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RESEARCH

Nitrogen Rate and Initiation Date Effects on Stockpiled Tall Fescue During Fall Grazing in Tennessee

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Abstract

In Tennessee, N is one of the most common limiting nutrients for tall fescue [*Schedonorus arundinaceus* (Schreb.) Dumort] production. Rising prices for N fertilizer have pressured cow-calf producers in Tennessee to reevaluate N management alternatives. The objectives of this study were to determine the effect of initiation date and N fertilization on stockpiled tall fescue yield, nutritive value, animal performance during fall grazing, and overall profitability of the production system. The research was conducted in tall fescue pastures at the Plateau AgResearch and Education Center in Crossville, TN from August 2013 to December 2014. A completely randomized design with three replications was applied to existing tall fescue pastures. Stockpile initiation dates were 1 August and 1 September, and N fertilization rates were 0 and 60 lb/acre N. With the exception of crude protein (CP) and in vitro dry matter digestibility (IVDMD), all other plant-related variables analyzed in this study showed a significant difference among monthly grazing periods. Nitrogen fertilization rate did not affect forage mass or nutritive value in both years. There were no significant interactions between initiation date and N fertilization rate for all animal performance measures. Data from this study suggests that with low beef prices ($0.75/lb), profits are maximized by initiating stockpiling in August with no N application.

The primary forage base used by cow-calf producers in Tennessee pastures is tall fescue, which is an excellent forage crop due its high nutritive value, high yield, and extended grazing season. . Management strategies such as stockpiling, which is the accumulation of forage for grazing at a later time (Fribourg and Bell, 1984), can extend the grazing season, reduce the amount of hay fed to cattle, and thus improve the profitability of livestock operations (Adams et al., 1994). Stockpiled tall fescue is low cost compared with other feed sources and can be used to maintain livestock for less than the cost of hay (Bishop-Hurley and Kallenbach, 2001).

The success of stockpiling depends on the accumulation period, rainfall, and fertilization management (Matches and Burns, 1995). Rayburn et al. (1979) found that higher tall fescue yields during the winter are usually obtained with the earliest stockpiling periods, but this higher yield is compromised by a

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Abbreviations: AU, animal unit; BW, body weight; CP, crude protein; IVDMD, in vitro dry matter digestibility; NDF, neutral detergent fiber; NDFD, neutral detergent fiber digestibility; TDN, total digestible nutrients.

Conversions: For unit conversions relevant to this article, see Table A.

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Table A. Useful conversions.

To convert Column 1 to Column 2, multiply by	Column 1 Suggested Unit	Column 2 SI Unit
0.304	foot, ft	meter, m
2.54	inch	centimeter, cm (10^{-2} m)
0.405	acre	hectare, ha
9.29×10^{-2}	square foot, sq ft	square meter, sq m
0.454	pound, lb	kilogram, kg
1.12	pound per acre, lb/acre	kilogram per hectare, kg/ha
5/9 (°F – 32)	Fahrenheit, °F	Celsius, °C

decrease in total nonstructural carbohydrates from 24.6 to 17.2% and a reduction in CP from 11.9 to 9.8%. Cuomo et al. (2005) showed that stockpiling smooth bromegrass (*Bromus inermis* Leyss.) later in the fall reduced yields and that an application of N increased the CP concentration compared with unfertilized pastures.

In the southeastern USA, N is one of the most common limiting inputs for forage production. Most tall fescue pastures are fertilized in the spring and late summer for stockpiling. The initiation date and the associated length of the accumulation period, along with N fertilization strategies, are important factors that affect the yield and nutritive value of stockpiled forage (Taylor and Templeton, 1976; Rayburn et al., 1979; Collins and Balasko, 1981a; Collins and Balasko, 1981b; Fribourg and Bell, 1984; Volesky et al., 2008); however, there are only a few, older studies showing the performance of cattle that graze stockpiled tall fescue in Tennessee.

Little is known about the effects of initiation date and N fertilization on yield, nutritive value, animal performance, and profitability of N application during fall grazing in Tennessee. Rising prices for N fertilizer as well as associated externalities of fertilizer use have pressured cow-calf producers in Tennessee to reevaluate N management alternatives. Therefore, the objectives of this study were to determine the effect of initiation date and N fertilization on stockpiled tall fescue yield, nutritive value, and subsequent animal performance during fall grazing, and overall profitability of the production system.

SITE DESCRIPTION, TREATMENTS, MEASUREMENTS, AND DATA ANALYSIS

The research was conducted at the Plateau AgResearch and Education Center of The University of Tennessee (36.02° N, 85.13°W, 1811-ft altitude) in Crossville, TN, from August 2013 to December 2014 in established 'Kentucky 31', endophyte-infected (E+) tall fescue pastures.

The soil was a Lily silt loam (a fine-loamy, siliceous, semi-active, mesic Typic Hapludults), a moderately deep, well-drained soil formed in residuum weathered primarily from sandstone. The initial soil nutrient levels at the experimental site were a pH of 5.8, 22 lb/acre P, 172 lb/acre K, 2384 lb/acre Ca, and 97 lb/acre Mg. The average temperature and precipitation for the study years and the long term are reported in Fig. 1.

A completely randomized design, in a 2 × 2 factorial arrangement with three replications was applied to

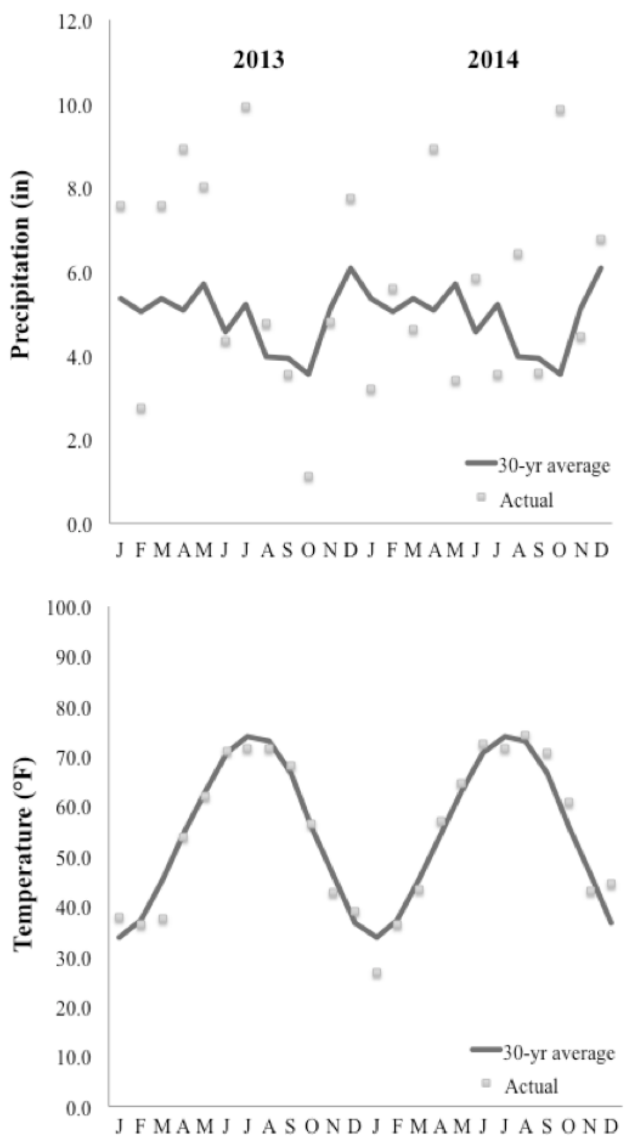

Fig. 1. Average monthly temperature and precipitation in 2013 and 2014 and 30-year average for Crossville, TN.

existing tall fescue pastures for a total of 12 three-acre pastures. These pastures were managed as fertilized pastures for the previous 15 years and were representative of pastures in Tennessee. Stockpile initiation dates were 1 August and 1 September. N fertilization rates were 0 and 60 lb/acre N applied as urea on the date of stockpile initiation for each treatment. The experimental units (pasture) at each stockpile initiation date were mowed to leave a stubble height of 5 inches on the initiation date for each treatment.

In both years, 84 steers were identified, weighed, and randomly distributed in groups of 7 steers per pasture under continuous stocking. All animals were weighed at the beginning and end of the study with an initial body weight (BW) of 679 ± 29 lb in 2013 and 553 ± 18 lb in 2014. The difference between the final BW and initial BW was used to calculate BW gain and divided by the total days of the experimental period to give the average daily gain (ADG). Stocking rate was calculated considering the total BW per acre, and expressed as animal unit (AU) per acre, where every AU corresponds to 1000 lb of BW. Pastures were allowed to accumulate forage from the initial fertilizer treatment application until beginning of grazing on 12 Sept. 2013 and 9 Sept. 2014.

At the beginning of the grazing period and weekly thereafter, the total aboveground dry matter forage mass was measured in each pasture with a calibrated rising plate meter (Sanderson et al., 2005). Forty points were measured at random across each pasture. Each week, 10 randomly placed 1-ft^2 samples areas were measured with the rising plate meter and then hand-clipped at ground level and dried to constant weight at 140°F to develop a regression equation for converting the rising plate meter reading to the total aboveground dry weight.

Samples to characterize morphological composition and nutritive value of the forage canopy were randomly collected from a 1-ft^2 area within each experimental unit on a weekly basis during the entire grazing period. Forage samples were collected above a 5-inch stubble height and then separated into the three following categories: dead material, stem plus leaf sheath, and green lamina. All samples were dried at 140°F to constant weight. Forage mass (lb/acre dry matter) was recorded for each category and summed to provide the total dry weight of each sample collected. The previously separated categories for each pasture were combined and ground through a 1-mm screen in a shear mill (Thomas-Wiley Laboratory Mill Model 4, H. Thomas) for laboratory analyses. Neutral detergent fiber (NDF), CP, IVDMD, total digestible nutrients (TDN), and neutral detergent fiber digestibility (NDFD) were predicted by means of near infrared spectroscopy (FOSS 5000, FOSS NIRSystems). Equations for the forage nutritive analyses were standardized and checked for accuracy with the 2013 mixed hay equation developed by the NIRS Forage and Feed Consortium (NIRSC, Hillsboro, WI). Software used for the NIRS analysis was Win ISI II (Infrasoft International, State College, PA). The global H statistical test compared the samples with the model and other samples within the database for accurate results, where all forage samples fit the equation with $H < 3.0$, and are reported accordingly (Murray and Cowe, 2004).

Means of each variable were calculated for each pasture, and such pastures were considered one experimental unit ($n = 12$). Data homogeneity, normality, and outlier values were verified. For the ANOVAs, the covariance structure for each variable was selected according to the Akaike information criterion. Weekly results of forage mass and forage nutritive value were pooled into monthly average. For all forage variables analyzed, the following interactions effects were considered: year × month, year × N rate, year × initiation, month × N rate, month × initiation, and N rate × initiation. Animal performance variables were evaluated without monthly period effects. Means effects were separated with Tukey's test ($P < 0.05$) for significance using the PROC MIXED of SAS (SAS Institute, 2008).

For each initiation date and N rate, net returns were found using a partial budgeting approach. This approach measures changes in revenues and costs resulting from implementing a change in production practices (Kay et al., 2012). The producer's objective function in this analysis is to choose the N fertilizer rate that maximizes expected net returns.

The total animal gain was determined for each of the four combinations of initiation date and N rate. The average price of N from urea during the last 10 years was determined from the USDA National Agricultural Statistical Services (USDA-NASS, 2013) and was \$0.56/lb. The high, average, and low price of stocker cattle was selected using a 10-year average price for 600- to 800-lb steer and heifer calves in Tennessee in the months of November and December (USDA-NASS, 2013). Since 2003, stocker cattle from 600 to 800 lb have sold at \$0.75/lb to \$2.25/lb with an average of \$1.50/lb. The price of N (lb) multiplied by the N rate (lb/acre) (i.e., costs) is subtracted from the price of beef (lb) multiplied by the gains (lb/acre) (i.e., revenue) to find the net returns for N (per acre). A sensitivity analyses was conducted for net returns across the range of stocker cattle and N prices across the last 10 years.

WEATHER DATA, FORAGE MASS, AND FORAGE NUTRITIVE VALUE

In 2013, rainfall from August to December averaged 4.4 inch/month, which was 3% below the 30-year average, and in 2014 it averaged 6.2 inch/month, which was 37% above the 30-year average. The mean air temperature from August to December was 0.1°F below and 2.9°F above the 30-year average in 2013 and 2014, respectively. Both average rainfall and temperature were considered adequate for pasture growth in Middle Tennessee in both years.

In 2013, concentrations of NDF ranged from 52.5 to 60.9%, IVDMD ranged from 60.1 to 65.1%, CP from 12.6 to 16.4%, and forage mass from 1027 to 2385 lb/acre during the entire experimental period. In 2014, NDF ranged from 59.1 to 62.9%, IVDMD from 61.2 to 65%, CP from 12.9 to 16.7%, and forage mass from 1242 to 3324 lb/acre. Averages are shown in Table 1.

For all plant-related variables analyzed in this study, there was a significant difference among monthly grazing periods, with the exception of CP and IVDMD. Forage mass, percentage of leaves, and NDF decreased by the end of the grazing period in November, while TDN and NDFD increased (Table 2). Animals have the tendency to consume green leaves when they are first available, which explains the reduction in the percentage of leaves and consequent decrease in forage mass. The decrease in NDF and increases in TDN and NDFD were not expected. Leaves have the greatest nutritive value of all morphological components (Burns et al., 2006). Even though the percentage of leaves decreased by the end of the grazing period, it remained higher than proportion of stems and dead material, which explains the slight increase in TDN and NDFD.

Crude protein and IVDMD were not affected by monthly grazing periods; however, the percentage of CP was affected by initiation date, showing higher values for stockpiling initiated in September (Table 2). Fribourg and Bell (1984) showed similar results, in which CP did not decrease when stockpiling was initiated in September. Stockpiling initiated in September with application of N has been shown to increase the appearance of young leaves, resulting in higher CP values (Gardner and Hunt, 1955; Wolf and von Boberfeld, 2003).

Table 1. Average forage mass, nutritive value, and animal performance of beef cattle grazing stockpiled tall fescue during fall in Tennessee.

Variable	Year	
	2013	2014
Forage mass		
Total (lb/acre)	1712 ± 685	2278 ± 1046
Leaves (%)	52.0 ± 18.3	53.4 ± 13.9
Stem (%)	37.4 ± 19.3	11.3 ± 7.08
Dead (%)	10.6 ± 9.84	37.5 ± 12.7
Nutritive value†		
CP (%)	14.5 ± 1.94	14.8 ± 1.91
NDF (%)	56.7 ± 4.21	59.4 ± 3.45
TDN (%)	63.9 ± 3.65	58.9 ± 5.64
IVDM (%)	62.6 ± 2.49	63.1 ± 1.91
NDFD (%)	51.7 ± 4.13	51.5 ± 3.46
Animal performance‡		
Initial BW (lb)	679 ± 29	553 ± 18
Final BW (lb)	719 ± 39	589 ± 18
ADG (lb/day)	0.46 ± 0.15	0.44 ± 0.13
BW gain (lb/acre)	58.1 ± 19.6	59.3 ± 20.9
Stocking rate (AU/acre)	1.08 ± 0.06	0.95 ± 0.06

† CP, crude protein; NDF, neutral detergent fiber; TDN, total digestible nutrients; IVDMD, in vitro dry matter digestibility; NDFD, neutral detergent fiber digestibility.

‡ BW, body weight; ADG, average daily gain, AU, animal unit (= 1000 lb BW).

Table 2. Forage mass and nutritive value of stockpiled tall fescue as affected by monthly period, stockpiling initiation date, and N fertilization rate during two consecutive years (2013 and 2014) in Tennessee.

Variable†	Month			N		Initiation		SEM	P value					
	Sept.	Oct.	Nov.	0 lb/acre	60 lb/acre	Aug.	Sept.		Month	N	Initiation	Month × N	Month × initiation	N × initiation
Forage mass														
Total (lb/acre)	2305a†	2431a	1329b	2113	1925	2022	2016	80.0	<0.0001	0.07	0.96	0.12	0.22	0.42
Leaves (%)	62.6a	51.0b	44.4c	53.1	51.5	53.6	51.5	11.4	<0.0001	0.28	0.29	0.76	0.04	0.85
Stem (%)	18.8c	25.5a	22.8b	22.2	23.0	21.5	23.3	12.7	<0.0001	0.24	0.19	0.57	0.0003	0.51
Dead (%)	18.6c	23.5b	32.8a	24.7	25.5	24.9	25.2	11.2	0.0002	0.58	0.89	0.70	0.56	0.60
Nutritive value‡														
CP (%)	15.0	14.5	14.5	14.7	14.5	14.3e	14.9d	1.39	0.23	0.67	0.02	0.60	0.61	0.69
NDF (%)	58.8a	59.2a	56.5b	58.1	58.3	58.4	58.0	2.76	<0.0001	0.89	0.58	0.61	0.006	0.77
TDN (%)	59.1b	59.5b	65.1a	61.6	60.9	61.1	61.4	3.53	<0.0001	0.32	0.51	0.82	0.02	0.53
IVDMD (%)	62.6	62.6	63.4	63.1	62.6	62.8	62.9	1.58	0.13	0.14	0.57	0.84	0.004	0.37
NDFD (%)	51.2b	50.6c	52.9a	51.9	51.2	51.3	51.8	2.60	0.002	0.65	0.81	0.14	0.36	0.38

† Means not followed by a common letter are significant at $P < 0.05$.

‡ CP, crude protein; NDF, neutral detergent fiber; TDN, total digestible nutrients; IVDMD, in vitro dry matter digestibility; NDFD, neutral detergent fiber digestibility.

Among all plant variables, there were no significant interactions between initiation date and N fertilization rate (Table 2). Past research showed that N fertilization generally increased forage mass (Rayburn et al., 1979) and the forage nutritive value of stockpiled tall fescue by increasing the concentration of CP (Collins and Balasko, 1981b). Conversely, in our study, the N fertilization rate did not affect forage mass or nutritive value in both years. These results could be attributed to the precipitation patterns that occurred. Despite sufficient average precipitation throughout the course of the experimental period, September appeared to have below-average precipitation in both years, which could have influenced N uptake by the plants (Fig. 1). A greater N response is expected when N is applied right before rainfall (Riesterer et al., 2000). Studies have shown that the yield of stockpiled tall fescue that was not fertilized ranges between 1684 and 1759 lb/acre in the August-to-December accumulation period (Taylor and Templeton, 1976; Rayburn et al., 1979), which agrees with our results for stockpiled tall fescue fertilized with 0 and 60 lb/acre N. These results suggest that if pastures are fertilized with 60 lb/acre N prior stockpiling (as recommended for Tennessee), the timing of application or split application should be considered rather then one single application. If the soil moisture status is low, N application in late summer may not result in high yields (Poore et al., 2000b). Year-to-year environmental variations can be greater than the differences in N fertilization rates, emphasizing the importance of weather conditions in determining forage yield during late summer and fall (Collins and Balasko, 1981a).

Weekly forage mass samples showed variable results among the N-fertilization-rate and initiation-date interactions (Fig. 2). In both years, forage mass was lower earlier in September, increased by mid-fall, and decreased by the end of the grazing period. Despite weekly forage mass showing no significant differences between N fertilization rates, pastures fertilized with 60 lb/acre N had a more consistent pattern than those not fertilized (Fig. 2). These results suggest that tall fescue pastures not fertilized prior to stockpiling can be more dependent on weather conditions and so become unpredictable for the producer.

ANIMAL PERFORMANCE

In 2013, ADG ranged from 0.31 to 0.61 lb/day, BW gain ranged from 38.5 to 77.7 lb/acre, and the stocking rate from 1.02 to 1.14 AU/acre. In 2014, ADG ranged from 0.31 to 0.37 lb/day, BW gain ranged from 38.4 to 80.2 lb/acre, and the stocking rate from 0.89 to 1.01 AU/acre. Averages are shown in Table 1. Initial and final BW did not differ between treatments but did differ between years ($P < 0.05$). Initial BW was heavier in 2013 than in 2014 (126 lb), and final BW was also heavier in 2013 than in 2014 (130 lb).

There were no significant interactions between initiation date and N fertilization rate for all animal performance measures (Table 3). Average daily gain was 0.45 lb/day over 76 days of grazing during the fall in both years across all treatments, but previous research has found the gain of unsupplemented calves grazing stockpiled tall fescue during winter to be 1 lb/day (McClure et al., 1977; Poore and Green, 1999). The

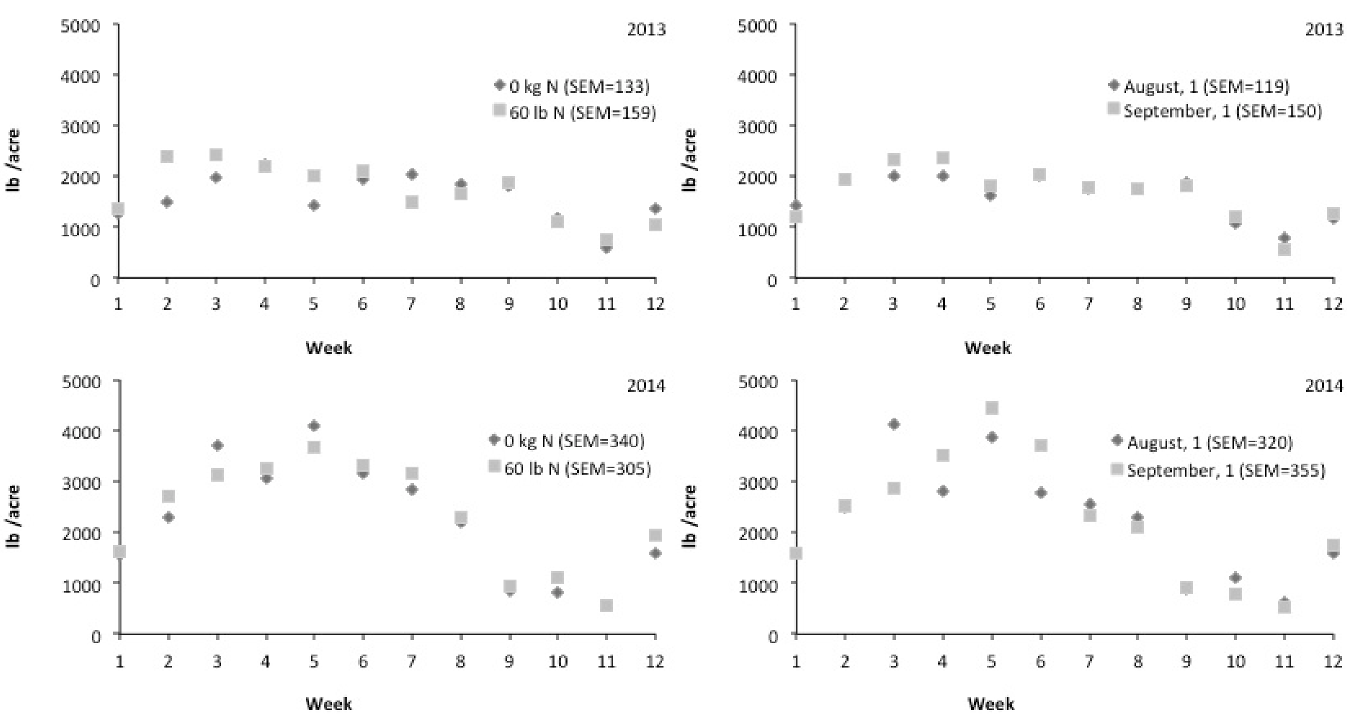

Fig. 2. Average weekly forage mass in 2013 and 2014 for different N fertilization rates and stockpiling initiation dates for tall fescue during fall grazing.

Table 3. Effects of N fertilization rate and stockpiling initiation date of stockpiled tall fescue on beef cattle performance during fall grazing in two consecutive years (2013 and 2014) in Tennessee.

Animal performance†	N rate		Initiation		SEM	*P* value		
	0 lb N	60 lb N	Aug.	Sep.		N	Initiation	N × initiation
ADG (lb/day)	0.49	0.40	0.42	0.49	0.02	0.34	0.56	0.29
BW gain (lb/acre)	63.4	54.0	54.0	63.4	6.50	0.43	0.43	0.37
Stocking rate (AU/acre)	1.02	1.01	1.01	1.02	0.11	0.86	0.82	0.77

† ADG, average daily gain; BW, body weight; AU, animal unit (= 1000 lb BW).

difference in ADG could be attributed to the period of stockpiling; ADG was lower when grazing was initiated during the fall. In addition, the stockpiled tall fescue pastures were extensively invaded by horsenettle (*Solanum carolinense* L.), which has low palatability and can reduce grazing efficiency (Bryson and DeFelice, 2009), possibly contributing to the lower-than-expected ADG in our study.

Nutrient concentrations in stockpiled tall fescue are usually above the requirement for beef cattle (Poore et al., 2000a). Of the studies that have been published on the performance of cattle grazing stockpiled tall fescue, most show a lower-than-expected performance on the basis of forage nutritive value (Poore et al., 2000b). Unsupplemented calves grazing stockpiled tall fescue had an ADG from 0.49 to 1.12 lb/day (McClure et al., 1977; Stuedemann et al., 1981; Poore and Green, 1999; Scott, 2000). In North Carolina, the forage nutritive value of stockpiled tall fescue decreased slightly while maintaining high CP levels (16%), which agrees with the lower performance of unsupplemented calves in the present study despite high CP throughout the experimental period. Evaluating the effects of N fertilization on forage production of tall fescue swards continuously grazed by sheep, Mazzanti and Lemaire (1994) showed that the effect of reduced N fertilizer on the forage consumption rate is more important than the N fertilizer effect on forage growth rate.

The effect of endophyte-infected tall fescue on animal responses have been extensively researched, showing its negative effect on the animal's physiological processes (Hill et al., 1994). Ergovaline, which is an ergot-like alkaloid produced by the endophytic fungus commonly found in Kentucky 31 is known to be toxic to livestock (Sleper and West, 1996). Kallenbach et al. (2003) determined the ergovaline concentration of stockpiled tall fescue and showed a decrease to low levels by mid- to late winter. More severe negative effects of ergot-like alkaloids in endophyte-infected tall fescue have been observed during fall grazing (Drewnoski et al., 2009). These findings suggest that delaying the use of these endophyte-infected pastures by mid- or late winter could minimize toxicity problems (Kallenbach et al., 2003). The use of endophyte-infected tall fescue in our study could have intensified the low performance achieved based on the forage nutritive value shown (Table 2).

ECONOMICS

Net returns per acre are shown in Fig. 3 for a range of N prices and beef prices in scenarios involving stockpile initiation date and N rate. The average weight gained per acre was 54.73 lb/acre when stockpiling was initiated in August and no N was applied, 53.29 lb/acre when stockpiling was initiated in August and 60 lb/acre N was applied, 53.31 lb/acre when stockpiling was initiated in September and no N was applied, and 73.49 lb/acre when stockpiling was initiated in September and 60 lb/acre N was applied. When the price of beef was $0.75/lb, the profit-maximizing production practice was usually to initiate stockpiling in August and apply no N fertilizer. At a beef price of $1.50/lb, a producer could receive a higher average net return by applying fertilizer and starting stockpiling in September if the price of N was below $0.46/lb. If N prices were above $0.46/lb, the producer could earn a greater average net return by beginning stockpiling in August and applying no N fertilizer. When the price of beef was $2.25/lb, a producer could maximize profits by stockpiling from September and applying N fertilizer if the price of N was less than $0.70/lb. If the price of N was greater than $0.70/lb, a producer could maximize profits by stockpiling in August and applying no fertilizer.

CONCLUSIONS

Forage mass and nutritive value of stockpiled tall fescue during fall grazing was not affected by interactions between the stockpiling initiation date and N fertilization rate; however, CP was higher when stockpiling was initiated in September. Our results suggest that weather conditions during the stockpiling period are of great importance when considering whether to apply N fertilizer.

Although ADG was considered lower than usual for animals grazing stockpiled tall fescue during fall, results from this study shows that a producer can still make a profit when considering the price of beef and the cost of fertilizer. Data from this study suggests that when the price of beef is low ($0.75/lb), producers can maximize profits by initiation stockpiling in August with no application of N. However, when the price of beef is high ($2.25/lb), initiating stockpiling in September combined with the application of 60lb/acre N can result in the most profitable scenario, considering that fertilizer costs are no higher than $0.70/lb.

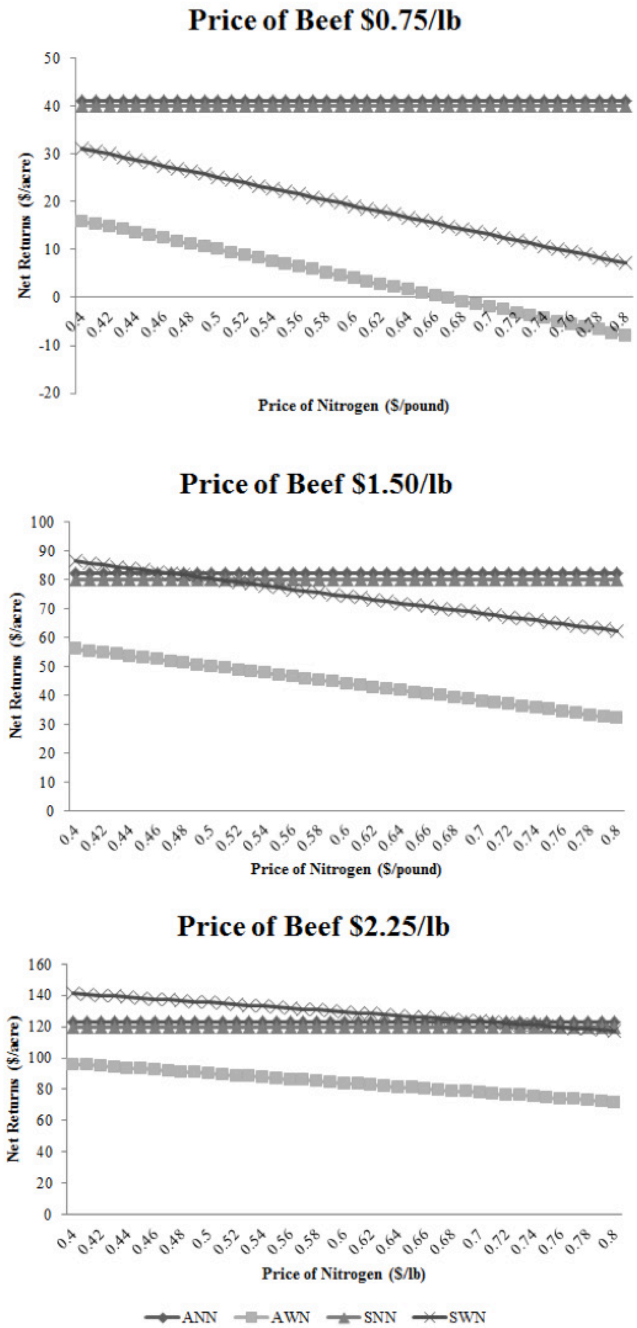

Fig. 3. Average net returns ($/acre) for stockpiling initiated in August with no N application (ANN), for stockpiling initiated in August with N application (AWN), for stockpiling initiated in September with no N application (SNN), and for stockpiling initiated in September with N application (SWN) at several beef and N prices.

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