Vol.4, No.9, 455-465 (2013)
http://dx.doi.org/10.4236/as.2013.49061

Agricultural Sciences

Productivity and nutritive quality of dallisgrass (*Paspalum dilatatum*) as influenced by cutting height and rate of fertilization with poultry litter or commercial fertilizer

Elias J. Bungenstab[1*], Adolfo C. Pereira Jr.[2], John C. Lin[3], James L. Holliman[3], Russell B. Muntifering[3]

[1]Van Beek Nutrition, Pocatello, USA; [*]Corresponding Author: elias@bungenstab.com.br
[2]Elanco Animal Health, Greenfield, USA
[3]Department of Animal Sciences, Auburn University, Auburn, USA

Received 30 June 2013; revised 30 July 2013; accepted 15 August 2013

ABSTRACT

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 is needed. 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.

Keywords: Dallisgrass; Productivity; Nutritive Quality; Poultry Litter

1. INTRODUCTION

Dallisgrass, *Paspalum dilatatum*, is a warm-season perennial grass indigenous to South America, primarily Uruguay, Argentina and southern Brazil [1]. According to Chase [2], it was first reported in the USA in 1840, collected in Louisiana, and named for Abner T. Dallis of La Grange, GA [3]. 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 [4]. 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 [5,6].

The influence of sward height on ingestive behavior and intake of dallisgrass by cattle has been documented in a number of studies [7-10]. 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.

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.

2. MATERIALS AND METHODS

2.1. 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˚C, and mean annual precipitation is 1400 mm. Precipitation and temperature were recorded daily throughout the experiment.

2.2. 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). 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 1222 (34N), 2443 (67N), 3665 (101N), and 4887 (134N) kg poultry litter/ha, respectively.

Half of the plots within each fertilizer source × application-rate treatment (n = 3) were assigned to aboveground 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.

2.3. 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˚C for 72 hr and ground to pass a 1-mm screen in a Wiley mill. Forage concentrations of crude protein (CP = N × 6.25) and dry matter (DM) were determined according to procedures of AOAC [11], and concentrations of neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) were determined sequentially according to the procedures of Van Soest *et al.* [12]. 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 [13].

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.

2.4. 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 leastsquares model fit [14]. 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.

3. RESULTS

3.1. Temperature and Precipitation

Monthly mean air temperatures (**Table 1**) approximated or were slightly higher than 30-yr averages for Marion Junction, AL in July, August and September of 2006 and 2007, but monthly total precipitation 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.

3.2. 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 2**). 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.

3.3. Crude Protein

There was no difference ($P = 0.71$) in forage concentration of CP between clipping-height treatments (**Table 3**). 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.

3.4. 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 4**). 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 1. Monthly mean air temperatures for 2006 and 2007, and 30-yr averages at Marion Junction, AL.

Month	Mean, ˚C			Avg. Precipitation, mm		
	2006	2007	30-yr	2006	2007	30-yr
Jan	11	8	7	105	93	149
Feb	8	7	9	136	54	119
Mar	14	16	13	60	39	163
Apr	21	16	17	23	34	123
May	22	23	22	90	3	104
Jun	26	27	26	28	101	113
Jul	**29**	**27**	**27**	**54**	**70**	**129**
Aug	**29**	**30**	**27**	**58**	**64**	**85**
Sep	**24**	**25**	**24**	**26**	**67**	**100**
Oct	18	20	18	85	66	75
Nov	12	12	13	173	39	111
Dec	9	11	8	124	58	128

Table 2. 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).

Table 3. 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).

Table 4. 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).

3.5. 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 5**). 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.

3.6. 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 6**). 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.

3.7. 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 7**). 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.

3.8. 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 8**). 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

Table 5. 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).

Table 6. 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).

Table 7. 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).

Table 8. 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).

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.

3.9. 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 9**). 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.

3.10. Magnesium

Clipping forage to a 5-cm height increased ($P < 0.001$) concentration of Mg over that of forage clipped to a 10-cm height (**Table 10**). 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 9. 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).

Table 10. 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).

3.11. 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 11**). There were no differences (P = 0.63) in forage concentrations of Al between fertilizer sources or among N application-rate treatments (P = 0.49).

3.12. 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 12**). 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).

3.13. 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 13**). There was no difference in forage Fe concentration between fertilizer-source (P = 0.69) or among N application-rate treatments (P = 0.39).

Table 11. 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).

Table 12. 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).

3.14. 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 14**). 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.

3.15. 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 15**). 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).

4. 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 graz-

Table 13. 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).

ing-animal performance [15]. 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 [7,9,10]. 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 [1,16-18]. Also, dallisgrass is best adapted to regions that receive more than 900 mm of annual rainfall [19], 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 [7-10]. 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 [17] for dallisgrass clipped to a 5-cm compared with a 15-cm height. Dallisgrass clipped to a 5-cm height yielded 1239 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 [20] 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.

Table 14. 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).

Yield of dallisgrass DM increased as a result of increasing N application from 34N and 67N to 134N. Similarly, Robinson *et al.* [18] reported an increase in dallisgrass DM yield from 5330 kg to 15,340 kg/ha when N fertilization rate was increased from 0 to 896 kg/ha. Likewise, Pizarro [1] reported increases in DM production from dallisgrass ranging from 2400 to 9000 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 [21] 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 [22] 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.* [19], who reported concentrations of CP in dallisgrass of 9.8% to 11%, and lower than that observed by Baréa *et al.* [23], who reported a wider range of concentrations of CP in dallisgrass of 10.7% to 18.6%. Using prediction equations of Linn and Marten [24], dallisgrass in the present study would be expected to have approximately 87% the relative feed value (RFV) of a mature, medium-quality alfalfa

Table 15. 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).

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 [25].

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 [26,27]. 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.* [28] 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 [3,29,30]. According to Gunter *et al.* [31], 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 [32]. 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 [33]. On average, concentrations of NDF in dallisgrass in the present study were slightly lower than those observed by Venuto *et al.* [19], 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.* [29], 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 [34]. 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.* [30], who reported concentrations of ADF in dallisgrass ranging from 35.2% to 39.5%, and intermediate to those observed by Acosta *et al.* [29], 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.* [28] 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 [34]. Concentration of lignin increases and digestibility of plant cell-wall constituents and total plant DM decreases with advancing forage maturity [35]. 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 [36]. 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 [36].

Forage concentrations of Ca in the present study were, on average, less than half of those reported by Brown and Rouse [22] 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.* [28] 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.* [18], 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 [36]. 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.* [28] 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.* [18].

Concentration of K was higher in forage amended with PL than CF, similar to results reported by Wood *et al.* [28] 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 [36]. 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.* [18], 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 [22] 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.* [18] 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.* [37] 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 $N \cdot ha^{-1} \cdot yr^{-1}$. Gascho and Hubbard [38] 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 2812 kg N/ha over a 5-yr period.

Iron concentration in forages grown in the US typically meets or exceeds animal dietary requirements [36]. Concentration of Fe in dallisgrass in the present study was well above the dietary requirement (50 mg/kg DM) for beef cattle [25], 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 1000 mg/kg DM [25]. 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 [36]. 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 [25]. Concentration of Mn, which is normally higher in forage than required by the animal [36], 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 [36]. 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 [36]. Concentration of Zn in dallisgrass was below that required (30 mg/kg DM) by beef cattle [25], and was not different between clipping-height and fertilizer-source treatments or among N application-rate treatments in the present study.

5. 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.

REFERENCES

[1] Pizarro, E.A. (2000) Potencial forrajero del género *Paspalum*. *Pasturas Tropicales*, **22**, 38-46.

[2] Chase, A. (1929) The North American species of *Paspalum*. *Contributions from the United States National Herbarium*, **28**, 310.

[3] Holt, E.C. (1956) Dallisgrass. *Texas Agricultural Experimental Station Bulletin*, **829**, 1-14.

[4] AASS (1996) Alabama agricultural statistics service. Montgomery.

[5] Davies, L.J. and Forde, B.J. (1991) Comparative responses of three subtropical grasses to combined frost and prolonged chilling treatments simulating a New Zealand winter. *New Zealand Journal of Agricultural Research*, **34**, 249-256. doi:10.1080/00288233.1991.10417661

[6] Evers, G.W. and Burson, B.L. (2004) Dallisgrass and other *Paspalum* species. In: Moser, L.E. *et al*., Eds., *Warm-Season* (*C4*) *Grasses*, (pp 681-713), Madison, Agronomy Monographs, 45.

[7] Lippke, H. (1981) Intake, digestibility, and sward characteristics of bermudagrass-dallisgrass pastures. *Texas Agricultural Experiment Station Progress Report*, **3826**, 173-174.

[8] Ungar, E.D., Genizi, A. and Detriment, M.W. (1991) Bite dimensions and herbage intake by cattle grazing short hand-constructed swards. *Agronomy Journal*, **83**, 973-978. doi:10.2134/agronj1991.00021962008300060010x

[9] Laca, E.L., Ungar, E.D., Seligman, N. and Demment, M.W. (1992) Effect of sward height and bulk density on bite dimensions of cattle grazing homogeneous swards. *Grass and Forage Science*, **47**, 91-102. doi:10.1111/j.1365-2494.1992.tb02251.x

[10] Flores, E.R., Laca, E.A., Griggs, T.C. and Demment, M.W. (1993) Sward height and vertical morphological differentiation determine cattle bite dimensions. *Agronomy Journal*, **85**, 527-532. doi:10.2134/agronj1993.00021962008500030001x

[11] AOAC (1995) Official methods of analysis. 16th Edition, Association of Official Analytical Chemists, Washington DC.

[12] Van Soest, P.J., Robertson, J.B. and Lewis, B.A. (1991) Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. *Journal of Dairy Science*, **74**, 3583-3597. doi:10.3168/jds.S0022-0302(91)78551-2

[13] Olsen, S.R. and Sommers, L.E. (1982) Phosphorus. In: Page, A.L., Miller, R.H. and Keeney, D.R., Eds., *Methods of Soil Analysis*. *Part* 2: *Chemical and Microbiological Properties*, American Society of Agronomy, Inc., Madison, 403-427.

[14] SAS Institute (2004) SAS/STAT user's guide. Version 9.1. SAS Institute Inc., Cary.

[15] Minson, D.J. and Wilson, J.R. (1994) Prediction of intake as an element of forage quality. In: Fahey Jr., G.C., *et al.*, Eds., *Forage Quality*, *Evaluation*, *and Utilization*, American Society of Agronomy, Inc., Madison, 533-563.

[16] Lovvorn, R.L. (1944) The effects of fertilization, species competition, and cutting treatments on the behavior of dallisgrass, *Paspalum dilatatum* Poir., and carpetgrass, *Axonopus affinis*, Chase. *Agronomy Journal*, **36**, 590-600. doi:10.2134/agronj1944.00021962003600070007x

[17] Holt, E.C. and McDaniel, J.C. (1963) Influence of clipping on yield, regrowth, and root development of dallisgrass, *Paspalum dilatatum* Poir., and kleingrass, *Panicum coloratum* L. *Agronomy Journal*, **55**, 561-564. doi:10.2134/agronj1963.00021962005500060018x

[18] Robinson, D.L., Wheat, K.G., Hubbert, N.L., Henderson, M.S. and Savoy Jr., H.J. (1988) Dallisgrass yield, quality and nitrogen recovery response to nitrogen and phosphorus fertilizers. *Communications in Soil Science and Plant Analysis*, **19**, 529-542. doi:10.1080/00103628809367957

[19] Venuto, B.C., Burson, B.L., Hussey, M.A., Redfearn, D.D., Wyatt, W.E. and Brown, L.P. (2003) Forage yield, nutritive value, and grazing tolerance of dallisgrass biotypes. *Crop Science*, **43**, 295-301. doi:10.2135/cropsci2003.0295

[20] Watson, V.W. and Ward, C.Y. (1970) Influence of intact tillers and height of cut on regrowth and carbohydrate reserves of dallisgrass (*Paspalum dilatatum* Poir.). *Crop Science*, **10**, 474-476. doi:10.2135/cropsci1970.0011183X001000050004x

[21] Jones, W.F. and Watson, V.H. (1991) Applied phosphorus and potassium effects on yield of dallisgrass-Bermudagrass pastures. *Journal of Plant Nutrition*, **14**, 585-597. doi:10.1080/01904169109364226

[22] Brown, J.M. and Rouse, R.D. (1953) Fertilizer effects on botanical and chemical composition of white clover-dallisgrass associations grown on Sumter clay. *Agronomy Journal*, **45**, 279-282. doi:10.2134/agronj1953.00021962004500070002x

[23] Baréa, K., Scheffer-Basso, S.M., Dall'Agnol, M. and de Oliveira, B.N. (2007) Management of *Paspalum dilatatum* Poir. biotype Virasoro. 1. Production, chemical composition and persistence. *Revista Brasileira de Zootecnia*, **36**, 992-999. doi:10.1590/S1516-35982007000500002

[24] Linn, J.G. and Martin, N.P. (1989) Forage quality tests and interpretation. University of Minnesota Extension Service Publication, St. Paul.

[25] NRC (1996) Nutrient requirements of beef cattle. 7th Edition, National Academy Press, Washington DC.

[26] Brisibe, E.A., Umoren, U.E., Brisibe, F., Magalhäes, P.M., Ferreira, J.F.S., Luthria, D., Wuh, X. and Prior, R.L. (2009) Nutritional characterization and antioxidant capacity of different tissues of *Artemisia annua* L. *Food Chemistry*, **115**, 1240-1246. doi:10.1016/j.foodchem.2009.01.033

[27] Nordheim-Viken, H., Volden, H. and Jørgensen, M. (2009) Effects of maturity stage, temperature and photoperiod on growth and nutritive value of timothy (*Phleum pratense* L.). *Animal Feed Science and Technology*, **152**, 204-218. doi:10.1016/j.anifeedsci.2009.04.012

[28] Wood, C.W., Torbert, H.A. and Delaney, D.P. (1993) Poultry litter as a fertilizer for bermudagrass: Effects on yield and quality. *Journal of Sustainable Agriculture*, **3**, 21-36. doi:10.1300/J064v03n02_05

[29] Acosta, G., Deregibusand, V.A. and Hammar, R. (1996) Inclusión de pasto miel (*Paspalum dilatatum*, Poir) en pasturas. 2. Efecto sobre el valor nutritivo. *Revista Argentina de Producción Animal*, **16**, 157-167.

[30] Ayala Torales, A.T., Acosta, G.L., Deregibus, V.A. and Moauro, P.M. (2000)Effects of grazing frequency on the production, nutritive value, herbage utilization, and structure of a *Paspalum dilatatum* sward. *New Zealand Journal of Agricultural Research*, **43**, 467-472. doi:10.1080/00288233.2000.9513443

[31] Gunter, S.A., Beck, P.A., Hutchison, S. and Phillips, J.M. (2005) Effects of stocking and nitrogen fertilization rates on steers grazing dallisgrass-dominated pasture. *Journal of Animal Science*, **83**, 2235-2242.

[32] Paterson, J.A., Belyea, R.L., Bowman, J.P., Kerley, M.S. and Williams, J.E. (1994) The impact of forage quality and supplementation regimen on ruminant animal intake and performance. In: Fahey Jr., G.C., *et al.*, Eds., *Forage Quality*, *Evaluation*, *and Utilization*, American Society of Agronomy, Inc., Madison, 59-114.

[33] Mertens, D.R. (1987) Predicting intake and digestibility using mathematical models of ruminal function. *Journal of Animal Science*, **64**, 1548-1558.

[34] Van Soest, P.J. (1994) Nutritional ecology of the ruminant. 2nd Edition, Cornell University Press, Ithaca.

[35] Jung, H.G. and Fahey Jr., G.C. (1983) Nutritional implications of phenolic monomers and lignin: A review. *Journal of Animal Science*, **57**, 206-219.

[36] Greene, L.W. (2000) Designing mineral supplementation of forage programs for beef cattle. *Journal of Animal Science*, **77**, 1-9.

[37] Franzluebbers, A.J., Wilkinson, S.R. and Stuedemann, J.A. (2004) Bermudagrass management in the southern piedmont USA: VIII. Soil pH and nutrient cations. *Agronomy Journal*, **96**, 1390-1399. doi:10.2134/agronj2004.1390

[38] Gascho, G.J. and Hubbard, R.K. (2006) Long-term impact of broiler litter on chemical properties of a Coastal Plain soil. *Journal of Soil and Water Conservation*, **61**, 65-74.

