PRODUCTIVITY, NUTRITIVE QUALITY AND UTILIZATION OF DALLISGRASS (*PASPALUM DILATATUM*) FOR BEEF CATTLE PRODUCTION AS INFLUENCED BY FERTILIZATION REGIME AND GRAZING MANAGEMENT

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VITA

Elias José Bungenstab, son of José G. Bungenstab and Clara M. Bungenstab, was born November 22, 1970 in São José das Laranjeiras, São Paulo State, Brazil and grew up on a farm in Maracaju, Mato Grosso do Sul State, Brazil. He received his bachelor's degree in Agricultural Engineering from Federal University of Mato Grosso do Sul, Brazil, in August, 1994. He also received a specialization degree in Soils and Environment from Federal University of Lavras, Minas Gerais State, Brazil, in November 1996. After working in the animal feeding industry for 5 years, during which he co-authored 2 books on beef cattle production in Mato Grosso do Sul State, Brazil, he attended Texas A&M University where he obtained his Master of Agriculture degree in December 2000. Elias returned to Brazil and worked as a feedlot nutritionist. He married Simone M. Resende, daughter of Amerco Resende de Oliveira and Maria Aparecida M. Resende, on May 28, 2005. Soon after his wedding, he started his Ph.D. program in ruminant nutrition under Dr. Russell Muntifering. Elias was the first president of the Animal Sciences Graduate Student Council at Auburn University, was recognized as one of the top 10 outstanding doctoral students by the Auburn University Graduate Student Council in 2008, and received 6 other honorary awards during his student career. After completion of his graduate program, Elias plans to work as a beef cattle nutritionist with the professional goal of making a positive impact on the beef cattle industry by improving efficiency and reducing costs of production.

DISSERTATION ABSTRACT

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Dallisgrass (*Paspalum dilatatum*) is well adapted to the Black Belt region of the southeastern US, and information on its productivity and nutritive quality as influenced by fertility and grazing management is needed in order to more fully develop its potential as a forage resource for the region. In each yr of a 2-yr study, an existing dallisgrass pasture that had been subdivided into 48 plots of 9.3 m^2 each was fertilized with the equivalent of 34 (34N), 67 (67N), 101 (101N) or 134 (134N) kg N/ha from poultry litter (PL) or commercial fertilizer (CF; NH_4NO_3). In both years, primary-growth and vegetative regrowth forage was harvested in mid-August and late September, respectively, and forage from each harvest was clipped to either a 5- or 10-cm stubble height. Forage cut to a 5-cm height yielded 71% more ($P < 0.001$) DM than forage cut to a 10-cm height, but forage dry matter (DM) yields were not different between CF and PL treatments across years and fertilization rates. Concentration of crude protein (CP) was greater ($P = 0.002$) for CF than PL forage and increased for both fertilizer sources with increasing rates of N application. Forage concentrations of cell-wall constituents were not different between CF and PL treatments. Forage amended with CF had a higher concentration of Ca, Mg and Mn than PL-amended forage; however, forage amended with PL had a higher concentration of P and K than CF-amended forage. There was no effect of fertilizer source on forage concentration of Al, Cu or Zn. Results indicate that PL and CF were comparable for supporting productivity and nutritive quality of dallisgrass on Black Belt soils. In a 2-yr grazing experiment, replicate 0.40-ha paddocks in a dallisgrass pasture were continuously grazed (CG), or replicate 0.40-ha paddocks were subdivided into either two 0.20-ha, three 0.13-ha or four 0.10-ha cells and rotationally grazed (RG) by yearling beef steers. In 2007, there was no effect ($P = 0.25$) of grazing treatment on ADG. Steers grazing 0.10-ha, 0.20-ha and CG paddocks had 106 ($P = 0.01$), 86 ($P = 0.03$) and 83 ($P = 0.03$) kg greater total gain per ha (GPA), respectively, than steers grazing 0.13-ha paddocks. In 2008, there were no differences among treatments in ADG ($P = 0.43$) or areal liveweight gain ($P = 0.90$). Correlation and regression analyses revealed positive statistical associations between steer performance and forage concentration of CP, areal mass of forage DM and areal mass of forage CP. Results indicate that productivity and quality of dallisgrass for stocker cattle production under intensive grazing management (forage allowance of ~ 1 kg DM/kg steer liveweight) were comparable between continuous and rotational-grazing systems.

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I. INTRODUCTION

Dallisgrass (*Paspalum dilatatum)* is a warm-season perennial grass indigenous to South America, primarily Uruguay, Argentina and southern Brazil (Pizarro, 2000). According to Chase (1929), it was first reported in the USA in 1840, collected in Louisiana, and named for Abner T. Dallis of La Grange, GA (Holt, 1956). Dallisgrass grows best on deep, moist, fertile, alluvial and basaltic clay soil and sandy soil, and its ideal rainfall range is from 900 to 1250 mm/year. It has little tolerance for salinity, is very tolerant to poor drainage and, because of its deep root system, is drought-tolerant following establishment (Evers and Burson, 2004). The ideal growing temperature range for dallisgrass is from 15 to 30ºC, it is indigenous in environments ranging from sea level to 1800 m elevation and latitude approximately 28º N to 35º S, and it is naturalized in areas up to 2100 m elevation and below latitude 35ºN. For these reasons, dallisgrass is well adapted to the Black Belt physiographic region of Alabama where it begins production early in the spring and generally becomes available for grazing earlier than other pasture grasses (Venuto et al., 2003). Dallisgrass is high in palatability and nutritive quality prior to maturation, and it has an open-type sod that allows its grazing season to be extended by interseeding perennial legumes and/or cool season annuals. Furthermore, dallisgrass tolerates frequent defoliation better and maintains its forage quality longer into the growing season than many other commonly utilized warm-season C_4 grasses (Davies and Forde, 1991). Dallisgrass is one of the better warm-season grasses in terms of nutritive quality, with CP concentration up to 14%, NDF concentration ranging from approximately 59 to 68%, and IVDMD typically between 40 to 63% (Acosta et al., 1996).

In spite of its positive agronomic and nutritive quality characteristics, dallisgrass represents just 10% of perennial warm-season grassland acreage in the state of Alabama, primarily in the Black Belt region where its major uses are for pasture and hay (AASS, 1996). Major limitations to more widespread use of dallisgrass are its relatively narrow range of adaptability to different soil types, poor seed production and susceptibility of seedheads to infestation with ergot (*Claviceps paspali*), all of which are compounded by poor soil fertility.

The depressed agricultural economy of the Black Belt region stems in large part from poor soil fertility that conceivably could be alleviated by economical importation of poultry litter from areas of intensive poultry production for use as a cost-effective alternative to commercial fertilizer. Dallisgrass responds well to commercial fertilizer up to 134 kg N/ha and to P and K based on soil test, but there is an extremely limited body of knowledge that producers can use in management decisions, application rate adjustments and prescription techniques for controlling and maximizing nutrient-use efficiency from poultry litter in forage-based beef cattle production systems in the Black Belt region. For these reasons, a 2-yr field-plot study was conducted to determine the primary productivity and nutritive quality of dallisgrass as influenced by rates of fertilization with poultry litter or commercial fertilizer. Results indicate that poultry litter offers potential as a cost-effective alternative to commercial fertilizer for supporting productivity and nutritive quality of dallisgrass on Black Belt soils.

Another major limitation to wider and more effective use of dallisgrass in the Black Belt region is the lack of information regarding its grazing tolerance and its production potential under intensive grazing management. In recognition of this limitation, a 2-yr grazing study was conducted to determine the primary productivity, and the extent of utilization and nutritive quality of dallisgrass as influenced by grazing management intensity using variable cattle-stocking densities. While productivity and quality of dallisgrass for stocker cattle production were comparable between continuous and rotational-grazing systems results indicate that intensive rotational grazing of dallisgrass may have potential for increasing forage productivity while maintaining nutritive quality compared with continuous grazing under certain conditions, and that increased forage productivity resulting from rotational grazing offers potential for increasing stocking rate and beef production from intensively managed dallisgrass pastures.

II. LITERATURE REVIEW

Dallisgrass

Background. The southeastern USA has over 12 million beef cows and supplies a major portion of the fed cattle inventory finished nationwide annually. Cow-calf production is the major enterprise, such operations are generally small, and calves are weaned and usually sold to feedlots for finishing in other parts of the country. This type of production system is often inefficient and presents a significant challenge to research scientists and Extension specialists who wish to develop year-round systems for growing and finishing beef cattle from forage (Hoveland, 1986).

Major challenges for any forage-based beef cattle enterprise are to increase yield and quality of forage produced, and to identify ways to utilize efficiently the total available resources in a system for maximizing animal gain and returns on investments (Reid and Klopfenstein, 1983). In order to achieve profitable production systems that enable producers to increase their returns on investments, there is a need to identify ways to maximize beef production from pasture and forage. Dallisgrass (*Paspalum dilatatum*), bermudagrass [*Cynodon dactylon* (L.) Pers.] and bahiagrass (*Paspalum notatum* Flugge) are the major warm-season grasses in the lower South, from eastern Texas and Oklahoma to the Atlantic Ocean. In this region, grasses are used mainly for grazing instead of harvested for hay as in other regions of USA (Hoveland, 2000). Use of dallisgrass in production systems represents one potential means of maintaining cattle on pasture for longer periods because of its early start in the spring and high nutritive quality, becoming available for grazing earlier in the spring and extending longer into the fall than other common warm-season perennial grasses (Venuto et al., 2003). It also has the advantage of growing well in association with bermudagrass, clovers and annual ryegrass (*Lolium multiflorum* Lam.), and it supports heavy grazing (Burson and Watson, 1995).

Dallisgrass is well adapted to the Black Belt physiographic region of Alabama. According to Holt and McDaniel (1963), dallisgrass maintained satisfactory yields under frequent harvests, and yield was greater when forage was clipped to a 5-cm than 15-cm height. However, Lovvorn (1944) observed a decrease in DM yield with defoliation to a 2.5-cm height, due presumably to decreased residual leaf area available for photosynthesis. Dallisgrass produced good-quality forage during the summer months (Burson and Watson, 1995) and had greater DM yield than crabgrass in response to fertilization with N (Lovvorn, 1944).

History and development. Dallisgrass, paspalum-grass, watergrass and paspalum are common names of *Paspalum dilatatum*; in South America it is called pasto miel (honeygrass), and paspalum in Australia (Rosengurtt et al., 1970). Dallisgrass is indigenous to South America, and the common biotype is believed to have originated in western Uruguay (Burson, 1991). The exact date that it was first brought to the USA is unknown, but it was reported growing in a herbarium in Louisiana around 1840 (Chase, 1929). According to Campbell (1999), dallisgrass was first introduced in Australia around 1870 when a small amount of seed was sent from South America to Baron von Mueller, who distributed the seed to farmers. *Paspalum* subsequently became popular around New South Wales and Southeastern Queensland (Bogdan, 1977).

Dallisgrass can be found in other subtropical and warm temperate regions, including India, some regions of Africa, Madagascar, The Philippines, Japan, part of New Zealand, Hawaii and the southern USA (Bogdan, 1977). Around the 1890s, some seeds of “watergrass” were sent from Australia to Abner T. Dallis of La Grange, GA who planted the seeds in a bermudagrass (*Cynodon dactylon* L. Pers.) sod. The new grass eventually overgrew the bermudagrass and, because of his enthusiasm and advocacy of the grass, what until then had been known as watergrass was named dallisgrass in his honor (Tabor, 1963).

Dallisgrass exists as both sexually propagated (tetraploid) and apomictic (penta- and hexaploid) biotypes and, because of its poor seed quality, has some establishment difficulties. The common biotype is apomictic (*Paspalum dilatatum* Poir. ssp. *dilatatum*), and the yellow-anthered biotype (*Paspalum dilatatum* ssp. *flavescens*) reproduces sexually (Burton, 1962). Since the early 1940s, G. W. Burton in Tifton, GA and C. W. Owen in Baton Rouge, LA attempted to improve common dallisgrass in the southeastern USA, but made no progress (Evers and Burson, 2004). Traditional approaches to plant improvement are not feasible because of its asexual reproduction (Pitman et al., 2005). Bashaw and Holt (1958) determined that the common biotype reproduces by apomixis, and the yellow-anthered biotype reproduces sexually.

Between late 1930s and 1950s, G. W. Burton worked on hybridization programs on dallisgrass, but the limited intra- and interspecific hybrids produced were inferior to the existing common dallisgrass biotypes (Burton, 1962). According to Evers and Burson (2004), very few hybrids were produced that resulted in new releases of improved dallisgrass cultivars. Other attempts to improve the grass were made utilizing ionizing radiation, which changed some morphological aspects of the plants but did not change the method of reproduction (Evers and Burson, 2004). Tissue culture was also utilized, but the somaclones obtained were not superior to the common biotype (Burson and Tischler, 1993).

Because of these limitations, the only viable means of improving common dallisgrass has been to identify and collect cultivars from other regions in the world. During the 1970s, Uruguayan dallisgrass biotypes were identified and collected in South America. Several accessions were compared with common dallisgrass over several years. Among the selected accessions, entry 554 was chosen due to its persistence (88%) at the end of a 3-yr grazing study, and also because it produced 2.6 times more forage than common dallisgrass in clipping trials in Louisiana. This selected entry was released recently as 'Sabine' dallisgrass by USDA-ARS, Louisiana State University AgCenter, and Texas AgriLife Research (Burson et al., 2009).

Utilization. According to Holt (1956), dallisgrass is an important forage crop in the southeastern USA due in large part to its high forage quality. It is a bunchgrass with short rhizomes, grows up to 50 cm tall, and is very leafy. It is best adapted to clay and loam soils in areas receiving plentiful rainfall (Ball et al., 2002). Dallisgrass is commonly utilized as pasture, but in some cases it is also harvested for hay. However, because it doesn't grow as tall as other subtropical perennial grasses, it does not produce as high yields, and therefore is used for hay mainly in locations where taller-growing grasses do not grow well (Evers and Burson, 2004).

Dallisgrass can tolerate defoliation very well because of accumulation of carbohydrate reserves in the stem bases and production of buds that will grow after defoliation (Ball et al., 2002), and it grows well during summer and during the warm part of the winter (Holt, 1956). It can tolerate poorly drained soils and temperatures below -3ºC (Davies and Forde, 1991), begins to grow earlier in the spring than other subtropical perennial grasses, and remains green for a longer period in the fall (Evers and Burson, 2004).

Venuto et al. (2003) evaluated five different accessions of dallisgrass in Louisiana and Texas for yield, persistence and nutritive quality. Stand persistence of the different accessions was satisfactory, but Uruguayan dallisgrass was superior in persistence and yield compared with common dallisgrass on poorly drained clay soils. On average, concentrations of CP were 9.8 and 11%, concentrations of NDF were 70.7 and 69.5%, and coefficients of IVDMD were 71.2 and 63.8% in Texas and Louisiana, respectively, across the five accessions. The authors reported no differences in nutritive quality between Uruguayan and common dallisgrass.

Dallisgrass grows well in mixtures with other forage species. Because of its open-type sod, it allows inter-seeding with ryegrass (*Lolium multiflorum* Lam.) and legumes such as clover (*Trifolium* spp.), which provides opportunity for utilization in year-round grazing systems (Evers and Burson, 2004).

Dallisgrass produces poor seed quality and quantity due to ergot (*Claviceps paspali*), which causes it to be slow in germinating due to low seed vigor (Burson and Tischler, 1993). According to Campbell (1999), it is highly susceptible to ergot, which contains an alkaloid and is a problem due to its toxicity to animals. In recognition of this problem, Schrauf et al. (2003) successfully incorporated ergot resistance into *Paspalum dilatatum* utilizing hybridization with *Paspalum urvillei*, which also enhanced genetic variability. Another means of avoiding ergot toxicity is threshing or combining the seeds before the forage is used for grazing or baled for hay, which can also provide seeds for future plantings (Holt, 1956).

Ayala Torales et al. (2000) tested the hypothesis that frequent defoliation would increase herbage utilization as a result of higher nutritive quality and lower herbage loss due to senescence. They evaluated net herbage accumulation, utilization and quality in Argentina utilizing a 5-yr-old stand of *Paspalum dilatatum* on which stocking rate had been adjusted to the available herbage mass in order to provide 22.7 kg of DM per cow daily. The authors found no differences in net herbage accumulation among different grazing frequencies, and herbage utilization was decreased by frequent grazing due to a more prostrate growth pattern. Nutritive quality was greater in summer with frequent defoliation, but otherwise was not different among grazing frequencies across the entire growing season. Also, primary production remained unchanged regardless of defoliation frequency, in agreement with Ball et al. (2002) who reported that dallisgrass can tolerate frequent defoliation.

Optimum rates of fertilization are dependent upon soil fertility and should be determined on the basis of soil test (Burson and Watson, 1995). Wilkinson and Langdale

(1974) reported that dallisgrass responded to fertilization up to 150 kg N/ha on sandy soils, and up to 225 kg N/ha on heavier clay soils. Gunter et al. (2005) observed significant growth response up to 336 kg N/ha on a poorly drained, silty clay loam soil in an Arkansas flood plain. Robinson et al. (1988) observed significant increases in forage yield, digestibility and nutrient concentration with increasing rates of N fertilization up to 896 kg /ha on a Louisiana silty loam soil. Gunter et al. (2005) found that net return per ha of dallisgrass-dominated pastures varied with stocking rate and rates of N fertilization; specifically, optimal net return was realized at a stocking rate between 5.7 and 7.3 steers/ha, and increased with increasing rates of N fertilization.

Grazing management

Background. Grazing management is an important tool in the production of animals on pasture (Vallentine, 2001). The main goal in managing the way animals graze pasture is to provide the proper amount of the highest quality forage possible to the grazing animal in order to optimize production (McKown et al., 1991).

Under grazing, primary productivity of plants decreases with increasing consumption of foliage because of the resulting decrease in solar energy capture. On the other hand, efficiency of harvesting increases with increasing number of grazing animals, provided this increase presents an opportunity to consume forage before it becomes senescent (Briske and Heitschmidt, 1991). There is generally a decrease in individual animal production as the number of animals grazed per unit area increases, but there is generally an increase in total production per unit area because areal production integrates individual animal production and number of animals per unit area. However, areal production shows a rapid decline once the number of animals per unit area exceeds carrying capacity, as shown in Figure 1. At this point, there is a sharp decrease in individual animal performance and, therefore, a significant decrease in areal production (Briske and Heitschmidt, 1991).

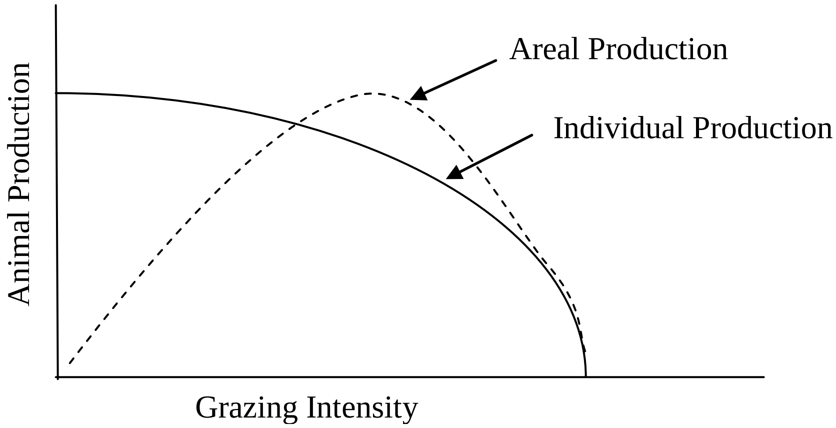


Figure 1. Individual and areal animal production in response to grazing intensity (Adapted from Briske and Heitschmidt, 1991).

The main goal of grazing management is to maximize areal gain, thereby reducing individual gain and increasing numbers of animals per unit area to achieve equilibrium between these variables (McKown et al., 1991).

In order to achieve the highest production of individual animals on forage, one can manage the pasture to provide the animals with the highest quality forage possible, increasing individual animal production and decreasing areal gain as a result of fewer animals per unit area that are able to select plants or plant parts with higher nutrient concentration. Barthram et al. (2002) achieved the highest individual performance of ewes and lambs in Scotland under lower stocking densities. Intuitively, it would appear to make sense to allow forage to grow and animals to select the highest quality forage possible, but the life span of an individual leaf is around 30 to 60 d (Ball et al., 2002). Therefore, leaves not eaten by animals will die and animals, if given an opportunity to do so, will avoid old leaves and preferentially eat younger leaves that are more palatable and higher in quality. However, undergrazing is a common result of this management technique. The consequence is often a reduction in plant production due to shading, which inhibits development of new tillers and reduces leaf area exposed to sun light (Smetham, 1990).

Another way to increase production is to increase the number of animals per unit area. This approach will generally decrease gain per animal because it reduces the opportunity for preferential selection due to competition resulting from the greater number of animals per unit area. Depending on the species composition of the pasture, with this approach there is risk of overgrazing that can result in weakened plants (Ball et al., 2002).

The optimum grazing management is difficult to achieve and depends on several factors, including the forage being managed, temperature, moisture, season of the year, type of animal and level of soil fertility, among others (Ball et al., 2002). Grazing management is based on seeking to optimize four principles: stocking rate, season, type of herbivore species and distribution of forage growth, all of which are variably important depending on management objectives and implications regarding cost of production (Vallentine, 2001).

Grazing methods. According to Smetham (1990), there are two primary grazing methods: continuous and intermittent. Continuous grazing, also known as continuous stocking, allows animals unrestricted access to an entire pasture throughout the grazing season. This method allows animals to select plants or parts of plants they desire most, creating opportunity to self-improve diet quality (Sharrow and Krueger. 1979), and it can be used with a fixed or variable stocking rate. When fixed, the risk of overgrazing or undergrazing during the season is greater because availability of forage DM changes throughout the grazing season (Matches and Burns, 1985). For that reason, continuous stocking is often misinterpreted to be an intrinsically poor management technique. However, it can produce just as good or better results if the manager adjusts the stocking rate as necessary in order to utilize the pasture to its full potential (Vallentine, 2001). In some cases it is possible to maintain stocking rate and fence off part of the pasture when there is a surplus of forage that can be utilized in times of shortage (Ball et al., 2002). Continuous grazing has the advantages of low input costs due to less investment in fences and water, and simpler management decisions are required compared with intermittent grazing (Matches and Burns, 1985).

Intermittent grazing can be in the form of creep grazing, forward creep grazing, strip grazing, limit grazing, deferred grazing or stockpiling, rotational stocking or rotational grazing (Ball et al., 2002). Creep grazing is the use of pasture that has been fenced in a manner that allows younger animals to have access to and benefit from forage of higher quality than that available to their dams. This approach is often used during the summer when pastures on which mature animals graze have lower quality, allowing calves to gain more weight due to having access to a better quality pasture (Ball et al., 2002). Bagley et al. (1987) reported increases of 12% in 205-d weight and 8% in weaning weight for calves receiving higher quality forage via creep grazing. Harvey and Burns (1988) reported an increase in calf production per ha because creep grazing allowed an increase in stocking rate.

Forward creep grazing is a system that permits calves early access (relative to their dams) to the next pasture to be grazed in a rotation, utilizing an opening in the fence or an electric-wire height that allows only the calves to enter. In this system, the calves always have access to forage of higher quality than that available to their dams (Vallentine, 2001). Blaser et al. (1983) reported an ADG advantage of 0.25 kg and 26 kg heavier final weight of calves under forward creep grazing compared with control calves. However, Jordan and Marten (1970) did not find any improvement in carrying capacity or lamb ADG with forward creep grazing compared with continuous grazing. In the same experiment, ewes of the forward creep grazing group lost more weight during the grazing season.

Strip grazing utilizes a portable fence that allows animals access to only part of the available forage, and it produces best results with high-quality forage. In this system, greater amounts of available forage are consumed. It also allows an increase in stocking rate and normally reduces wastage due to trampling (Smetham, 1990). With low-quality forages, individual animal gain may be reduced because of decreased selection (Ball et al., 2002). Strips may vary in size, with allowable times for grazing ranging from several days to a few hours a day. Due to the intensive management and investment required, this system is used most often in land-limited, forage-based dairies (Matches and Burns, 1985). The use of strip grazing can help to better manage available forage and reduce under-or overgrazing, and the decision to move or maintain animals on a particular strip of the pasture can be made relatively easily (Gordon et al., 1959). However, Pulido and Leaver (2003) observed decreased intake and grazing time by cows grazing perennial ryegrass (*Lolium perenne*)-dominated swards under strip grazing compared with continuous grazing, reportedly due to animals anticipating moving to the next strip of higher forage availability.

Limit grazing allows animals to graze low-quality forage for most of the day, with access to high-quality forage during other times of the day. This system is best used when the supply of high-quality forage may be exhausted prematurely if animals were allowed to graze it for extended periods (Vallentine, 2001). In a study with native tallgrass prairie, Coleman et al. (2001) used limit grazing of wheat pasture twice a week as a protein supplement. They found it to be adequate and comparable to supplementation with oilseeds for supplying cow-calf demands for supplemental protein in the Southern Great Plains.

Stockpiling is a system in which forage is allowed to accumulate during one time period and be used at a later time. It is an effective management tool for decreasing or altogether eliminating the cost of producing hay. From an economic standpoint, it is important that the accumulated forage be utilized in a manner that allows it to be consumed with minimal waste (Mays and Washko, 1960). Stockpiling is most commonly used with cool season grasses, specially tall fescue. Warm-season grasses can be stockpiled, but the stockpiled forage will have lower nutritive quality due to senescence. Waste will be higher if animals continuously graze the stockpiled forage, so strip grazing the accumulated forage is generally the best approach (Ball et al., 2002). Generally, there is an increase in DM yield with increasing period of forage accumulation, but there is a consequent decrease in forage quality. Stockpiling may not be feasible for all forages; the majority of legumes, for example, cannot be effectively stockpiled because they will normally lose their leaves before being utilized (Matches and Burns, 1985).

Rotational grazing (rotational stocking) consists of subdividing pasture into smaller paddocks that are grazed with a high stocking density for a period of time, followed by a rest period while the other paddocks are grazed. When forage is growing rapidly and rotation is more frequent, the grazing animal benefits from selection of abundant, high-quality regrowth. On the other hand, when forage is growing slowly, this system can provide a more homogeneous availability of forage in one paddock before moving to the next (Matches and Burns, 1985). According to Ball et al. (2002), there is potentially an increase in carrying capacity of between 20 and 30% compared with continuous grazing, which is one of the greatest advantages of this system. Improved persistence of plants likely to be overgrazed in a continuous grazing situation is also a major advantage of rotational grazing, and it is possible to maintain unused forage for utilization later as long as the plant is amendable to this kind of management, or if there is a possibility of producing hay or silage from this excess (Matches and Burns, 1985). Rotational grazing provides an opportunity to decrease pasture contamination by weeds, because animals are forced to eat most of the available forage in a given plot before they move to the next one (Smetham, 1990). This reduces the likelihood of a competitive advantage for weeds resulting from them not being grazed, plus will reduce weed seed production. In general, rotational grazing is a more sophisticated management method and, contrary to continuous grazing, requires a more dedicated and experienced forage manager in order for the system to succeed. Also, additional requirements for fence and water make this system more input-intensive (Matches and Burns, 1985).

The most important consideration when planning grazing management is stocking rate. When it is not synchronous with available DM, any grazing management system could conceivably fail (Walker, 1995). The maximum stocking rate that maintains or improves the forage of a particular area is the carrying capacity, and in order to determine the optimal stocking rate it is necessary to determine the carrying capacity of the forage under consideration (Walker, 1995). When stocking rate exceeds carrying capacity, it is likely that pasture botanical composition will be altered due to diet selection imposed by the animal, resulting in an advantage to the less preferred plants (Maharning, 2009). Optimal stocking rate varies with type of forage, climate, and soil type; therefore, it is not constant during the year. Climate is the single factor that most influences optimal stocking rate and presents the greatest unanticipated challenges to the forage manager (Ohlenbusch and Watson. 1994).

Continuous vs. rotational grazing. Published reports provide conflicting results from comparisons of continuous vs. rotational grazing systems that can be attributed mainly to differences in the way experiments are conducted (Briske et al., 2008), forage species, type of animals used, climate, soils and environmental factors (Bertelsen et al., 1993).

According to Derner et al. (2008), stocking rate has a greater influence on results of grazing studies than intrinsic characteristics of the grazing systems under investigation. These authors, working with mixed-grass prairie systems of the North American Great

Plains in a long-term study, reported a decrease of 16 and 12% in ADG in a comparison of heavy stocking rates with light and moderate stocking rates, respectively. There was a significant decrease in ADG with increasing stocking rate and grazing pressure; however, animal gain per unit area responded in the opposite manner and increased with increasing stocking rate and grazing pressure. Steer ADG was reduced by 6% with short-duration rotational grazing compared with season-long continuous grazing.

McCollum et al. (1999) reported increased ADG and gain per area for beef cattle from continuous compared with rotational grazing of tallgrass prairie in north-central Oklahoma. Their results showed that, at 52 animal-unit-days (AUD)/ha, continuous grazing resulted in 11% higher ADG than rotational grazing, and at 90 AUD/ha this difference increased to 20% under similar stocking rates for both treatments. An important observation in this study was that overall weather conditions were favorable to forage production, with precipitation above average for the experimental period and temperatures for spring and summer slightly below average. According to the authors, there was a decrease in forage intake for the rotationally grazed group, which may explain the reduction in weight gains and 20% more residual ungrazed forage in the rotationally grazed pastures.

Heitschmidt et al. (1982) reported similar ADG by Hereford/Angus crossbred growing heifers from continuously and rotationally grazed prairie vegetation dominated by various combinations of short and mid-grasses. There were different stocking rates for each treatment, 4 AUM/ha in the rotational system and 2 AUM/ha in the continuous, for which the 2-fold increase in stocking rate resulted in a doubling in production per unit area.

Sharrow and Krueger (1979) reported an increase of 15% in total lamb liveweight gain per ha from rotationally grazed compared with continuously grazed perennial ryegrass (*Lolium perenne*)-dominated pastures, but grazing system had no effect on lamb birth weight or lamb crop percentage. Lauriault et al. (2005) reported no differences in ADG or gain per ha between beef cattle rotationally or continuously grazing irrigated alfalfa and tall wheatgrass pastures in the Southern High Plains.

Bertelsen et al. (1993) compared continuous grazing with two systems of rotational grazing, one consisting of 6 paddocks grazed for 6 d each, and the other consisting of 11 paddocks grazed for 3 d each. Paddocks received 30 d rest between grazing sessions for both rotational grazing treatments. Stocking rate was adjusted using put-and-take heifers in order to maintain forage (50% alfalfa, 40% tall fescue, and 10% orchardgrass) height between 8 and 15 cm after a paddock had been grazed. Heifer ADG did not differ among treatments. However, due to 42% greater stocking rate in the rotationally grazed paddocks, there was an increase of 40 and 34% in gain per ha for the 6-paddock and 11-paddock system, respectively, over continuously grazed paddocks.

Hafley (1996) reported 29% higher ADG (0.27 kg/d) by yearling steers from continuously than rotationally grazed ryegrass (*Lolium multiflorum* Lam.). However, due to almost twice the stocking rate in the rotationally grazed paddocks, there was a 34% increase in gain per ha over continuously grazed paddocks.

Rotational grazing systems are expected to improve animal production per unit of land area over continuous grazing due to a higher percentage of utilization of available forage and to enhanced forage production. The rest period between grazing sessions enables the plants to recover and grow faster than under continuous grazing. Reduction in grazing selectivity is also an important factor. Stocking density is higher under rotationally than continuous grazing, and animals will have decreased opportunity for selection (Briske et al., 2008); therefore, forage is grazed more uniformly, resulting in more homogenous plant growth in the paddock after cattle have moved to the next paddock. However, there are several other factors that play important roles in any grazing situation, such as climate, forage, animal, soil and environment, among others. Interactions among all these factors ultimately determine the success or failure of any production system.

Research on rangeland generally shows little to no advantage of rotational over continuous grazing systems with regard to plant and animal production (Briske et al., 2008). The main objective of rangeland production system is not always to maximize animal or forage production, but to maintain equilibrium between production and preservation of environmental resources. Therefore, systems show different responses under rangeland conditions compared with improved forages for which high animal and forage production levels are expected. However, even under intensive production systems, production is highly dependent on other factors that influence plant and animal production, and not just the grazing system itself.

Forage Nutrition and Fertilization

Background. In order for plants to grow, they require a proper balance of different inputs that affect plant development. Following soil moisture and solar radiation, soil fertility (i.e., the enrichment of soil with essential nutrients) is the next limiting factor for plant growth (Follett and Wilkinson, 1985). All plants require 16 essential elements for growth, but plant species differ in their ability to extract the proper amount of each element necessary for growth and production. In order to determine the optimum fertilization regime for managed plant systems, it is necessary to know the elemental requirements of each species in question (Follett and Wilkinson, 1985).

The three primary means by which plants absorb nutrients from the soil are root growth, mass flow and diffusion. Roots grow and come in contact with nutrients in soil solution in order to absorb them. Mass flow is the flow of nutrients with the water that is absorbed by roots. Nutrients required by the plant that are not absorbed by these two processes, if present in the soil, can be taken up by diffusion. Diffusion results from a different gradient potential between roots and the surrounding soil solution (Barber et al., 1963; Follett and Wilkinson, 1985).

The quantity of nutrients absorbed by the plant depends on several factors such as nutrient concentration in the soil solution, age, specie, cultivar, temperature and interactions among nutrients in the soil solution, among others (Barber, 1995). According to Follett and Wilkinson (1985), plant uptake, precipitation as insoluble salts, immobilization resulting from microbial processes and fixation by clay minerals may reduce the concentration of available nutrients in the soil solution.

Utilization of plant and soil analyses can help prevent plant nutrient deficiencies and therefore increase forage yield and quality (Barber et al., 1963). Plant analyses can be used as an indicator of good fertilization practices, soil fertility and other factors affecting plant development. In order to use them properly, one needs to know the elemental composition of the specie under consideration, which is usually obtained from fertility studies (Melsted et al., 1969). Soil analysis provides information on the concentration of nutrients needed by plants as well as those that may be detrimental to plant development. Based on soil analysis, it may be possible to detect nutrient deficiencies that are due to low levels of the nutrient or unavailability in the soil due to nutrient interactions (Follett and Wilkinson, 1985).

Normally, soil for analysis is manually taken from the top 15 cm, but in doing so it is important to consider that forages may have a deep root system. One way to increase nutrient availability to plants is to increase root mass, which increases the surface for absorption and facilitates the mass flow process of absorption once root expansion provides access to other soil nutrient pools (Follett and Wilkinson, 1985).

Based on plant nutrient requirements and soil analyses, it is possible to determine the amount and type of nutrients needed to optimize yield and quality of forage (Ball et al., 2002). The means by which nutrients can be added to the soil include synthetic fertilizers, atmospheric deposition, soil mineralization and organic matter decomposition, and animal manures (Follett and Wilkinson, 1985). Nutrients absorbed by plants from soil are removed from the area by growing animals or as hay harvested from a forage stand. Animals recycle a portion of the plant nutrients through feces and urine, but also retain a portion of the plant nutrients to support their maintenance and growth (Ball et al., 2002).

Nitrogen. Nitrogen (N) is the nutrient that most commonly limits plant growth. Plant roots absorb N primarily as inorganic nitrate (NO_3^-) and ammonium (NH_4^+) ions. Bacteria are responsible for converting most of the N available in the soil to NO_3^-. Plants convert the NO_3^- absorbed to NH_4^+ via reductive nitrification. This enzymatically catalyzed process is seriously affected by drought and low light intensity due to a decrease in the activity of nitrate reductase enzyme (Miller and Heichel, 1995).

Soil, vegetation, animal recycling and the atmosphere are sources of N for plants (Dubeux et al., 2007). The atmosphere contains 78% of gas composition as N in the elemental form (N_2) that cannot be directly used in plant metabolism (Follett and Wilkinson, 1985). Atmospheric N is the largest source in the biosphere, about 16,000 times the soil and terrestrial biotic N combined, and requires biological N fixation by bacteria to become available to plants. This process requires energy, about 960 kJ for each mole of N_2 fixed, which is the main reason why N is the most limiting element in agriculture (Dubeux et al., 2007). Nitrogen in the soil is mostly found in soil organic matter, which can accumulate over time (Follett and Wilkinson, 1985).

It is uncommon to have naturally-occurring optimum levels of N for meeting crop requirements in most soils. Unless the forage under cultivation is a legume, there is a high likelihood that N fertilization will be necessary to provide optimum forage production (Follett and Wilkinson, 1985). Nitrogen must be added to soil based on the plant species cultivated, expected yield, period of usage and climate. Efficiency of fertilization is greatly affected by the forage stand, amount of moisture available and soil pH. Depending on soil pH and rates of N application, it may become necessary to add limestone ($CaCO_3$) because high N levels can increase soil acidity (Miller and Reetz, 1995).

Soil pH. Soil acidity is one of the most significant factors limiting plant productivity. Low soil pH can cause a decrease in nutrient availability, depress soil microorganism populations and activity, and cause changes in soil particle aggregation that can lead to structural problems commonly associated with low-organic-matter soils. Each plant has a different range of optimum pH values, and some forages can tolerate acidity better than others (Follett and Wilkinson, 1985; Miller and Reetz, 1995). In order to increase soil pH and decrease acidity, it is necessary to apply a source of Ca (calcium) and Mg (magnesium) that is capable of neutralizing soil acidity. Limestone is the material most commonly used for this purpose (Follett and Wilkinson, 1985).

Phosphorus. Phosphorus (P) is utilized by plants in both organic and inorganic forms. Phosphorus is important for numerous chemical reactions and processes in plants, and it is found in ATP, phospholipids and other plant constituents (Follett and Wilkinson, 1985). Phosphorus is deficient in soils in most of the southeastern USA (Miller and Reetz, 1995). After N, P is the element most likely to be deficient in cropping systems. Insoluble P becomes attached to soil particles and is mobilized with erosion. Soluble P can be plant-absorbed once it is in the soil water phase portion, and losses of soil soluble P are thus generally small (Nelson, 1999).

Growing plants can uptake up to 20% of fertilizer P applied in the soil. Each plant specie has a different capability to take up P from soil (Friesen et al., 1997).

Poultry litter vs. commercial fertilizer. Approximately 9.1 billion broilers are raised annually in the USA. Five southern states (Georgia, Arkansas, Alabama, Mississippi and North Carolina) account for 60% of this production with 5.5 billion broilers per year (NASS, 2008). Considering that production of each bird results in accumulation on average of 1.2 kg of litter (manure and cellulosic material from bedding) (Patterson et al., 1998), annual production of litter amounts to 6.6 million Mg/yr (DM basis). Broiler producers are challenged to find ways to dispose of this litter without polluting the environment.

Poultry litter has been used for decades as a source of nutrients for row crops and forages, especially N, P, K (potassium) and several other nutrients. However, if land application is practiced continuously, there may be a risk of environmental pollution (Wood et al., 1993; Kingery et al., 1994; Schomberg et al., 2009). Poultry litter has a bulk density of 422 ± 24 kg/m^3 (Das et al., 2002), which makes long-distance transportation uneconomical and increases the likelihood of land application in the same areas where poultry production is concentrated and litter is produced (Schomberg et al., 2009).

Use of poultry litter as a fertilizer is a common agronomic practice for recycling nutrients in agricultural soil. Besides increasing soil nutrient concentration, land-applied poultry litter is reported to increase soil porosity, bulk density and organic matter content that in turn enhances microbial activity in soil (Wood et al., 1993). There is also an advantage of protecting soil from erosion. Once established, perennial forages can benefit from repeated applications of poultry litter. On average, 60% of the N in land-applied litter is available to the plants in the first year, 20% is volatilized and lost, and the remaining 20% becomes available after the first year (Evers, 1998).

Wood et al. (1993), compared poultry litter and commercial fertilizer for ’Tifton 44‘ bermudagrass when applied at rates of 112, 224 and 336 kg N/ha in split applications as ammonium nitrate (NH_4NO_3) or a single application of 5.6, 11.2 or 22.4 Mg/ha of poultry litter. Bermudagrass was harvested to simulate hay production, and yield and nutritive quality were determined for six cuttings in each of the two years of the study. According to the authors, poultry litter fertilization produced similar yield and forage quality as that of commercial fertilizer at the highest rates of application. Commercial fertilizer produced higher yields at lower application rates, which may suggest lower N availability during part of the growing season in the poultry litter treatments. The authors suggested that climatic conditions were more favorable for mineralization of N in poultry litter in the second year than the first year of the study. There was no difference in forage yield between fertilizer sources for the first two cuttings in the second year, and poultry litter produced higher yields than did commercial fertilizer by the third cutting. Forage quality was not different between treatments across application rates. However, concentrations of CP and crude fiber increased with increasing N application rate. On the other hand, percentage TDN decreased with increasing rates of N applications. Forage concentration of K and Ca were higher for the poultry litter than the commercial fertilizer treatment. Also, there was an increase in these two elements in forage as levels of N application increased in the poultry litter treatment. Uptake of K by forage at the lowest level of poultry litter application was similar to that at the highest rate of commercial fertilizer application (Wood et al., 1993).

Evers (1998) conducted an experiment with Coastal bermudagrass fertilized with poultry litter or commercial fertilizer ($N–P_2O_5–K_2O$ ratio 3-1-2) applied at different rates in split or single applications. Forage yield was maximized when poultry litter was applied at a rate of 8.96 Mg/ha in a single application in late spring. Each 907 kg of poultry litter resulted in yield of Coastal bermudagrass equivalent to that from 20 kg N, 7 kg P_2O_5 and 14 kg K_2O as commercial fertilizer.

The nutrient composition of poultry litter is such that, when it is used as a fertilizer material, N is still the most limiting nutrient for forage production. Therefore, in order not to underutilize the other remaining nutrients in poultry litter, it may be necessary to supply additional N, either from commercial fertilizer or from legumes that can provide N through symbiotic fixation (Evers, 1998).

Franzluebbers et al. (2004a) conducted an experiment with Coastal bermudagrass in which they evaluated three different N sources applied at equivalent rates, and four defoliation regimes. The treatments were imposed over 5 yr and included 225 kg $N \cdot ha^{-1} \cdot yr^{-1}$ from NH_4NO_3 applied in split applications in May and July, crimson clover as a cover crop to provide half of the N with the other half from a single NH_4NO_3 application in July, and broiler litter (average 74% DM) applied in split applications in May and July at an average rate of 5.4 Mg/ha. Defoliation regimes included cutting biomass at the end of the growing season and leaving it on site, grazing to maintain a high forage mass at 3.0 Mg/ha, grazing to maintain a low forage mass of 1.5 Mg/ha, and removing the forage 5 cm above ground every month of the summer as hay. There were no differences among treatments for forage yield during any single year; however, across all 5 yr, commercial fertilizer provided an average of 12% greater yield (8.28 Mg/ha) than the clover plus commercial fertilizer treatment (7.36 Mg/ha) and 20% greater yield than the broiler litter treatment (6.92 Mg/ha). The high-forage-mass treatment had greater estimated forage productivity than the low-forage-mass treatment across all 5 yr (9.2 vs. 7.5 $Mg \cdot ha^{-1} \cdot yr^{-1}$, respectively).

III. PRODUCTIVITY AND NUTRITIVE QUALITY OF DALLISGRASS (*PASPALUM DILATATUM*) AS INFLUENCED BY RATE OF FERTILIZATION WITH POULTRY LITTER OR COMMERCIAL FERTILIZER

Introduction

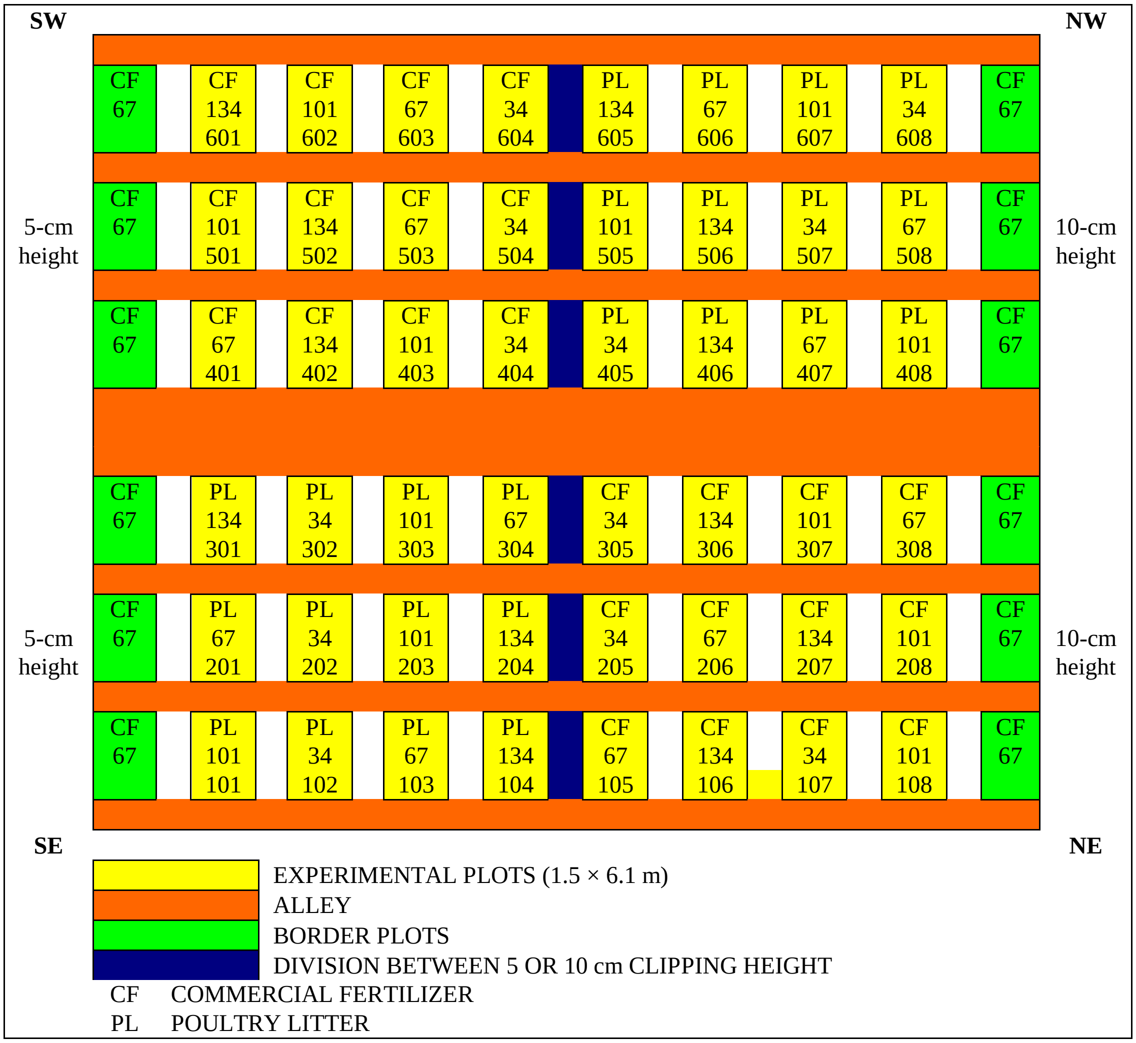
Dallisgrass, *Paspalum dilatatum*, is a warm-season perennial grass indigenous to South America, primarily Uruguay, Argentina and southern Brazil (Pizarro, 2000). According to Chase (1929), it was first reported in the USA in 1840, collected in Louisiana, and named for Abner T. Dallis of La Grange, GA (Holt, 1956). Dallisgrass represents just 10% of the perennial warm-season grassland acreage in the State of Alabama, where its major uses are for pasture, hay and silage (AASS, 1996). It responds well to fertilization with N up to 134 kg/ha, and optimally to P and K based on soil test. Furthermore, dallisgrass tolerates frequent defoliation better and maintains its forage quality longer into the growing season than many other commonly utilized perennial C_4 grasses. (Davies and Forde, 1991; Evers and Burson, 2004).

Productivity of pastureland in response to fertilization can be expected to differ for different fertilizer sources, soil types, forage species and meteorological conditions. In the case of poultry litter, there is currently a very limited body of systems-level knowledge that producers can use in management decisions, litter application rate adjustments, and prescription techniques for controlling and maximizing nutrient-use efficiency in forage-based beef cattle production systems. In the Black Belt region of Alabama, depressed agricultural economies stem in part from oftentimes poor soil fertility in pasture, hayfields and row crops. Economical transportation of poultry litter could enable export of litter from areas of intensive poultry production to the Black Belt region for use as a cost-effective alternative to commercial fertilizer on pasturelands. For these reasons, we conducted a field-plot study to determine the primary productivity and nutritive quality of dallisgrass as influenced by rates of fertilization with poultry litter or commercial fertilizer.

Materials and methods

Site characteristics. The experimental site was an existing dallisgrass pasture located at the Black Belt Research and Extension Center in Marion Junction, AL (32.5° lat., 87.2° long., 61 m elev.). The pasture had been utilized for grazing prior to 1990, and since 1990 it has been utilized for hay production. In 2001 to 2004, the pasture was over-seeded in the fall with oats and received 67 kg of N/ha in the spring and early summer of each yr prior to the experiment. The soil beneath the pasture is a clayey loam with a mean pH of 7.9. Mean annual temperature at the site is 17.6 ºC, and mean annual precipitation is 1400 mm. Precipitation and temperature were recorded daily throughout the experiment.

Treatments. Forage in the pasture was clipped to a height of 10 cm on July 17, 2006, and the study area was subdivided into 48 plots of 9.3 m^2 each (1.5 m × 6.1 m) according to the layout in Figure 2. Each plot received the equivalent of 34 (34N), 67 (67N), 101 (101N) or 134 (134N) kg N/ha from either poultry litter (PL; 2.75% N, air-dry basis) or commercial fertilizer (CF; 35% N as NH_4NO_3). Commercial fertilizer was applied to half of the plots utilizing a tractor and spreader, and PL was applied manually to the remaining half of the plots. The PL consisted of wood shavings and manure collected from chicken houses in North Alabama. Prior to transport to the research site, PL was ground to pass a 5-mm screen in a hammer mill and stored in a sealed container under refrigeration. In order to facilitate its transportation to the research site and application to field plots, PL was pre- weighed into paper bags in quantities of 1.14, 2.27, 3.41 and 4.54 kg that corresponded to 1,222 (34N), 2,443 (67N), 3,665 (101N), and 4887 (134N) kg poultry litter/ha, respectively.



CF 67	CF 134 601	CF 101 602	CF 67 603	CF 34 604	PL 134 605	PL 67 606	PL 101 607	PL 34 608	CF 67
CF 67	CF 101 501	CF 134 502	CF 67 503	CF 34 504	PL 101 505	PL 134 506	PL 34 507	PL 67 508	CF 67
CF 67	CF 67 401	CF 134 402	CF 101 403	CF 34 404	PL 34 405	PL 134 406	PL 67 407	PL 101 408	CF 67
CF 67	PL 134 301	PL 34 302	PL 101 303	PL 67 304	CF 34 305	CF 134 306	CF 101 307	CF 67 308	CF 67
CF 67	PL 67 201	PL 34 202	PL 101 203	PL 134 204	CF 34 205	CF 67 206	CF 134 207	CF 101 208	CF 67
CF 67	PL 101 101	PL 34 102	PL 67 103	PL 134 104	CF 67 105	CF 134 106	CF 34 107	CF 101 108	CF 67

🟨 EXPERIMENTAL PLOTS (1.5 × 6.1 m)
🟧 ALLEY
🟩 BORDER PLOTS
🟦 DIVISION BETWEEN 5 OR 10 cm CLIPPING HEIGHT
CF COMMERCIAL FERTILIZER
PL POULTRY LITTER

Figure 2. Layout of experimental and border plots.

Half of the plots within each fertilizer source × application-rate treatment (n = 3) were assigned to above-ground clipping heights of either 5 or 10 cm that simulated different intensities of grazing management. In order to minimize the influence of environmental conditions external to the study area, 12 border plots were maintained around the experimental plots. Border plots received 34N from CF and were clipped to the same height as the study plots to which they were contiguous.

Forage harvesting, sampling and laboratory analyses. Forage was clipped with a flail-chopping mower when it achieved a mean target height of 20 cm on August 21, and then again on September 25. Harvested forage was collected into plastic baskets and immediately weighed on a portable field scale. Samples of forage from each plot were placed into tared paper bags, weighed, dried at 55^{o} C for 72 hr and ground to pass a 1-mm screen in a Wiley mill. Forage concentrations of CP and DM were determined according to procedures of AOAC (1995), and concentrations of NDF, ADF and ADL were determined sequentially according to the procedures of Van Soest et al. (1991). Concentrations of P, K, Ca, Mg, Al, Cu, Fe, Mn and Zn were measured using inductively coupled argon plasma (ICAP) spectroscopy according to the procedures of Olsen and Sommers (1982).

The experiment was repeated in 2007, at which time forage in each plot was clipped to a height of 10 cm on April 23, amended with the same fertilization treatments as those applied in 2006, and harvested on August 16 and then again on September 27 at the same clipping heights as those assigned in 2006.

Statistical analyses. Data were analyzed by analysis of variance for a completely randomized design with a 2 × 2 × 4 factorial arrangement of treatments (3 replicates/treatment) in which harvest was treated as a repeated measure using the PROC MIXED procedures of SAS and standard least-squares model fit (SAS Inst., Inc., Cary, NC). Components of the statistical model included clipping height, fertilizer source, fertilizer application rate and their two- and three-way interactions treated as fixed effects, and year treated as a random effect. Plot was considered the experimental unit. All data are reported as least squares means ± SE, and the significance level was preset at $P < 0.10$ for all analyses.

Results

Temperature and precipitation. Monthly mean air temperatures (Table 1) approximated or were slightly higher than 30-yr averages (Table 2) for Marion Junction, AL in July, August and September of 2006 and 2007, but monthly total precipitation (Table 3) was 42, 69 and 26% of average for July, August and September, respectively, in 2006, and was 55, 75 and 67% of average, respectively, for the these three months in 2007.

Table 1. Monthly mean air temperatures for 2006 and 2007, and 30-yr averages at Marion Junction, AL

Month	**Avg. High, ºC**			**Avg. Low, ºC**			**Mean, ºC**		
	2006	**2007**	**30-yr**	**2006**	**2007**	**30-yr**	**2006**	**2007**	**30-yr**
Jan	18	14	13	4	3	1	11	8	7
Feb	14	14	16	1	0	2	8	7	9
Mar	21	24	20	6	8	6	14	16	13
Apr	28	23	24	13	9	9	21	16	17
May	28	30	28	16	15	15	22	23	22
Jun	34	34	32	19	20	19	26	27	26
Jul	**36**	**32**	**33**	**22**	**22**	**21**	**29**	**27**	**27**
Aug	**35**	**37**	**33**	**22**	**23**	**21**	**29**	**30**	**27**
Sep	**31**	**31**	**31**	**17**	**19**	**17**	**24**	**25**	**24**
Oct	25	26	25	10	13	11	18	20	18
Nov	19	20	19	4	4	6	12	12	13
Dec	16	17	14	2	5	2	9	11	8

Table 2. Differences in monthly mean air temperatures in 2006 and 2007 from 30-yr averages at Marion Junction, AL

Month	**Avg. High, ºC**		**Avg. Low, ºC**		**Mean, ºC**	
	2006	**2007**	**2006**	**2007**	**2006**	**2007**
Jan	1	6	1	4	1	5
Feb	-1	-2	0	0	0	-1
Mar	-1	0	0	1	0	0
Apr	0	4	-3	2	-1	3
May	0	0	-1	-1	0	0
Jun	-1	1	-2	-1	-1	0
Jul	**0**	**3**	**0**	**1**	**0**	**2**
Aug	**2**	**4**	**0**	**1**	**1**	**2**
Sep	**2**	**2**	**-2**	**-2**	**0**	**0**
Oct	1	2	0	-1	1	0
Nov	1	1	3	1	2	1
Dec	-2	1	-2	-2	-2	-1

Table 3. Monthly precipitation for 2006 and 2007, and differences from 30-yr averages at Marion Junction, AL

Month	**Avg. Precipitation, mm**			**Differences, mm**	
	2006	**2007**	**30-yr**	**2006**	**2007**
Jan	105	93	149	-43	-55
Feb	136	54	119	17	-65
Mar	60	39	163	-104	-124
Apr	23	34	123	-99	-88
May	90	3	104	-14	-101
Jun	28	101	113	-85	-11
Jul	**54**	**70**	**129**	**-75**	**-58**
Aug	**58**	**64**	**85**	**-27**	**-21**
Sep	**26**	**67**	**100**	**-74**	**-33**
Oct	85	66	75	9	-9
Nov	173	39	111	63	-72
Dec	124	58	128	-4	-70
Total	**962**	**688**	**1398**	**-436**	**-710**

Dry matter yield. Forage cut to a 5-cm height yielded 71% more ($P < 0.001$) DM than forage cut to a 10-cm height (Table 4). There was no difference in DM yield between fertilizer-source treatments; however, the 134N treatment yielded one-third more DM than the 34N ($P = 0.015$) and 67N ($P = 0.012$) treatments.

Table 4. Forage DM yield (kg/ha) from dallisgrass amended with commercial fertilizer (CF) or poultry litter (PL) at 4 rates of N application and clipped to a 5- or 10-cm height

Clipping height	5 cm		10 cm		Mean
N application rate, kg/ha	CF	PL	CF	PL	
34	934	785	450	386	640^{a}
67	846	804	452	408	627^{a}
101	907	898	639	491	734^{ab}
134	957	1,031	682	676	836^{b}
Mean	911	879	556	490	
Clipping-height mean	895^{c}		523^{d}		

^{a,b}Within a column, means without a common superscript differ ($P = 0.04$; SEM = 126; n = 48).
^{c,d}Within a row, means without a common superscript differ ($P < 0.001$; SEM = 119; n = 96).

Crude protein. There was no difference (*P* = 0.71) in forage concentration of CP between clipping-height treatments (Table 5). However, forage amended with CF had 0.8 percentage unit higher (*P* = 0.002) concentration of CP than PL-amended forage. Forage receiving 134N had 1.2 and 0.8 percentage units higher concentration of CP than the 34N (*P* = 0.001) and 67N (*P* = 0.035) treatments, respectively, but was not different (*P* = 0.21) from the 101N treatment. Forage receiving 101N had 0.7 percentage unit higher (*P* = 0.039) CP concentration than 34N, but was not different (*P* = 0.37) from the 67N treatment.

Table 5. Concentration of CP (%, DM basis) in dallisgrass amended with commercial fertilizer (CF) or poultry litter (PL) at 4 rates of N application and clipped to a 5- or 10-cm height

Fertilizer source	CF		PL		Mean
N application rate, kg/ha	5 cm	10 cm	5 cm	10 cm	
34	9.8	9.2	8.7	9.0	9.2^{a}
67	10.3	9.7	9.2	9.2	9.6^{ab}
101	10.6	10.1	9.3	9.7	9.9^{bc}
134	10.8	10.9	9.9	9.9	10.4^{c}
Mean	10.4	10.0	9.3	9.4	
Fertilizer-source mean	10.2^{d}		9.4^{e}		

[a,b,c] Within a column, means without a common superscript differ (*P* = 0.009; SEM = 0.3; n = 48).

[d,e] Within a row, means without a common superscript differ (*P* = 0.002; SEM = 0.2; n = 96).

Neutral detergent fiber. Clipping forage to a 10-cm height resulted in a 0.9 percentage-unit increase (*P* = 0.02) in NDF concentration compared with clipping to a 5-cm height (Table 6). A clipping height × fertilizer source interaction (*P* = 0.06) was observed such that forage amended with PL and clipped to a 10-cm height had 1.0 and 1.7 percentage units higher NDF concentration than forage clipped to a 5-cm height and amended with CF (*P* = 0.06) and PL (*P* = 0.003), respectively.

Table 6. Concentration of NDF (%, DM basis) in dallisgrass amended with commercial fertilizer (CF) or poultry litter (PL) at 4 rates of N application and clipped to a 5- or 10-cm height

Clipping height	5 cm		10 cm		Mean
N application rate, kg/ha	CF	PL	CF	PL	
34	67.1	66.3	67.3	68.7	67.4
67	66.6	66.4	67.4	66.9	66.8
101	65.9	67.0	66.8	67.6	66.8
134	67.1	64.5	65.9	67.8	66.3
Mean	66.7^{a}	66.0^{a}	66.8^{ab}	67.7^{b}	
Clipping-height mean	66.4^{c}		67.3^{d}		

[a,b]Within a row, means without a common superscript differ (*P* = 0.06; SEM = 1.7; n = 48).
[c,d]Within a row, means without a common superscript differ (*P* = 0.02; SEM = 1.7; n = 96).

Acid detergent fiber. Forage clipped to a 10-cm height had 0.8 percentage unit higher (*P* = 0.002) concentration of ADF than forage clipped to a 5-cm height (Table 7). Forage receiving 134N had 1.1 and 0.7 percentage units lower ADF concentration than the 34N (*P* = 0.001) and 67N (*P* = 0.06) treatments, respectively. Forage receiving 101N had 0.6 percentage unit lower (*P* = 0.09) ADF concentration than the 34N treatment, but was not different from the 67N (*P* = 0.66) or 134N (*P* = 0.13) treatments.

Table 7. Concentration of ADF (%, DM basis) in dallisgrass amended with commercial fertilizer (CF) or poultry litter (PL) at 4 rates of N application and clipped to a 5- or 10-cm height

Clipping height	5 cm		10 cm		Mean
N application rate, kg/ha	CF	PL	CF	PL	
34	33.8	33.9	34.4	35.0	34.3^{a}
67	33.8	33.7	34.1	33.8	33.9^{ab}
101	33.0	33.7	34.0	34.1	33.7^{bc}
134	33.2	31.8	33.6	34.1	33.2^{c}
Mean	33.5	33.3	34.0	34.3	
Clipping-height mean	33.4^{d}		34.2^{e}		

[a,b,c] Within a column, means without a common superscript differ (*P* = 0.015; SEM = 0.3; n = 48).

[d,e] Within a row, means without a common superscript differ (*P* = 0.002; SEM = 0.2; n = 96).

Acid detergent lignin. Clipping forage to a 5-cm height resulted in a 0.2 percentage-unit increase ($P = 0.08$) in ADL concentration compared with clipping to a 10-cm height (Table 8). A clipping height × fertilizer source interaction ($P = 0.08$) was observed such that forage amended with CF and clipped to a 5-cm height had 0.4, 0.5 and 0.4 percentage units higher ADL concentration than PL-amended forage clipped to a 5-cm height ($P = 0.04$), CF-amended forage clipped to a 10-cm height ($P = 0.02$), and PL-amended forage clipped to a 10-cm height ($P = 0.04$), respectively.

Table 8. Concentration of ADL (%, DM basis) in dallisgrass amended with commercial fertilizer (CF) or poultry litter (PL) at 4 rates of N application and clipped to a 5- or 10-cm height

Clipping height	5 cm		10 cm		Mean
N application rate, kg/ha	CF	PL	CF	PL	
34	4.2	3.9	3.7	3.8	3.9
67	4.2	3.8	3.8	3.7	3.9
101	4.3	3.7	3.6	3.9	3.9
134	4.2	3.8	3.9	3.8	3.9
Mean	4.2^a	3.8^b	3.7^b	3.8^b	
Clipping-height mean	4.0^c		3.8^d		

[a,b]Within a row, means without a common superscript differ ($P = 0.08$; SEM = 0.1; n = 48).
[c,d]Within a row, means without a common superscript differ ($P = 0.08$; SEM = 0.1; n = 96).

Calcium. Forage clipped to a 10-cm height had 0.05 percentage unit lower ($P < 0.001$) concentration of Ca than forage clipped to a 5-cm height (Table 9). There was a 0.03 percentage unit higher ($P = 0.003$) concentration of Ca in forage amended with CF (0.49%) than PL (0.46%), but there were no differences ($P = 0.63$) in forage concentration of Ca among N application-rate treatments.

Table 9. Concentration of Ca (%, DM basis) in dallisgrass amended with commercial fertilizer (CF) or poultry litter (PL) at 4 rates of N application and clipped to a 5- or 10-cm height

Clipping height	5 cm		10 cm		Mean
N application rate, kg/ha	CF	PL	CF	PL	
34	0.50	0.51	0.46	0.43	0.48
67	0.52	0.50	0.46	0.44	0.48
101	0.51	0.48	0.47	0.42	0.47
134	0.49	0.47	0.48	0.42	0.46
Mean	0.51	0.49	0.47	0.43	
Clipping-height mean	0.50^a		0.45^b		

^{a,b}Within a row, means without a common superscript differ ($P < 0.001$; SEM = 0.01; n = 96).

Phosphorus. Forage clipped to a 5-cm height had 0.01 percentage unit higher ($P = 0.01$) concentration of P than forage clipped to a 10-cm height (Table 10). There was a 0.01 percentage unit higher ($P < 0.001$) concentration of P in forage amended with PL (0.18%) than CF (0.17%), but forage concentrations of P were not different ($P = 0.68$) among N application-rate treatments. A clipping height × fertilizer source interaction ($P = 0.06$) was observed such that forage amended with PL and clipped to a 5-cm height had 0.02, 0.03 and 0.02 percentage unit higher concentration of P than CF-amended forage clipped to a 5-cm height ($P < 0.001$), CF-amended forage clipped to a 10-cm height ($P < 0.001$), and PL-amended forage clipped to a 10-cm height ($P = 0.002$), respectively. Also, forage amended with PL and clipped to a 10-cm height had 0.01 percentage unit higher ($P < 0.08$) concentration of P than forage clipped to a 10-cm height and amended with CF.

Table 10. Concentration of P (%, DM basis) in dallisgrass amended with commercial fertilizer (CF) or poultry litter (PL) at 4 rates of N application and clipped to a 5- or 10-cm height

Clipping height	5 cm		10 cm		Mean
N application rate, kg/ha	CF	PL	CF	PL	
34	0.18	0.18	0.17	0.17	0.18
67	0.17	0.19	0.16	0.17	0.17
101	0.16	0.19	0.16	0.17	0.17
134	0.16	0.18	0.17	0.18	0.17
Mean	0.17^{ab}	0.19^{c}	0.16^{a}	0.17^{b}	
Clipping-height mean	0.18^{d}		0.17^{e}		

^{a,b,c}Within a row, means without a common superscript differ ($P = 0.06$; SEM = 0.01; n = 48).
^{d,e}Within a row, means without a common superscript differ ($P = 0.01$; SEM = 0.01; n = 96).

Potassium. Forage clipped to a 10-cm height had 0.07 percentage unit higher ($P = 0.001$) concentration of K than forage clipped to a 5-cm height (Table 11). There was a 0.29 percentage unit higher ($P < 0.001$) concentration of K in forage amended with PL (1.03%) than CF (0.74%), but there were no differences ($P = 0.11$) among N application-rate treatments in forage concentrations of K. A clipping height × fertilizer source interaction ($P < 0.001$) was observed such that forage amended with CF and clipped to a 5-cm height had 0.39, 0.18 and 0.36 percentage unit lower concentration of K than forage clipped to a 5-cm height and amended with PL ($P < 0.001$), forage clipped to a 10-cm height and amended with CF ($P < 0.001$), and forage clipped to a 10-cm height and amended with PL ($P < 0.001$), respectively. Also, forage amended with PL and clipped to a 5-cm height had 0.21 percentage unit higher ($P < 0.001$) concentration of K than forage clipped to a 10-cm height and amended with CF, and forage amended with CF and clipped to a 10-cm height had 0.18 percentage unit lower ($P < 0.001$) concentration of K than forage clipped to a 10-cm height and amended with PL. A fertilizer source × N application rate interaction ($P < 0.001$) was also observed. Forage concentration of K increased as N application rate increased in forage amended with PL such that the 34N treatment (0.91%) had 0.10, 0.17, and 0.20 percentage unit lower concentration of K than the 67N (1.01%; $P = 0.02$), 101N (1.08%; $P < 0.001$), and 134N (1.11%; $P < 0.001$) treatments. Forage amended with PL and 67N had 0.10 percentage unit lower ($P = 0.04$) concentration of K than the 134N treatment. In contrast, forage amended with CF and receiving 34N (0.79%) had 0.09 percentage unit higher ($P = 0.04$) concentration of K than the 134N (0.70%) treatment, but did not differ from the 67N (0.72%; $P = 0.13$), and 101N (0.75%; $P = 0.40$) treatments.

Table 11. Concentration of K (%, DM basis) in dallisgrass amended with commercial fertilizer (CF) or poultry litter (PL) at 4 rates of N application and clipped to a 5- or 10-cm height

Clipping height	5 cm		10 cm		Mean
N application rate, kg/ha	CF	PL	CF	PL	
34	0.69	0.93	0.89	0.89	0.85
67	0.65	1.05	0.78	0.98	0.87
101	0.66	1.12	0.84	1.05	0.92
134	0.59	1.08	0.81	1.13	0.90
Mean	0.65^{a}	1.04^{b}	0.83^{c}	1.01^{b}	
Clipping-height mean	0.85^{d}		0.92^{e}		

[a,b,c]Within a row, means without a common superscript differ ($P < 0.001$; SEM = 0.02; n = 48).
[d,e]Within a row, means without a common superscript differ ($P = 0.001$; SEM = 0.02; n = 96).

Magnesium. Clipping forage to a 5-cm height had increased ($P < 0.001$) concentration of Mg over that of forage clipped to a 10-cm height (Table 12). There was a 0.06 percentage unit higher ($P < 0.001$) concentration of Mg in forage amended with CF (0.25%) than PL (0.19%), but there were no differences ($P = 0.70$) among fertilizer-rate treatments in forage concentration of Mg. An interaction ($P = 0.06$) was observed such that each clipping-height × fertilizer-source treatment was different ($P < 0.001$) from each other. Also, a fertilizer source × N application-rate interaction ($P < 0.001$) was observed. Forage concentration of Mg increased with increasing N application rate in forage amended with CF such that 34N (0.23%) had 0.02, 0.04, and 0.03 percentage unit lower concentration of Mg than the 67N (0.25%; $P = 0.02$), 101N (0.27%; $P < 0.001$), and 134N (0.26%; $P < 0.001$) treatments. Forage amended with CF and 67N had 0.02 percentage unit lower ($P = 0.09$) concentration of Mg than the 101N treatment. In contrast, concentration of Mg decreased with increasing N application rate in forage amended with PL such that 34N (0.20%) had 0.02 percentage unit higher concentration of Mg than the 101N (0.18%; *P* = 0.009) and 134N (0.18%; *P* = 0.008) treatments.

Table 12. Concentration of Mg (%, DM basis) in dallisgrass amended with commercial fertilizer (CF) or poultry litter (PL) at 4 rates of N application and clipped to a 5- or 10-cm height

Clipping height	5 cm		10 cm		Mean
N application rate, kg/ha	CF	PL	CF	PL	
34	0.25	0.22	0.21	0.18	0.22
67	0.28	0.20	0.22	0.18	0.22
101	0.30	0.19	0.24	0.17	0.22
134	0.28	0.19	0.25	0.17	0.22
Mean	0.27^a	0.20^b	0.23^c	0.17^d	
Clipping-height mean	0.24^e		0.20^f		

^{a,b,c,d}Within a row, means without a common superscript differ (*P* = 0.06; SEM = 0.01; n = 48).
^{e,f}Within a row, means without a common superscript differ (*P* < 0.001; SEM = 0.01; n = 96).

Aluminum. Clipping forage to a 5-cm height resulted in a 407 mg/kg increase ($P < 0.001$) in concentration of Al compared with clipping to a 10-cm height (Table 13). There were no differences ($P = 0.63$) in forage concentrations of Al between fertilizer sources or among N application-rate treatments ($P = 0.49$)

Table 13. Concentration of Al (mg/kg, DM basis) in dallisgrass amended with commercial fertilizer (CF) or poultry litter (PL) at 4 rates of N application and clipped to a 5- or 10-cm height

Clipping height	5 cm		10 cm		Mean
N application rate, kg/ha	CF	PL	CF	PL	
34	838	1,091	420	295	661
67	586	523	302	479	473
101	695	799	462	286	561
134	728	864	302	322	554
Mean	712	819	372	346	
Clipping-height mean	766^{a}		359^{b}		

[a,b]Within a row, means without a common superscript differ ($P < 0.001$; SEM = 339; n = 96).

Copper. Clipping forage to a 5-cm height resulted in a 1.4 mg/kg increase (*P* = 0.03) in concentration of Cu compared with clipping to a 10-cm height (Table 14). There was no difference in forage concentration of Cu between fertilizer-source (*P* = 0.17) or among N application-rate treatments (*P* = 0.38); however, a fertilizer source × N application-rate interaction (*P* = 0.02) was observed such that forage amended with PL and 101N (9.6 mg/kg) had 3.9 mg/kg higher (*P* = 0.002) concentration of Cu than forage amended with PL and 34N (5.7 mg/kg). However, there were no differences (*P* = 0.15) among N application-rate treatments in concentration of Cu in CF-amended forages. Also, a clipping height × fertilizer source × N application rate interaction was observed (*P* = 0.10).

Table 14. Concentration of Cu (mg/kg, DM basis) in dallisgrass amended with commercial fertilizer (CF) or poultry litter (PL) at 4 rates of N application and clipped to a 5- or 10-cm height

Clipping height	5 cm		10 cm		Mean
N application rate, kg/ha	CF	PL	CF	PL	
34	6.1	6.6	8.7	4.9	6.6
67	6.6	7.1	5.3	8.1	6.8
101	6.6	12.9	5.3	6.3	7.8
134	8.9	8.5	6.7	6.8	7.7
Mean	7.1	8.8	6.5	6.5	
Clipping-height mean	7.9^{a}		6.5^{b}		

[a,b]Within a row, means without a common superscript differ (*P* = 0.03; SEM = 0.7; n = 96).

Iron. Clipping forage to a 5-cm height resulted in a 273 mg/kg increase ($P < 0.001$) in concentration of Fe compared with clipping to a 10-cm height (Table 15). There was no difference in forage Fe concentration between fertilizer-source ($P = 0.69$) or among N application-rate treatments ($P = 0.39$).

Table 15. Concentration of Fe (mg/kg, DM basis) in dallisgrass amended with commercial fertilizer (CF) or poultry litter (PL) at 4 rates of N application and clipped to a 5- or 10-cm height

Clipping height	5 cm		10 cm		Mean
N application rate, kg/ha	CF	PL	CF	PL	
34	522	770	290	198	445
67	362	363	198	294	304
101	488	539	346	173	387
134	495	568	220	197	370
Mean	467	560	264	216	
Clipping-height mean	513^a		240^b		

[a,b]Within a row, means without a common superscript differ ($P < 0.001$; SEM = 215; n = 96).

Manganese. Forage clipped to a 5-cm height had 28 mg/kg higher ($P < 0.001$) concentration of Mn than forage clipped to a 10-cm height (Table 16). There was an 18 mg/kg higher ($P = 0.008$) concentration of Mn in forage amended with CF (159 mg/kg) than PL (141 mg/kg), but there were no differences ($P = 0.17$) among N application-rate treatments in forage concentration of Mn. A clipping height × fertilizer source interaction ($P < 0.001$) was observed such that forage amended with CF and clipped to a 5-cm height had 47 and 37 mg/kg lower concentration of Mn than PL-amended forage clipped to a 5-cm height ($P < 0.001$) and CF-amended forage clipped to a 10-cm height ($P < 0.001$), respectively. Forage amended with PL and clipped to a 10-cm height had 46, 93 and 83 mg/kg lower concentration of Mn than CF-amended forage clipped to a 5-cm height ($P < 0.001$), PL-amended forage clipped to a 5-cm height ($P < 0.001$), and CF-amended forage clipped to a 10-cm height CF ($P < 0.001$), respectively.

Table 16. Concentration of Mn (mg/kg, DM basis) in dallisgrass amended with commercial fertilizer (CF) or poultry litter (PL) at 4 rates of N application and clipped to a 5- or 10-cm height

Clipping height	5 cm		10 cm		Mean
N application rate, kg/ha	CF	PL	CF	PL	
34	168	193	200	87	162
67	138	197	166	100	150
101	137	205	169	84	149
134	121	156	178	109	141
Mean	141^{a}	188^{b}	178^{b}	95^{c}	
Clipping-height mean	164^{d}		136^{e}		

[a,b,c]Within a row, means without a common superscript differ ($P < 0.001$; SEM = 33; n = 48).
[d,e]Within a row, means without a common superscript differ ($P < 0.001$; SEM = 32; n = 96).

Zinc. Forage clipped to a 5-cm height had 5.0 mg/kg higher ($P < 0.001$) concentration of Zn than forage clipped to a 10-cm height (Table 17). There was no fertilizer source effect ($P = 0.21$) on forage concentration of Zn. However, forage receiving 134N had 2.8 and 2.4 mg/kg higher concentration of Zn than 34N ($P = 0.02$) and 67N ($P = 0.05$) forages, respectively. A clipping height × fertilizer source interaction ($P < 0.001$) was observed such that forage amended with CF and clipped to a

5-cm height had 4.2 mg/kg lower Zn concentration than forage clipped to a 5-cm height and amended with PL (*P* < 0.001). Forage amended with PL and clipped to a 10-cm height had 3.9, 8.1 and 2.1 mg/kg lower concentration of Zn than CF-amended forage clipped to a 5-cm height (*P* = 0.001), PL-amended forage clipped to a 5-cm height (*P* < 0.001), and CF-amended forage clipped to a 10-cm height CF (*P* = 0.08), respectively. Forage amended with PL and clipped to a 5-cm height had 6.0 mg/kg higher concentration of Zn than forage clipped to a 10-cm height and amended with CF (*P* < 0.001).

Table 17. Concentration of Zn (mg/kg, DM basis) in dallisgrass amended with commercial fertilizer (CF) or poultry litter (PL) at 4 rates of N application and clipped to a 5- or 10-cm height

Clipping height	5 cm		10 cm		Mean
N application rate, kg/ha	CF	PL	CF	PL	
34	24.0	29.7	27.6	21.8	25.8^{d}
67	26.1	28.6	24.1	25.7	26.2^{d}
101	27.6	35.6	23.7	22.8	27.5^{ef}
134	31.7	32.2	26.7	23.5	28.6^{f}
Mean	27.4^{a}	31.6^{b}	25.6^{a}	23.5^{c}	
Clipping-height mean	29.5^{g}		24.5^{h}		

^{a,b,c}Within a row, means without a common superscript differ (*P* < 0.001; SEM = 1.5; n = 48).
^{d,e,f}Within a column, means without a common superscript differ (*P* = 0.08; SEM = 1.5; n = 48).
^{g,h}Within a row, means without a common superscript differ (*P* < 0.001; SEM = 1.3; n = 96).

Discussion

Information on forage yield is used by the resource manager to establish forage allowance, and for this reason it is an especially important factor influencing grazing-animal performance (Minson and Wilson, 1994). Also, yield is directly related to sward density, structure and height, all of which have been shown to be key determinants of grazing behavior and voluntary forage intake by cattle (Lippke, 1981; Laca et al., 1992; Flores et al, 1993). Because of the truncated experimental period utilized in each year of the present study, cumulative production of dallisgrass was somewhat less than more typical seasonal production reported by other investigators (Lovvorn, 1944; Holt and McDaniel, 1963; Pizarro, 2000; Robinson et al., 1988). Also, dallisgrass is best adapted to regions that receive more than 900 mm of annual rainfall (Venuto et al., 2003), and lack of rainfall may partially explain why forage in the present study did not develop to its full production potential, especially in 2007.

The influence of sward height on ingestive behavior and intake of dallisgrass by cattle has been documented in a number of studies (Lippke, 1981; Ungar et al., 1991; Laca et al., 1992; Flores et al., 1993). In general, these authors have reported that cattle modify their bite mass, defoliation area and depth of grazing in the forage canopy in response to changes in sward height, forage density, and relative proportions of leaf and stem tissue. Less extensively studied is the resilience of dallisgrass to forage and grazing-animal management practices that result in low stubble heights and significantly reduced photosynthetic leaf area and carbohydrate reserves for production of vegetative regrowth. Clipping dallisgrass to a 5-cm height resulted in an increase of more than 70% in DM yield over clipping to a 10-cm height, which is considerably greater than the 11.5% increase in DM yield reported by Holt and McDaniel (1963) for dallisgrass clipped to a 5-cm compared with a 15-cm height. Dallisgrass clipped to a 5-cm height yielded 1,239 and 552 kg DM/ha for first and second harvests, respectively, across both years of the study; however, dallisgrass clipped to a 10-cm height yielded only 592 and 455 kg DM/ha for first and second harvests, respectively. Because regrowth DM yield compared favorably between the cutting-height treatments, cutting primary growth to the lower stubble height evidently did not compromise its regrowth potential compared with that of primary growth clipped to the higher stubble height. Watson and Ward (1970) reported higher daily and total seasonal regrowth yields with reductions in clipping height, and suggested that dallisgrass could tolerate clipping to stubble heights as low as 2.5 cm as long as at least 10% of tillers were left intact.

Yield of dallisgrass DM increased as a result of increasing N application from 34N and 67N to 134N. Similarly, Robinson et al. (1988) reported an increase in dallisgrass DM yield from 5,330 kg to 15,340 kg/ha when N fertilization rate was increased from 0 to 896 kg/ha. Likewise, Pizarro (2000) reported increases in DM production from dallisgrass ranging from 2,400 to 9,000 kg/ha over a 5-yr period with increasing N fertilization from 0 to 500 kg/ha in increments of 100 kg/ha. Jones and Watson (1991) reported increases in yield of dallisgrass-bermudagrass pasture with increasing rates of fertilization with N, but no yield response to fertilization with either P or K alone in the absence of added N. Brown and Rouse (1953) also reported increases in yield of dallisgrass DM with increasing rates of N fertilization in a greenhouse study with white clover-dallisgrass cultures.

Forage protein is an important source of N for ruminal microorganisms, and an important goal of forage management is to derive as much of the N requirement as possible from forage in order to limit or eliminate the need for supplementation. The range of forage concentrations of CP observed in the present study was similar to that observed by Venuto et al. (2003), who reported concentrations of CP in dallisgrass of 9.8 to 11%, and lower than that observed by Baréa et al. (2007), who reported a wider range of concentrations of CP in dallisgrass of 10.7 to 18.6%. Using prediction equations of Linn and Marten (1989), dallisgrass in the present study would be expected to have approximately 87% the relative feed value (RFV) of a mature, medium-quality alfalfa hay; i.e., ~ 60% TDN. Values for CP concentration and RFV of dallisgrass in the present study may be compared with those required by a growing beef steer of 340 kg liveweight (8.5% CP and 60% TDN, DM basis) from a daily DM intake of 9.2 kg to achieve an ADG of 0.80 kg (NRC, 1996).

There was no difference in forage concentration of CP between the two clipping-height treatments. Nutritive quality varies within the forage canopy such that stems and younger leaves in the upper canopy are of higher quality than stems and older or dead leaves in the lower canopy (Brisibe et al., 2009; Nordheim-Viken et al., 2009). Results of the present study are interpreted to mean that quality of available forage in the lower canopy would not be expected to differ between grazing management intensities that produce variable stubble heights below 10 cm.

Forage concentration of CP was greater for CF than PL treatments. Wood et al. (1993) observed no difference between N-source treatments in CP concentration of ‘Tifton 44’ Bermudagrass amended with either CF or PL; however, there was an increase in CP concentration with increasing rates of fertilization with N. Similarly, forage concentration of CP increased in both CF- and PL-amended dallisgrass with increasing rates of N application in the present study, in agreement with other published reports of dallisgrass response to fertilization with N (Holt, 1956; Acosta et al., 1996; Ayala Torales et al., 2000). According to Gunter et al. (2005), dallisgrass typically has higher CP concentration and *in vivo* DM digestibility than bermudagrass (*Cynodon dactylon*), and supports greater liveweight gain in stocker cattle.

Concentration of NDF is negatively correlated with voluntary intake of forage DM (Paterson et al., 1994). The NDF fraction represents the recalcitrant fibrous components (primarily cellulose, hemicellulose and lignin fractions) of the plant cell wall that are negatively correlated with forage density and in turn form the physical basis of its utility as a predictor of DMI (Mertens, 1987). On average, concentrations of NDF in dallisgrass in the present study were slightly lower than those observed by Venuto et al. (2003), who reported concentrations of 70.7% for dallisgrass grown in Texas and 69.5% for dallisgrass grown in Louisiana. However, concentrations of NDF in the present study were very similar to those observed by Acosta et al. (1996), who reported a mean value of 67.6% for dallisgrass in the spring in Buenos Aires, Argentina. Clipping at 10-cm height resulted in a slightly higher (< 1 percentage unit) NDF concentration than clipping at 5-cm height, but this difference would not be expected to have a measurable effect on voluntary DM intake by a free-grazing ruminant animal.

Forage concentration of ADF is negatively correlated with its digestibility *in vivo*, and comprises the lignin, cutin, cellulose, indigestible N and silica fractions of the plant cell wall (Van Soest, 1994). In the present study, concentration of ADF was slightly higher (< 1 percentage unit) in dallisgrass clipped to a 10-cm than 5-cm height, but this increase would not be expected to have a measurable effect on digestibility *in vivo*. Values for ADF were slightly below those observed by Ayala Torales et al. (2000), who reported concentrations of ADF in dallisgrass ranging from 35.2 to 39.5%, and intermediate to those observed by Acosta et al. (1996), who reported values ranging from 31.3% in the winter to 39.7% in the summer in Argentina. Higher rates of fertilization resulted in lower concentrations of ADF in dallisgrass in the present study, in contrast to findings of Wood et al. (1993) who reported increased concentration of crude fiber with increasing rates of N fertilization in ‘Tifton 44’ Bermudagrass.

Plant cell wall availability to herbivores is limited by different factors, one of the most important being lignin (Van Soest, 1994). Concentration of lignin increases and digestibility of plant cell-wall constituents and total plant DM decreases with advancing forage maturity (Jung and Fahey, 1983). Clipping to a 5-cm height resulted in a higher concentration of ADL than that in forage clipped to a 10-cm height, which can be explained by the fact that younger leaves and stems are located in the upper stratum of the forage canopy, and therefore lignin concentration is expected to be higher in the lower stratum where the more mature steams and leaves are located. However, it is unlikely that the small difference in concentration of lignin between clipping-height treatments in the present study would be sufficient to result in a measurable difference in cell-wall or whole-plant DM digestibility *in vivo*.

Forage concentration of minerals is dependent upon numerous factors, including plant development stage, climatic conditions, soil characteristics and fertilization regime (Greene, 2000). Among these, soil fertilization can be manipulated by the resource manager in order to provide different types and quantities of nutrients for plants; generally, it is more economical to fertilize plants in order to achieve maximum growth, and then supplement as necessary to meet requirements for animal production (Greene, 2000).

Forage concentrations of Ca in the present study were, on average, less than half of those reported by Brown and Rouse (1953) for dallisgrass cultivated in a greenhouse in association with white clover. Concentrations of Ca were higher in dallisgrass amended with CF than PL in the present study, in contrast to the study by Wood et al. (1993) in which Ca concentration in ‘Tifton 44’ Bermudagrass amended with PL was higher than in unfertilized forage or forage amended with ammonium nitrate. Results of the present study are similar to those of Robinson et al. (1988), who reported Ca concentration values for dallisgrass of 0.39 to 0.48%.

Phosphorus is arguably the single mineral element that is most commonly deficient for meeting animal requirements from grazed forages. Because of its importance in various metabolic processes in animals, notably energy metabolism, dietary P deficiency can very likely result in a deficiency of energy (Greene, 2000). In the present study, concentration of P was higher in dallisgrass amended with PL than CF, in contrast to the study by Wood et al. (1993) in which there was no difference in concentrations of P between ‘Tifton 44’ Bermudagrass amended with CF or PL. Also, concentration of P was higher in dallisgrass clipped to a 5-cm than 10-cm height. In general, values were lower than the range of values (0.27 to 0.29%) reported by Robinson et al. (1988).

Concentration of K was higher in forage amended with PL than CF, similar to results reported by Wood et al. (1993) for ‘Tifton 44’ Bermudagrass; however, there was an increase in K accumulation with increasing rate of N fertilization with PL and a decrease in K concentration with increasing rate of N fertilization with CF in their study, in contrast to the present study in which rate of N application had no effect on K concentration in dallisgrass. Forages normally contain sufficient K for meeting grazing animals’ requirements; however, high (> 2.5%) forage concentration of K may interfere with bioavailability of Mg (Greene, 2000). Concentration of K in dallisgrass averaged 0.89% in the present study, well below the threshold at which it can potentially be problematic for Mg absorption, and less than half of that in the study by Robinson et al. (1988), who reported concentrations of K in dallisgrass of 2.04 to 2.24%. Potassium concentrations in this study, on average, were similar to those reported by Brown and Rouse (1953) for dallisgrass grown in a greenhouse in association with white clover. Concentration of Mg was higher in dallisgrass amended with CF than PL, and increased with increasing rate of N application from CF, in agreement with Robinson et al. (1988) who reported an increase from 0.19 to 0.36% Mg when N application rate was increased from 0 to 896 kg/ha.

Utilization of PL as a fertilizer source has an advantage over synthetic fertilizers of providing trace minerals that are important for plant and animal nutrition. However, it is important to recognize the potential for toxicity to livestock that may result from repeated land-application of PL and possible accumulation of certain trace minerals in soil and grazed forage. Franzluebbers et al. (2004b) reported 4.1 and 7.8 mg/kg greater concentrations of extractable-soil Zn and Cu, respectively, in the upper 15-cm horizon of a Piedmont soil at the end of a 5-yr period of land-application of PL at a rate of 196 kg N· ha^{-1}· yr^{-1}. Gascho and Hubbard (2006) reported a four- and five-fold increase in concentrations of Cu and Zn, respectively, in the surface of a Tifton soil in the Coastal Plain of Georgia following land-application of PL at a rate of 2,812 kg N/ha over a 5-yr period.

Iron concentration in forages grown in the US typically meets or exceeds animal dietary requirements (Greene, 2000). Concentration of Fe in dallisgrass in the present study was well above the dietary requirement (50 mg/kg DM) for beef cattle (NRC, 1996), and was higher in forage clipped to a 5- than 10-cm height. Some trace elements are not required or may be required in small amounts, and if ingested and absorbed in excessive amounts can be toxic to cattle. Aluminum is one such trace mineral for which the maximum tolerable concentration (MTC) for beef cattle is 1,000 mg/kg DM (NRC, 1996). Dallisgrass clipped to a 5-cm height had a higher concentration of Al than forage clipped to a 10-cm height and, with the exception of forage amended with PL at the 34N application rate, had concentrations of Al that were below the MTC for beef cattle.

Suboptimal Cu status in ruminants may be caused by low forage concentration of Cu, high concentration of a Cu antagonist such as Fe, or a combination of both (Greene, 2000). Concentration of Cu in the present study was higher for dallisgrass clipped to a 5- than 10-cm height, and on average was below the concentration required (10 mg/kg DM) by beef cattle (NRC, 1996). Concentration of Mn, which is normally higher in forage than required by the animal (Greene, 2000), was higher in dallisgrass amended with CF than PL in the present study. Zinc and Cu are often deficient in warm-season grasses, and normally are the most limiting trace minerals in both warm-season and cool-season forages (Greene, 2000). Deficiencies of trace minerals in grazed forage require supplementation in order to meet animal requirements for maximum performance and optimal health. Zinc is one such trace mineral for which deficiency in forages is not uncommon in the US (Greene, 2000). Concentration of Zn in dallisgrass was below that required (30 mg/kg DM) by beef cattle (NRC, 1996), and was not different between clipping-height and fertilizer-source treatments or among N application-rate treatments in the present study.

Implications

Results indicate that dallisgrass can withstand defoliation to a 5-cm stubble height, thereby increasing DM yield compared with defoliation to a 10-cm stubble height, without compromising forage quality or capacity for regrowth. Also, dallisgrass amended with PL or CF was comparable in productivity and nutritive quality as determined by laboratory analysis. Dallisgrass amended with PL had higher concentrations of P and K than CF-amended dallisgrass, but trace-mineral profiles were not markedly different between dallisgrass amended with PL or CF. Results are interpreted to mean that poultry litter may offer potential as a safe, cost-effective alternative to commercial fertilizer for supporting productivity and nutritive quality of dallisgrass on Black Belt soils.

IV. PRODUCTIVITY, UTILIZATION AND NUTRITIVE QUALITY OF DALLISGRASS (*PASPALUM DILATATUM*) AS INFLUENCED BY STOCKING DENSITY UNDER CONTINUOUS OR ROTATIONAL GRAZING

Introduction

Dallisgrass (*Paspalum dilatatum*) is a warm-season perennial grass indigenous to South America, primarily Uruguay, Argentina and southern Brazil (Pizarro, 2000). Dallisgrass represents just 10% of the perennial warm-season grassland acreage in the State of Alabama where its major uses are for pasture, hay and silage (AASS, 1996). It is a perennial bunchgrass, very leafy with rough edges, grows around 25 to 50 cm tall, and utilizes the C_4 photosynthesis pathway. Dallisgrass is utilized as a pasture grass in the southeastern USA because of its high nutritive quality and availability for grazing earlier in the spring and longer into the fall than other warm-season perennial grasses (Venuto et al., 2003). It is well adapted to clay soils in the Black Belt physiographic region of Alabama, but information on dallisgrass under intensive grazing management is limited. Therefore, research on its tolerance under intensive grazing is needed to more fully develop it as a pasture resource for grazing cattle. The objective of the present study was to determine the productivity, utilization and nutritive quality of dallisgrass as influenced by grazing management using variable cattle-stocking densities.

Materials and methods

Site Characteristics. The experimental site comprised existing dallisgrass (*Paspalum dilatatum*) pastures located at the Black Belt Research and Extension Center in Marion Junction, AL (32.5° lat., 87.2° long., 61 m elev.). The pastures had been planted to tall fescue (*Lolium arundinaceum*) in 1980 and utilized for grazing by beef cattle. In the spring of 2006, pastures were sprayed with gramoxone to eradicate the fescue, and dallisgrass was seeded into the pastures with a Hay Buster® no-till drill at a rate of 22.4 kg/ha on June 27. The pastures were again overseeded with dallisgrass at 16.8 kg/ha by no-till on April 3, 2007 and May 7, 2008 to obtain a more uniform and dense stand. In both 2007 and 2008, pastures received 67 kg of N/ha as ammonium nitrate in late spring. The soil in the pastures is a clayey loam with a mean pH of 7.9. Mean annual temperature at the site is 17.6 ºC, and mean annual precipitation is 1400 mm. Precipitation and temperature were recorded daily throughout the experiment.

Treatments. Replicate 0.40-ha paddocks in the dallisgrass pastures were continuously grazed (CG), or replicate 0.40-ha paddocks were subdivided with electric fencing into either two 0.20-ha, three 0.13-ha or four 0.10-ha cells and rotationally grazed (RG) as illustrated in Figure 3. In the first year of the 2-year grazing study, 3 Angus × Simmental crossbred steers (initial BW, 354 ± 6 kg) were assigned randomly to each paddock on July 16, 2007. In the second year, 3 Angus × Simmental crossbred steers (initial BW, 310 ± 6 kg) were assigned randomly to each paddock on July 14, 2008. Within RG treatments, 0.20-, 0.13- and 0.10-ha cells were grazed for 7 d followed by 7, 14 or 21 d rest, respectively. Animals were weighed at 28-d intervals in both years, and grazing was terminated after 84 d on October 9 in 2007 and on October 7 in 2008.

Steers were born in the fall and received blackleg booster and Bovi-shield® vaccinations 30 d prior to weaning in mid-August, at which time they received a booster vaccination of Bovi-sheild® and were treated with Ivomec® dewormer. The steers were then pre-conditioned for 45 d during which they had *ad libitum* access to a diet consisting of 28% cracked corn, 7% cottonseed meal, 60% soy hull pellets, 3% molasses and 2% Bovitec® mineral, including *ad libitum* access to dallisgrass hay. At the end of the pre-conditioning phase, steers were placed on dallisgrass and fescue pasture, depending on availability, and supplemented as necessary with hay. Two weeks prior to the experiment, steers were again treated with Ivomec® and implanted with Ralgro®.

In both years, grazing was initiated when forage had attained a mean height of approximately 20 cm, corresponding to a forage allowance of approximately 1,100 kg DM/ha in the forage canopy above 10 cm as determined and validated by the investigators in another experiment previously described in this manuscript. Because of persistent drought and declining forage availability, 1 steer was removed from each paddock after 28 d in 2007, and grazing was discontinued on 1 of the CG paddocks after 56 d in both years, on September 11, 2007 and September 9, 2008. Ample shade was provided in each grazing cell, and cattle had *ad libitum* access to water and trace-mineralized salt[1]. The study was conducted according to protocol that had been approved by the Institutional Animal Care and Use Committee of Auburn University.

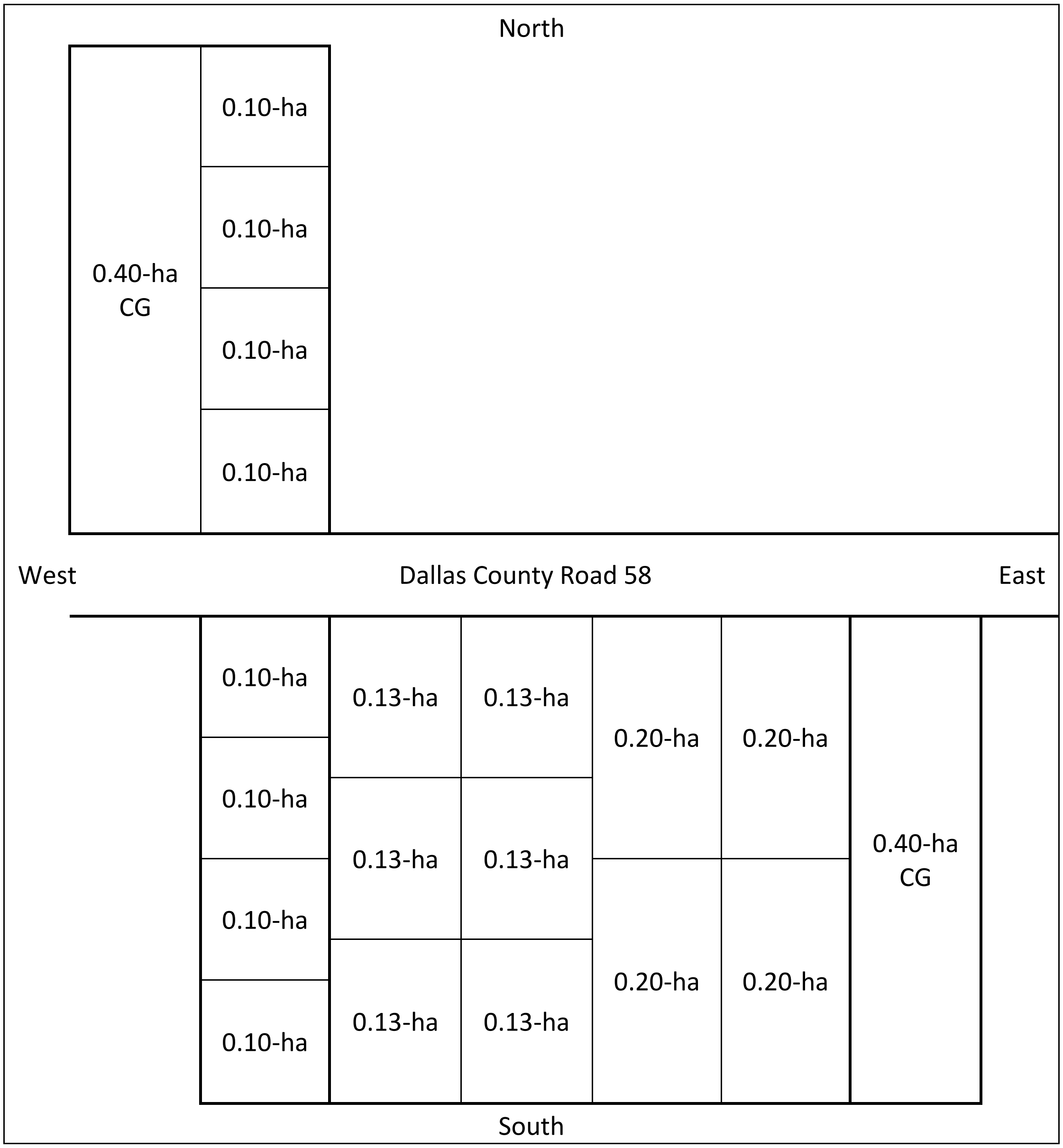


Figure 3. Layout of experimental paddocks.

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[1] Composition: Ca,19-22%; P, 6-13%; NaCl, 13-15%; Mg, 2%; K, 1%; Co, 10 mg/kg; Cu, 1,800 mg/kg; I, 20 mg/kg; Mn, 5,400 mg/kg;Se, 26 mg/kg; Zn, 5,400 mg/kg; Vit. A, 363,436 IU/kg; Vit D_3, 88,106 IU/kg; Vit. E, 441 IU/kg.

Forage harvesting, sampling and laboratory analyses. Pre-graze forage mass and quality, and post-graze forage mass were measured weekly in RG cells, concurrently with measurement of forage DM mass and quality in CG paddocks. For RG treatments, pre-graze forage was sampled in successive cells to be grazed before cattle were moved into them, and post-graze forage was sampled in recently grazed cells from which the cattle were being moved; CG cells were also sampled every 7 d. Swaths (1.22 m × 1.22 m) of forage were harvested using a flail-chopping mower set to a 5-cm clipping height. Four random swaths were harvested in CG cells, 3 in the 0.20-ha cells, and 2 each in the 0.13- and 0.10-ha cells. Harvested forage was collected into plastic baskets and immediately weighed on a portable field scale. Samples of forage harvested from each cell were placed into tared paper bags, weighed, dried at 55^{o} C for 72 hr and ground to pass a 1-mm screen in a Wiley mill. Forage concentrations of CP and DM were determined according to procedures of AOAC (1995), and concentrations of NDF, ADF and ADL were determined sequentially according to the procedures of Van Soest et al. (1991). Mean forage mass was calculated as the average of the four pre-graze forage mass and four post-graze forage mass determinations made for each paddock within each 28-d period. Forage DM allowance for each paddock was calculated as mean forage mass per unit of steer live weight within each 28-d period.

Statistical analyses. Data were analyzed using mixed model procedures for a completely randomized design with 4 treatments (2 replicates/treatment) using the PROC MIXED procedures of SAS and standard least-squares model fit (SAS Inst., Inc., Cary, NC). Because of severe drought in the first year of the experiment, data from each year were analyzed separately. In each year, components of the statistical model for ADG, forage-mass metrics, and forage concentrations of CP, ADF, NDF and ADL included grazing treatment, 28-d periods, and treatment × period interaction designated as fixed effects. In each year, components of the statistical model for total liveweight gain per ha included grazing treatments designated as fixed effects. Paddock was considered the experimental unit. Statistical associations between forage characteristics and animal performance were determined by correlation analysis using PROC CORR procedures, and by stepwise regression analysis using PROC REG procedures (SAS Inst., Inc., Cary, NC). Treatment means were separated by the LSMEANS procedure (SAS Inst. Inc., Cary, NC) when protected by F-tests significant at α of 0.10, and are reported as least squares means ± SE.

Results

Temperature and precipitation. Monthly mean air temperatures (Table 18) approximated or were slightly higher than 30-yr averages (Table 19) for Marion Junction, AL in July, August, September and October of 2007, and approximated or were slightly lower than 30-yr averages in these same months in 2008. Monthly total precipitation (Table 20) was 55, 75, 67 and 88% of average for July, August, September and October, respectively, in 2007, and was 47, 271, 4 and 44% of average, respectively, for these four months in 2008.

Table 18. Monthly mean air temperatures for 2007 and 2008, and 30-yr averages at Marion Junction, AL

Month	**Avg. High, ºC**			**Avg. Low, ºC**			**Mean, ºC**		
	2007	**2008**	**30-yr**	**2007**	**2008**	**30-yr**	**2007**	**2008**	**30-yr**
Jan	14	12	13	3	0	1	8	6	7
Feb	14	17	16	0	2	2	7	9	9
Mar	24	21	20	8	6	6	16	13	13
Apr	23	24	24	9	12	9	16	18	17
May	30	28	28	15	16	15	23	22	22
Jun	34	33	32	20	21	19	27	27	26
Jul	**32**	**33**	**33**	**22**	**21**	**21**	**27**	**27**	**27**
Aug	**37**	**31**	**33**	**23**	**21**	**21**	**30**	**26**	**27**
Sep	**31**	**29**	**31**	**19**	**19**	**17**	**25**	**24**	**24**
Oct	**26**	**24**	**25**	**13**	**11**	**11**	**20**	**17**	**18**
Nov	20	19	19	4	3	6	12	11	13
Dec	17	16	14	5	4	2	11	10	8

Table 19. Differences in monthly mean air temperatures in 2007 and 2008 from 30-yr averages at Marion Junction, AL

Month	**Avg. High, ºC**		**Avg. Low, ºC**		**Mean, ºC**	
	2007	**2008**	**2007**	**2008**	**2007**	**2008**
Jan	1	-1	2	-1	1	-1
Feb	-2	1	-2	0	-2	0
Mar	4	1	2	0	3	0
Apr	-1	0	0	3	-1	1
May	2	0	0	1	1	0
Jun	2	1	1	2	1	1
Jul	**-1**	**0**	**1**	**0**	**0**	**0**
Aug	**4**	**-2**	**2**	**0**	**3**	**-1**
Sep	**0**	**-2**	**2**	**2**	**1**	**0**
Oct	**1**	**-1**	**2**	**0**	**2**	**-1**
Nov	1	-1	-2	-3	-1	-2
Dec	3	2	3	2	3	2

Table 20. Monthly precipitation for 2007 and 2008, and differences from 30-yr averages at Marion Junction, AL

Month	**Avg. Precipitation, mm**			**Differences, mm**	
	2007	**2008**	**30-yr**	**2007**	**2008**
Jan	93	104	149	-55	-45
Feb	54	121	119	-65	2
Mar	39	97	163	-124	-67
Apr	34	110	123	-88	-13
May	3	78	104	-101	-26
Jun	101	98	113	-11	-14
Jul	**70**	**61**	**129**	**-58**	**-68**
Aug	**64**	**230**	**85**	**-21**	**145**
Sep	**67**	**4**	**100**	**-33**	**-96**
Oct	**66**	**33**	**75**	**-9**	**-42**
Nov	39	51	111	-72	-60
Dec	58	112	128	-70	-16
Total	**688**	**1098**	**1398**	**-710**	**-300**

Average Daily Gain. In 2007, steers gained 0.27 kg/d and 0.48 kg/d more in the first than second ($P = 0.01$) and third ($P < 0.001$) periods, respectively, and 0.22 kg/d more ($P = 0.05$) in the second than third period. There was no effect ($P = 0.25$) of grazing treatment on ADG; however, a treatment × period interaction ($P = 0.05$) was observed for ADG. In 2008, there were no differences among treatments ($P = 0.43$) or periods ($P = 0.79$) for ADG (Table 22).

Table 21. Average daily gain (kg/d) for steers from continuously grazed (CG) paddocks and rotationally grazed 0.10-, 0.13- and 0.20-ha cells in 2007

Period	Treatment				Mean
	0.10-ha	0.13-ha	0.20-ha	CG	
0 to 28 d	$0.47^{ab,cd}$	0.20^{c}	$0.56^{a,de}$	$0.84^{a,e}$	0.52^{f}
28 to 56 d	$0.50^{b,c}$	0.19^{cd}	$0.31^{ab,cd}$	$0.01^{b,d}$	0.25^{g}
56 to 84 d	0.15^{a}	0.09	0.07^{b}	-0.16^{b}	0.04^{h}
Mean	0.37	0.16	0.31	0.23	

^{a,b}Within a column, means without a common superscript differ ($P = 0.05$; SEM = 0.13; n = 2).
^{c,d,e}Within a row, means without a common superscript differ ($P = 0.05$; SEM = 0.13; n = 2).
^{f,g,h}Within a column, means without a common superscript differ ($P = 0.001$; SEM = 0.07; n=8).

Table 22. Average daily gain (kg/d) for steers from continuously grazed (CG) paddocks and rotationally grazed 0.10-, 0.13- and 0.20-ha cells in 2008

Period	Treatment				Mean
	0.10-ha	0.13-ha	0.20-ha	CG	
0 to 28 d	0.29	0.35	0.35	0.45	0.36
28 to 56 d	0.21	0.34	0.42	0.37	0.33
56 to 84 d	0.43	0.29	0.36	0.41	0.37
Mean	0.31	0.33	0.37	0.41	

Gain per area. Steers grazing 0.10-ha, 0.20-ha and CG paddocks had 106 (P = 0.01), 86 (P = 0.03) and 83 (P = 0.03) kg greater total gain per ha (GPA), respectively, than steers grazing 0.13-ha paddocks in 2007 (Table 23). However, there were no differences (P = 0.90) in total areal gain among treatments in 2008.

Table 23. Gain per area (kg/ha) for steers from continuously grazed (CG) paddocks and rotationally grazed 0.10-, 0.13- and 0.20-ha cells in 2007 and 2008

Year	Treatment				Mean
	0.10-ha	0.13-ha	0.20-ha	CG	
2007	187^{a}	81^{b}	167^{a}	164^{a}	150
2008	191	202	233	212	209
Mean	189	141	200	188	

[a,b]Within a row, means without a common superscript differ ($P < 0.05$; SEM = 18; n = 2).

Pre-graze forage mass. Pre-graze forage mass was 667 and 1,299 kg DM/ha greater in the first than the second (*P* = 0.08) and third (*P* = 0.004) periods, respectively, in 2007 (Table 24). However, pre-graze forage mass was not different (*P* = 0.17) among grazing treatments in 2007.

Table 24. Pre-graze forage mass (kg DM/ha) in continuously grazed (CG) paddocks and rotationally grazed 0.10-, 0.13- and 0.20-ha cells in 2007

Period	Treatment				Mean
	0.10-ha	0.13-ha	0.20-ha	CG	
0 to 28 d	3,462	3,340	3,099	2,392	3,073[a]
28 to 56 d	2,808	2,470	2,857	1,489	2,406[b]
56 to 84 d	2,189	1,953	1,431	1,524	1,774[b]
Mean	2,820	2,587	2,462	1,802	

[a,b]Within a column, means without a common superscript differ (*P* = 0.01; SEM = 250; n = 8).

Pre-graze forage mass was 1,206 and 2,068 kg DM/ha greater in the first than second (*P* = 0.005) and third (*P* < 0.001) periods, respectively, and was 862 kg DM/ha greater (*P* = 0.04) in the second than third period in 2008 (Table 25). However, pre-graze forage mass was not different (*P* = 0.21) among grazing treatments in 2008.

Table 25. Pre-graze forage mass (kg DM/ha) in continuously grazed (CG) paddocks and rotationally grazed 0.10-, 0.13- and 0.20-ha cells in 2008

Period	Treatment				Mean
	0.10-ha	0.13-ha	0.20-ha	CG	
0 to 28 d	4,464	3,557	3,846	3,431	3,824[a]
28 to 56 d	2,858	2,047	3,254	2,314	2,618[b]
56 to 84 d	1,687	992	1,777	2,567	1,756[c]
Mean	3,003	2,198	2,959	2,770	

[a,b]Within a column, means without a common superscript differ (*P* < 0.001; SEM = 251; n = 8).

Post-graze forage mass. Post-graze forage mass was 820 and 1,071 kg DM/ha greater in the first than second (*P* = 0.01) and third (*P* = 0.004) periods, respectively, in 2007 (Table 26). However, post-graze forage mass was not different (*P* = 0.49) among grazing treatments in 2007.

Table 26. Post-graze forage mass (kg DM/ha) in continuously grazed (CG) paddocks and rotationally grazed 0.10-, 0.13- and 0.20-ha cells in 2007

Period	Treatment				Mean
	0.10-ha	0.13-ha	0.20-ha	CG	
0 to 28 d	2,682	2,555	3,048	2,479	2,691^{a}
28 to 56 d	2,075	2,160	2,034	1,214	1,871^{b}
56 to 84 d	1,847	1,958	1,192	1,483	1,620^{b}
Mean	2,201	2,224	2,091	1,725	

^{a,b}Within a column, means without a common superscript differ (*P* = 0.008; SEM = 202; n = 8).

Post-graze forage mass was 867 and 1,281 kg DM/ha greater in 0.20-ha than 0.10-ha (*P* = 0.05) and 0.13-ha (*P* = 0.008) RG treatments, respectively, and was 980 kg/ha greater (*P* = 0.04) for CG paddocks than 0.13-ha cells in 2008 (Table 27). Also, post-graze forage mass was 1,185 and 1,822 kg DM/ha greater in the first than second (*P* = 0.005) and third (*P* < 0.001) periods, respectively, in 2008.

Table 27. Post-graze forage mass (kg DM/ha) in continuously grazed (CG) paddocks and rotationally grazed 0.10-, 0.13- and 0.20-ha cells in 2008

Period	Treatment				Mean
	0.10-ha	0.13-ha	0.20-ha	CG	
0 to 28 d	3,055	2,371	4,018	3,273	3,179^{a}
28 to 56 d	1,740	1,513	2,703	2,022	1,994^{b}
56 to 84 d	971	640	1,647	2,169	1,357^{b}
Mean	1,922^{cd}	1,508^{c}	2,789^{e}	2,488^{de}	

^{a,b}Within a column, means without a common superscript differ (*P* = 0.001; SEM = 250; n = 8).
^{c,d,e}Within a row, means without a common superscript differ (*P* = 0.03; SEM = 289; n = 6).

Mean forage mass. Mean forage mass was 744 and 1,185 kg DM/ha greater in the first than second (P = 0.03) and third (P = 0.003) periods, respectively, in 2007 (Table 28). However, mean forage mass was not different (P = 0.25) among grazing treatments in 2007.

Table 28. Mean forage mass (kg DM/ha) in continuously grazed (CG) paddocks and rotationally grazed 0.10-, 0.13- and 0.20-ha cells in 2007

Period	Treatment				Mean
	0.10-ha	0.13-ha	0.20-ha	CG	
0 to 28 d	3,072	2,947	3,074	2,436	2,882^{a}
28 to 56 d	2,441	2,315	2,446	1,352	2,138^{b}
56 to 84 d	2,018	1,955	1,311	1,503	1,697^{b}
Mean	2,510	2,406	2,277	1,763	

^{a,b}Within a column, means without a common superscript differ (P = 0.008; SEM = 214; n = 8).

Mean forage mass was 1,196 and 1,946 kg DM/ha greater in the first than second ($P = 0.004$) and third ($P < 0.001$) periods, respectively, and was 750 kg/ha greater ($P = 0.06$) in the second than third period in 2008 (Table 29). However, mean forage mass was not different ($P = 0.12$) among grazing treatments in 2008.

Table 29. Mean forage mass (kg DM/ha) in continuously grazed (CG) paddocks and rotationally grazed 0.10-, 0.13- and 0.20-ha cells in 2008

Period	Treatment				Mean
	0.10-ha	0.13-ha	0.20-ha	CG	
0 to 28 d	3,760	2,964	3,932	3,351	3,502^{a}
28 to 56 d	2,299	1,780	2,979	2,168	2,306^{b}
56 to 84 d	1,329	816	1,712	2,368	1,556^{c}
Mean	2,463	1,853	2,874	2,629	

[a,b,c] Within a column, means without a common superscript differ ($P < 0.001$; SEM = 247; n = 8).

Forage allowance. Forage allowance did not differ (*P* = 0.21) among grazing treatments or 28-d periods (*P* = 0.26) in 2007 (Table 30).

Table 30. Forage allowance (kg DM/kg BW) in continuously grazed (CG) paddocks and rotationally grazed 0.10-, 0.13- and 0.20-ha cells in 2007

Period	Treatment				Mean
	0.10-ha	0.13-ha	0.20-ha	CG	
0 to 28 d	1.15	1.12	1.16	0.90	1.08
28 to 56 d	1.28	1.25	1.28	0.71	1.13
56 to 84 d	1.04	1.05	0.67	0.78	0.88
Mean	1.16	1.14	1.04	0.79	

Forage allowance was 0.54 and 0.88 kg DM/kg BW greater in the first than second (*P* = 0.002) and third (*P* < 0.001) periods, respectively, and was 0.34 kg DM/kg BW greater (*P* = 0.04) in the second than third period in 2008 (Table 31). However, forage allowance was not different (*P* = 0.14) among grazing treatments in 2008.

Table 31. Forage allowance (kg DM/kg BW) in continuously grazed (CG) paddocks and rotationally grazed 0.10-, 0.13- and 0.20-ha cells in 2008

Period	Treatment				Mean
	0.10-ha	0.13-ha	0.20-ha	CG	
0 to 28 d	1.64	1.30	1.69	1.39	1.50^a
28 to 56 d	0.98	0.76	1.24	0.86	0.96^b
56 to 84 d	0.55	0.34	0.69	0.91	0.62^c
Mean	1.05	0.80	1.21	1.05	

^{a,b,c}Within a column, means without a common superscript differ (*P* < 0.001; SEM = 0.10; n= 8).

Crude protein. Forage concentration of CP was 2.6 and 1.2 percentage units higher in the first than second (*P* < 0.001) and third (*P* = 0.01) periods, respectively, and 1.4 percentage units higher (*P* = 0.005) in the third than second period in 2007 (Table 32). Forage in 0.10-ha cells had 0.8 and 1.3 percentage units higher concentration of CP than 0.20-ha cells (*P* = 0.09) and CG paddocks (*P* = 0.02), respectively. Forage in the 0.13-ha RG treatment had 1.3 percentage units higher (*P* = 0.02) concentration of CP than CG forage.

Table 32. Concentration of CP (%, DM basis) in dallisgrass from continuously grazed (CG) paddocks and rotationally grazed 0.10-, 0.13- and 0.20-ha cells in 2007

Period	Treatment				Mean
	0.10-ha	0.13-ha	0.20-ha	CG	
0 to 28 d	11.8	11.5	11.2	10.7	11.3^{a}
28 to 56 d	9.0	9.1	8.5	8.2	8.7^{b}
56 to 84 d	11.0	10.9	9.6	8.8	10.1^{c}
Mean	10.6^{d}	10.5^{de}	9.8^{ef}	9.2^{f}	

[a,b,c]Within a column, means without a common superscript differ (*P* < 0.001; SEM = 0.3; n = 8).
[d,e,f]Within a row, means without a common superscript differ (*P* = 0.05; SEM = 0.3; n = 6).

Forage concentration of CP was 0.4 percentage unit higher (*P* = 0.02) for the first than second period, and 0.4 percentage unit higher (*P* = 0.03) for the third than second period in 2008 (Table 33). Forage in the 0.20-ha RG treatment had 0.6, 0.4 and 0.9 percentage unit higher concentration of CP than forage in the 0.10-ha RG (*P* = 0.02), 0.13-ha RG (*P* = 0.08) and CG (*P* = 0.002) treatments, respectively. Forage in 0.13-ha cells had 0.5 percentage unit higher (*P* = 0.04) concentration of CP than CG paddocks. There was also a treatment × period interaction (*P* = 0.01) for forage concentration of CP in 2008.

Table 33. Concentration of CP (%, DM basis) in dallisgrass from continuously grazed (CG) paddocks and rotationally grazed 0.10-, 0.13- and 0.20-ha cells in 2008

Period	Treatment				Mean
	0.10-ha	0.13-ha	0.20-ha	CG	
0 to 28 d	6.9^{a,c}	7.3^{ab,c}	8.0^{a,d}	7.3^{a,c}	7.3^{e}
28 to 56 d	6.6^{a,c}	6.8^{a,c}	7.8^{a,d}	6.4^{b,c}	6.9^{f}
56 to 84 d	7.9^{b,c}	7.8^{b,c}	7.2^{b,d}	6.6^{ab,d}	7.3^{e}
Mean	7.1^{gh}	7.3^{g}	7.7^{i}	6.8^{h}	

^{a,b}Within a column, means without a common superscript differ (*P* = 0.01; SEM = 0.2; n = 2).
^{c,d}Within a row, means without a common superscript differ (*P* = 0.01; SEM = 0.2; n = 2).
^{e,f}Within a column, means without a common superscript differ (*P* = 0.04; SEM = 0.1; n = 8).
^{g,h,i}Within a row, means without a common superscript differ (*P* = 0.01; SEM = 0.1; n = 6).

Forage in CG paddocks had 128, 104 and 75 kg/ha lower areal mass of CP than 0.10-ha cells (*P* = 0.01), 0.13-ha cells (*P* = 0.03) and 0.20-ha cells (*P* = 0.10), respectively, in 2007 (Table 34). Areal mass of CP was 138 and 166 kg/ha higher in the first than second (*P* = 0.002) and third (*P* = 0.001) periods, respectively.

Table 34. Areal mass of CP (kg/ha) in dallisgrass from continuously grazed (CG) paddocks and rotationally grazed 0.10-, 0.13- and 0.20-ha cells in 2007

Period	Treatment				Mean
	0.10-ha	0.13-ha	0.20-ha	CG	
0 to 28 d	405	382	348	254	347^{a}
28 to 56 d	249	224	245	119	209^{b}
56 to 84 d	238	212	139	134	181^{b}
Mean	297^{c}	273^{c}	244^{c}	169^{d}	

[a,b]Within a column, means without a common superscript differ (*P* = 0.001; SEM = 24; n = 8).
[c,d]Within a row, means without a common superscript differ (*P* = 0.05; SEM = 28; n = 6).

Areal mass of CP was 98 and 155 kg/ha higher in the first than second (*P* = 0.004) and third (*P* < 0.001) periods, respectively, and 57 kg/ha higher (*P* = 0.07) in the second than third period in 2008 (Table 35).

Table 35. Areal mass of CP (kg/ha) in dallisgrass from continuously grazed (CG) paddocks and rotationally grazed 0.10-, 0.13- and 0.20-ha cells in 2008

Period	Treatment				Mean
	0.10-ha	0.13-ha	0.20-ha	CG	
0 to 28 d	307	259	306	254	281[a]
28 to 56 d	190	138	255	152	184[b]
56 to 84 d	133	77	127	170	127[c]
Mean	210	158	229	192	

[a,b,c]Within a column, means without a common superscript differ (*P* < 0.001; SEM = 20; n = 8).

Neutral detergent fiber. Forage concentration of NDF was 2.0 percentage units lower (*P* = 0.01) in the first than second period, but concentrations of NDF were not different among grazing treatments (*P* = 0.21) in 2007 (Table 36).

Table 36. Concentration of NDF (%, DM basis) in dallisgrass from continuously grazed (CG) paddocks and rotationally grazed 0.10-, 0.13- and 0.20-ha cells in 2007

Period	Treatment				Mean
	0.10-ha	0.13-ha	0.20-ha	CG	
0 to 28 d	63.4	64.1	65.4	65.5	64.6^{a}
28 to 56 d	66.6	65.9	66.9	67.2	66.6^{b}
56 to 84 d	66.2	64.5	64.9	67.5	65.8^{ab}
Mean	65.4	64.8	65.7	66.7	

^{a,b,c}Within a column, means without a common superscript differ (*P* = 0.03; SEM = 0.5; n = 8).

Forage concentration of NDF was 2.9 percentage units lower ($P < 0.001$) in the first than second period, and was 2.6 percentage units lower ($P < 0.001$) in the third than second period in 2008 (Table 37). Forage in the 0.13-ha RG treatment had 1.0 and 1.2 percentage units lower concentration of NDF than forage in the 0.10-ha RG ($P = 0.03$) and CG ($P = 0.02$) treatments, respectively.

Table 37. Concentration of NDF (%, DM basis) in dallisgrass from continuously grazed (CG) paddocks and rotationally grazed 0.10-, 0.13- and 0.20-ha cells in 2008

Period	Treatment				Mean
	0.10-ha	0.13-ha	0.20-ha	CG	
0 to 28 d	71.0	70.9	71.0	71.5	71.1^{a}
28 to 56 d	74.7	73.8	73.4	73.9	74.0^{b}
56 to 84 d	71.8	69.8	71.3	72.8	71.4^{a}
Mean	72.5^{c}	71.5^{d}	71.9^{cd}	72.7^{c}	

^{a,b}Within a column, means without a common superscript differ ($P < 0.001$; SEM = 0.3; n = 8).
^{c,d}Within a row, means without a common superscript differ ($P = 0.06$; SEM = 0.3; n = 6).

Acid detergent fiber. Forage concentration of ADF was 1.2 and 0.8 percentage units lower in the first than second (*P* = 0.02) and third (*P* = 0.09) periods, respectively, in 2007 (Table 38). Forage in the 0.20-ha RG treatment had 1.3 and 1.7 percentage units higher concentration of ADF than the 0.10-ha (*P* = 0.03) and 0.13-ha (*P* = 0.006) RG treatments, respectively.

Table 38. Concentration of ADF (%, DM basis) in dallisgrass from continuously grazed (CG) paddocks and rotationally grazed 0.10-, 0.13- and 0.20-ha cells in 2007

Period	Treatment				Mean
	0.10-ha	0.13-ha	0.20-ha	CG	
0 to 28 d	32.6	33.2	34.6	33.6	33.5^{a}
28 to 56 d	34.7	33.6	35.8	34.8	34.7^{b}
56 to 84 d	34.2	33.5	35.1	34.6	34.3^{b}
Mean	33.8^{c}	33.4^{c}	35.1^{d}	34.3^{cd}	

^{a,b}Within a column, means without a common superscript differ (*P* = 0.04; SEM = 0.3; n = 8).
^{c,d}Within a row, means without a common superscript differ (*P* = 0.03; SEM = 0.4; n = 6).

Forage concentration of ADF was 1.7 percentage units lower (*P* = 0.001) in the first than second period, and was 1.1 percentage units lower (*P* = 0.02) in the third than second period in 2008 (Table 39). Forage in the 0.10-ha RG treatment had 0.8 percentage unit higher (*P* = 0.10) concentration of ADF than the 0.13-ha RG treatment, and forage in the 0.20-ha RG treatment had 1.2 and 1.3 percentage units higher concentration of ADF than the 0.13-ha RG (*P* = 0.02) and CG (*P* = 0.02) treatments, respectively.

Table 39. Concentration of ADF (%, DM basis) in dallisgrass from continuously grazed (CG) paddocks and rotationally grazed 0.10-, 0.13- and 0.20-ha cells in 2008

Period	Treatment				Mean
	0.10-ha	0.13-ha	0.20-ha	CG	
0 to 28 d	38.8	38.7	39.6	38.3	38.8^{a}
28 to 56 d	41.0	40.3	41.2	39.7	40.5^{b}
56 to 84 d	39.9	38.3	40.2	39.1	39.4^{a}
Mean	39.9^{c}	39.1^{d}	40.3^{c}	39.0^{d}	

^{a,b}Within a column, means without a common superscript differ (*P* = 0.004; SEM = 0.3; n = 8).
^{c,d}Within a row, means without a common superscript differ (*P*= 0.05; SEM = 0.3; n = 6).

Acid detergent lignin. Forage concentration of ADL was 0.54 and 0.56 percentage units higher in the third than first ($P < 0.001$) and second ($P < 0.001$) periods, respectively, in 2007 (Table 40). However, forage concentrations of ADL were not different ($P = 0.23$) among grazing treatments in 2007.

Table 40. Concentration of ADL (%, DM basis) in dallisgrass from continuously grazed (CG) paddocks and rotationally grazed 0.10-, 0.13- and 0.20-ha cells in 2007

Period	Treatment				Mean
	0.10-ha	0.13-ha	0.20-ha	CG	
0 to 28 d	2.25	2.35	2.45	2.35	2.35^{a}
28 to 56 d	2.45	2.25	2.30	2.30	2.33^{a}
56 to 84 d	2.85	2.80	3.10	2.80	2.89^{b}
Mean	2.52	2.47	2.62	2.48	

[a,b]Within a column, means without a common superscript differ ($P < 0.001$; SEM = 0.05; n = 8).

Forage concentration of ADL was 0.33, 0.35 and 0.40 percentage unit lower in the CG treatment than the 0.10-ha (*P* = 0.01), 0.13-ha (*P* = 0.01) and 0.20-ha (*P* = 0.005) RG treatments, respectively, in 2008 (Table 41).

Table 41. Concentration of ADL (%, DM basis) in dallisgrass from continuously grazed (CG) paddocks and rotationally grazed 0.10-, 0.13- and 0.20-ha cells in 2008

Period	Treatment				Mean
	0.10-ha	0.13-ha	0.20-ha	CG	
0 to 28 d	2.70	2.75	2.80	2.60	2.71
28 to 56 d	2.75	2.70	2.85	2.50	2.70
56 to 84 d	2.95	3.00	2.95	2.30	2.80
Mean	2.80^{a}	2.82^{a}	2.87^{a}	2.47^{b}	

^{a,b}Within a row, means without a common superscript differ (*P* = 0.02; SEM = 0.07; n = 6).

Statistical associations between forage characteristics and animal-performance variables. Average daily gain was positively correlated (Table 42) with areal mass of CP (kg/ha), pre-graze forage mass and post-graze forage mass, and negatively correlated with forage concentration of ADL in 2007. In 2008, ADG was positively correlated with forage concentration of CP (%). Gain per ha was not correlated with any forage characteristics in 2007, but it was positively correlated with areal mass of CP , pre-graze forage mass, post-graze forage mass and mean forage mass in 2008.

Table 42. Correlation coefficients between forage characteristics[1] and animal-performance[2] variables for steers from continuously grazed (CG) paddocks and rotationally grazed 0.10-, 0.13- and 0.20-ha cells in 2007 and 2008

Item	ADG				GPA			
	2007	*P*-value	2008	*P*-value	2007	*P*-value	2008	*P*-value
CP[3], kg	0.45	0.03	0.19	0.40	-0.25	0.55	0.78	0.02
CP, %	0.31	0.15	0.40	0.06	-0.08	0.84	0.55	0.16
PRE	0.46	0.03	0.11	0.63	-0.25	0.55	0.73	0.04
MFM	0.51	0.01	0.18	0.41	-0.27	0.52	0.81	0.02
POS	0.53	0.009	0.25	0.25	-0.29	0.48	0.79	0.02
DM/BW	0.29	0.18	0.15	0.50	-0.32	0.44	0.79	0.02
NDF	-0.18	0.41	-0.14	0.53	0.13	0.76	-0.07	0.86
ADF	-0.23	0.30	-0.15	0.50	0.21	0.61	0.05	0.90
ADL	-0.44	0.04	-0.03	0.87	0.11	0.80	-0.16	0.70

[1] PRE = pre-graze forage mass (kg/ha), POS = post-graze forage mass (kg/ha), MFM = mean forage mass (kg/ha) and DM/BW = forage DM allowance (kg DM/ kg BW), and forage concentrations of CP, ADF (%), NDF (%) and ADL (%).

[2] GPA = gain per area (kg/ha).

[3] CP = amount of CP represented by forage concentration of CP (%) × pre-graze forage mass (kg DM/ha)

Stepwise linear regression (Table 43) revealed that post-graze forage mass accounted for 28% of the variability in steer ADG in 2007. Forage concentration of CP accounted for 16% of the variability in steer ADG, and mean forage mass (kg DM/ha) explained 65% of the variability in total steer gain per ha in 2008.

Table 43. Linear regression of independent variables of forage characteristics[1] on dependent variables of animal-performance[2] for steers from continuously grazed (CG) paddocks and rotationally grazed 0.10-, 0.13- and 0.20-ha cells in the year 2007 and 2008

Dependent variable	Year	*P*-value	Intercept	POS	CP	MFM	r^2	RMSE[3]
ADG	2007	0.0093	-0.1877	0.0002			0.28	0.25
ADG	2008	0.0558	-0.1547		0.0701		0.16	0.10
GPA	2008	0.0157	48.2758			0.0661	0.65	29.81

[1] POS = post-graze forage mass, MFM = mean forage mass, and forage concentration (%) of CP.
[2] ADG = average daily gain, GPA = gain per area.
[3] Root mean square error.

Discussion

Among perennial warm-season forages commonly utilized for pasture in the southeastern US, dallisgrass arguably has the greatest unrealized potential for maximizing total seasonal beef production between April and October because of its high nutritive quality, availability for grazing earlier in the spring and longer into the fall than other perennial warm-season grasses (Venuto et al., 2003; Burson et al., 2009), and its persistence and capacity to support heavy grazing (Burson and Watson, 1995). Gunter et al. (2005) reported that steer ADG from dallisgrass was maximized under low stocking rates, and that increasing stocking rate maximized total liveweight gain per unit area under continuous-grazing management. However, until the present study, the influence of stocking density and duration of rest period on dallisgrass productivity and beef cattle performance under intensive rotational grazing had not been investigated.

There was no difference among treatments for steer ADG in either 2007 or 2008; however, ADG decreased from 0.5 kg/d in the first 28-d period to near zero in the third 28-d period in 2007. The summer of 2007 was characterized by drought of historical proportions that necessitated removal of 1 steer from each paddock after 28 d in order to maintain forage DM availability at an acceptable level in all treatments. Also, one of the continuously grazed paddocks was removed from the experiment after 56 d in 2007 due to unacceptably low DM availability, and the same paddock was also removed from the experiment preceding the last 28 d in 2008. Even though total monthly precipitation was above average in August of 2008, there was no measurable rainfall after August 26 through the remainder of the study. Dallisgrass requires high temperatures for breaking seed dormancy and sufficient water availability for rapid germination and early root growth (Cornaglia et al., 2005), a combination of weather conditions that normally occurs infrequently, especially during extreme drought such as that experienced in 2007. Steer performance did not differ among grazing-system treatments or 28-d periods in 2008, and was more characteristic of that expected under more favorable amounts of precipitation. Harris et al. (1963) reported ADG from dallisgrass-white clover of 0.67 kg in a comparison of irrigated vs. non-irrigated pastures in north Alabama. Gunter et al. (2005) reported ADG ranging from 0.40 kg under a stocking rate of 11.1 steers/ha to 0.65 kg under a stocking rate of 6.2 steers/ha across 4 N-fertilization rates on pastures consisting of approximately 50:50 dallisgrass and Bermudagrass. Mean values for ADG across all treatments and periods in 2007 (0.27 kg) and 2008 (0.36 kg) compared favorably with a mean ADG of 0.35 kg for steers grazing irrigated or non-irrigated dallisgrass-white clover with sod-seeded rye in the Lower Coastal Plain of Alabama (Brown et al., 1965).

In 2007, approximately one-fourth of the variability in ADG was accounted for by variability in post-graze forage mass (kg DM/ha) as determined by regression analysis. Correlation analysis revealed a positive association between ADG and pre-graze, post-graze and mean forage mass. Pre-graze, post-graze and mean forage mass declined over the course of the 84-d study, but forage allowance remained unchanged (1 kg DM/kg BW) as a result of removing one steer from each paddock after the first 28 d. For this reason, change in forage mass alone does not provide a satisfactory explanation for the pattern of ADG observed across treatments between the first and last 28-d periods, nor among treatments within the first two 28-d periods in 2007. Steers grazing CG paddocks made very satisfactory ADG in the first, maintained BW in the second and lost BW in the third 28-d period, whereas a moderate rate of ADG was maintained by RG steers in the first two 28-d periods and then declined sharply in the third 28-d period. Concurrently, forage concentration of CP across all treatments decreased by 2.6 percentage units between the first and second 28-d period, and then increased by 1.4 percentage units between the second and third 28-d period. The rate and extent of decline in forage concentration of CP was more pronounced for the CG than RG treatments, similar to the pattern observed for ADG, such that it was 1.1 percentage units lower for the CG than RG treatments over the 84-d study. Areal mass of CP (kg

CP/ha) declined between the first and second 28-d period, and the combination and patterns of declining forage mass and forage concentration of CP resulted in an areal mass of CP that was 38% less for the CG than RG treatments over the 84-d study. Steer ADG was correlated with areal mass of CP in 2007, which is interpreted to mean that statistical associations between ADG and forage mass revealed by correlation and regression analyses were mediated in part by changes in forage concentration of CP.

In contrast to 2007, there were no statistical associations detected by correlation or regression analysis between ADG and any measure of forage mass in 2008. As was observed in 2007, pre-graze, post-graze and mean forage mass declined over the course of the 84-d study. In contrast to 2007, forage allowance decreased between the first and last 28-d period, but no adjustment in stocking rate was necessary to maintain forage allowance at an acceptable level in all treatments. Forage concentration of CP across all treatments decreased by only 0.4 percentage unit between the first and second 28-d periods, returned to its initial value by the third 28-d period, and was only 0.6 percentage unit higher for the RG treatments than the CG treatment over the entire 84-d study. Areal mass of CP declined between the first and second 28-d period as in 2007, but was not different among treatments over the 84-d study. Steer ADG was 0.35 kg over the 84-d study in 2008 and, in contrast to the pattern of ADG observed in 2007, was not different among grazing treatments or 28-d periods. In 2008, approximately one-sixth of the variability in ADG was accounted for by variability in forage concentration of CP as determined by regression analysis,

Total liveweight gain per area was lower for the 0.13-ha RG than other treatments in 2007; however, there was no difference in gain per area among treatments in 2008. Gunter et al. (2005) reported 332 to 574 kg gain/ha from mixed dallisgrass-Bermudagrass pasture under stocking rates that ranged from 3.7 to 8.6 steers/ha, respectively, in 140- and 125-d grazing periods. On average, total steer gain/ha in the present study was similar to that reported by Gunter et al. (2005) for the 3.7 steers/ha stocking rate when reconciled for comparison on the basis of 84 d. Brown et al. (1965) reported annual total gain of 433 kg/ha from irrigated and non irrigated dallisgrass-white clover with sod-seeded rye in the Lower Coastal Plain of Alabama. Harris et al. (1963) reported total yearling-steer gain of 299 kg/ha from irrigated and non-irrigated dallisgrass-white clover over 154 d under a put-and-take system of pasture management, which is slightly higher than that in the first year (2007) of the present study when reconciled for comparison on the basis of 84 d. Hill et al. (1982) reported calf gain of 296 kg/ha from dallisgrass grazed for 118 d/yr over 2 yr by cow-calf pairs in southcentral Lousiana. In the present study, there were no statistical associations detected by correlation or regression analysis between total liveweight gain per area and any of the other dependent variables in 2007. In 2008, positive correlations were detected between total gain per area and pre-graze, post-graze and mean forage mass, forage allowance and areal mass of CP; approximately two-thirds of the variability in gain per area could be explained on the basis of mean forage mass.

Forage concentration of cell-wall constituents is correlated with DM intake and digestibility *in vivo*. Because forage cell-wall constituents represent such a large fraction of total plant DM, especially in warm season-adapted C_4 grasses, concentration and composition of plant cell walls is arguably the single factor that most influences forage DM utilization by grazing animals (Paterson et al., 1994). In the present study, forage concentrations of NDF averaged 65.7 and 72.2% across grazing treatments and 28-d periods in 2007 and 2008, respectively, which compare very favorably with values reported elsewhere in the literature. Acosta et al. (1996) reported NDF concentration in dallisgrass of 67.6, 63.6, 58.7and 60.8% during spring, summer, fall and winter, respectively, in Argentina. Baréa et al. (2007) reported NDF concentrations in dallisgrass of 67.3, 69.1, and 66.4% during spring, summer and fall, respectively, in southern Brazil when forage was cut at 30-d intervals, and 71.8, 70.3 and 68.5% during spring, summer, and fall, respectively, when cut at a 45-d interval.

Forage concentrations of ADF in the present study were comparable to values reported elsewhere in the literature, averaging 34.2 and 39.6% in 2007 and 2008, respectively, across grazing treatments and 28-d periods. Baréa et al. (2007) reported ADF concentrations in dallisgrass of 44.9, 45.8 and 40.6% during spring, summer, and fall, respectively, when forage was clipped at 30-d intervals, and 46.8, 46.1 and 42.4% during spring, summer, and fall, respectively when clipped at 45-d intervals. Acosta et al. (1996) reported concentrations of ADF in dallisgrass of 38.8, 39.7, 35.8 and 31.3% during spring, summer, fall and winter, respectively. Ayala Torales et al. (2000) reported concentrations of ADF in dallisgrass of 39.5 and 38.7% for frequently grazed and infrequently grazed plants, respectively, during the spring, and 35.2 and 38.9% for frequently grazed and infrequently grazed plants, respectively, during the summer in Argentina.

The present study was designed to test the hypothesis that productivity, nutritive quality and utilization of dallisgrass for steer liveweight gain is improved by rotational compared with continuous grazing, and it was conducted in 2 successive years that differed markedly in meteorological conditions during a common mid-July to early-October grazing period. Utilizing a uniform stocking rate, there was no difference overall between these grazing systems in either 2007 or 2008 on forage productivity, nutritive quality or utilization by beef cattle for liveweight gain. However, patterns of change in forage mass and cattle liveweight gain were different between 2007 and 2008, as were the nature and strength of statistical associations between forage characteristics and cattle performance in each yr of the study. Results are consistent with those of Aiken (1998), who reported a difference in forage productivity, stocking rates and steer performance between rotational and continuous grazing of the cool-season component, but not the warm-season component, of bermudagrass sod-seeded with wheat and ryegrass. In this regard, Briske et al. (2008) have stated that stocking rate and weather variability, not grazing system *per se*, account for most of the variability in plant and animal production from grazed pasture and rangeland, and they caution against the tendency to accept outright the superiority of rotational over continuous grazing systems. Also, comparisons between continuous and rotational grazing systems are often confounded by managerial variability, and intuitively but falsely equate the latter with more sophisticated management. As stated by Briske et al. (2008), "…management commitment and ability are the most pivotal components of grazing system effectiveness"…such that "well managed continuous grazing would be more effective than poorly managed rotational grazing."

Rotational grazing is typically expected to increase animal production over continuous grazing due to enhanced forage productivity. Agronomic theory posits that the rest period between grazing sessions enables defoliated plants to recover and grow faster than under continuous grazing. Because stocking density is higher and animals have less opportunity for selective grazing, forage is grazed more uniformly, resulting in more homogenous plant growth in the paddock after cattle have been moved to the next paddock (Briske et al., 2008). McNaughton (1979) has presented an optimization theory by which primary productivity increases with increasing utilization, represented by intensity of grazing, up to a threshold at which it decreases with increasing utilization; this point of diminishing positive increments is the optimal utilization level. The present experiment was designed to evaluate continuous and rotational grazing of dallisgrass at similar stocking rates, which did not enable determination of a discrete optimal utilization level. Additional experimentation utilizing different stocking rates would be necessary to obtain information on optimal utilization of dallisgrass. Precipitation is a major determinant of primary forage productivity, and an ideal approach in such experiments would be to manage grazing in a manner that enables plant regrowth under intensive rotational grazing to derive maximum benefit from precipitation during rest periods (Briske et al., 2008). Unfortunately, even though weather forecasting can be utilized successfully in management decision-making to minimize weather-related risk, precipitation amounts and patterns are not currently forecast with sufficient accuracy to enable their exploitation for maximum benefit to forage primary production.

In some cases, it may take several years before production responses to adjustments in a forage management regimen become evident (Briske et al., 2008). The current experiment comprised 84-d grazing periods in each of 2 successive years, which restricted the ability to capture the full range of variables that could possibly influence forage and animal production from grazed dallisgrass pasture. Furthermore, the continuous-grazing treatment was managed as effectively and as intensively as the rotational-grazing treatments (> 7 steers/ha initial stocking rate, mean forage allowance of 1 kg forage DM/kg steer liveweight), and resulted in respectable steer liveweight gain on an areal basis. However, patterns of pre-, post-graze and mean forage mass and forage allowance suggest that dallisgrass may respond differently to different stocking rates under certain conditions. To illustrate, post-graze forage mass on the last sampling date in October 2008 was approximately 1,200 kg DM/ha for the 0.10-ha RG treatment and 1,100 kg DM/ha for the CG treatment. However, even under conditions of extreme drought in 2007, post-graze forage mass on the last sampling in October exceeded 2,700 kg DM/ha for the 0.10-ha RG treatment and approximately 1,550 kg DM/ha for the CG treatment. These observations suggest the possibility of an initial positive adaptation of dallisgrass to rotational grazing in 2007 that was not sustained in 2008. Longer-term research under variable stocking rates would be necessary to determine conclusively whether rotational grazing of dallisgrass offers potential for markedly increasing beef cattle production over well managed continuous grazing.

Implications

Forage productivity, nutritive quality and beef production from rotational and continuous grazing of dallisgrass were similar in successive years of a 2-yr study characterized by extreme drought (2007) and normal precipitation (2008). However, patterns of change in areal mass of forage DM and CP, forage concentration of CP and liveweight gain by beef cattle were different between the two years, as were the nature and strength of statistical associations detected between forage-mass metrics, forage chemical composition and beef cattle performance. Further research is needed to ascertain whether increasing stocking rates could result in increased beef production from rotational compared with continuous grazing of dallisgrass.

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