal performance and was consistent with previous observations which indicate lack of sufficient forage for ad libitum consumption at this HA (Sollenberger and Moore, 1997).

There was a linear decrease in average daily gain (ADG) with increasing SR from 4 to 12 heifers ha^{-1}. There was significant reduction in ADG on bahiagrass and Mulato pastures by mid-summer. The decrease in ADG later in the experimental period is likely due to a combination of water standing on the pasture, which caused discomfort of the animals, and decreased forage nutritive value. Average daily gain was the greatest at 8 least at 12 heifers ha^{-1}. Gain per hectare was the greatest at 8 heifers ha^{-1}. Under stocked pastures accumulate forage that becomes both underutilized and hence the low gain per unit land area basis (Mott and Lucas, 1952). There were no conclusive differences in ADG and GHA between species.

Defoliation Management Response

Treatments were the factorial combinations of two regrowth intervals (2 and 4 wk) and three stubble heights (2.5, 7.5, and 12.5 cm) evaluated in 1 yr. Treatments were replicated four times in a completely randomized design. Mulato plots were planted in May 2007. Plot size was 3 x 2 m with a1-m alley between plots. Plots were staged to a 15-cm stubble on 17 Aug. 2007. Herbage accumulation data were reported for a given 4- wk period based on one harvest of the 4-wk treatment and two harvests of the 2-wk treatment. For laboratory analyses, harvested samples were analyzed for IVDOM and N concentration. Mulato cover was quantified at the start and end of the experimental period to determine stand persistence.

Herbage Mass Accumulation and Nutritive Value

Mulato produced low yield in early fall and excellent yield during summer. The decline in yield in autumn can be attributed to shorter daylengths (Sinclair et al., 2003) and possibly to the below–average rainfall (26 mm less than normal in October). The rate of decline in yield toward autumn was less at a 2- wk lowest frequency than at 4 wk. Total herbage yield of Mulato when clipped at 2 wk (twice a month) was greater than at 4 wk.

The decline in CP in months when HMA was greater was attributed to dilution of CP across leaves. In general, CP and IVDDM of Mulato harvested in October were greater than that of forage harvested in August through to September. Herbage CP of Mulato was greater at 2 wk, regardless of stubble height, than for the 4- wk regrowth interval. Forage digestibility of Mulato was greater at 2- than 4- wk regrowth interval through the clipping period except in October.

Persistence

There was no difference in persistence between the 2- and 4- wk defoliation treatments except at the 7.5- cm stubble height where the Mulato cover was greater at the 4- wk regrowth interval. Clipping Mulato below 2.5 cm at a regrowth interval of less than 2 wk would likely result in decreased persistence of less than 60% of the initial stand after 1 yr.

Implications of the Research

Animals grazing Mulato pastures did not have greater animal performance despite Mulato's superior HM, HMA, and nutritive value than bahiagrass. Considering the inputs and edaphic-climatic conditions of this study, Mulato should be grazed at a stocking rate of 8 heifers ha^{-1} to optimize GHA and ADG. However, long-term studies should be conducted to evaluate the persistence of Mulato pastures grazed at this stocking rate for multiple years. Because Mulato was more negatively impacted by flooding conditions of the soil than bahiagrass, Mulato should be planted in areas with well-drained soils. A defoliation regime of 4 wk regrowth interval at a 7.5- cm stubble height is recommended for optimizing HMA of Mulato while maintaining the persistence of the stand. There is potential for Mulato as an alternative forage for bahiagrass pastures in South Florida, however, future research on persistence of Mulato on varied soil moisture conditions and at different latitudes is needed to determine the adaptability of Mulato throughout Florida.

APPENDIX
DATA TABLE

Table A-1. Weather data for Years 2007 and 2008 in Ona, FL.

Month	Rainfall			Average temperature		
	2007	2008	65-yr Average	2007	2008	63-yr Average
	----------------mm----------			-----------------°C-------------------		
Jan.	36.8	23.6	54.9	17.2	16.0	9.7
Feb.	51.3	39.9	66.8	15.4	18.3	10.3
Mar.	16.0	57.4	79.2	19.0	18.8	12.5
Apr.	41.9	7.9	63.0	20.1	20.0	14.4
May	10.4	71.1	94.7	23.2	24.1	17.4
June	206.0	253.2	220.7	25.2	25.3	20.6
July	154.4	198.1	212.6	26.2	25.8	21.8
Aug.	210.8	254.0	209.6	27.0	26.3	22.1
Sep.	171.2	142.7	186.9	25.8	26.1	21.7
Oct.	52.3	41.9	78.0	24.8	22.2	18.2
Nov.	2.3		49.0	18.6		13.8
Dec.	52.6		51.1	18.7		10.7
Total	**1006**	**1089.8**	**1366.5**			

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BIOGRAPHICAL SKETCH

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