Journal of Applied Farm Economics

Volume 5 | Issue 1 Article 2

2022

Perennial Warm-Season Grass Forages Impact on Cow-Calf Profitability in the Fescue Belt

Kyle A. Brazil
University of Tennessee, Knoxville, kbrazil@abcbirds.org

Patrick D. Keyser
University of Tennessee, Knoxville, pkeyser@utk.edu

Andrew P. Griffith
University of Tennessee, Knoxville, agriff14@utk.edu

Christopher N. Boyer
University of Tennessee, Knoxville, cboyer3@utk.edu

J. Travis Mulliniks
University of Tennessee, Knoxville, travis.mulliniks@unl.edu

Perennial Warm-Season Grass Forages Impact on Cow-Calf Profitability in the Fescue Belt

Cover Page Footnote

We acknowledge G. Bates, professor and Director of the UT Beef and Forage Center, University of Tennessee, Knoxville, for his assistance. A private donor, who wished to remain anonymous, funded this research.

Perennial Warm-Season Grass Forages Impact on Cow-Calf Profitability in the Fescue Belt

Kyle A. Brazil (University of Tennessee), Patrick D. Keyser (University of Tennessee), Andrew P. Griffith (University of Tennessee), Christopher N. Boyer (University of Tennessee), and J. Travis Mulliniks (University of Tennessee)

ABSTRACT

Incorporating a perennial warm-season grass (WSG) into tall fescue (*Lolium arundinaceum* [Schreb.] Darbysh.) forage systems in the fescue belt can help avoid the effects of fescue toxicosis on beef cattle (*Bos taurus*) reproduction and animal performance and provide forage during summer when fescue production is low. However, little information is available on the economics of incorporating WSG into fescue-based forage systems. We developed a simulation model to compare profitability of three forage systems—100% tall fescue, 70% tall fescue/30% bermudagrass (*Cynodon dactylon*), and 70% tall fescue/30% switchgrass (*Panicum virgatum*)—while also comparing spring- and fall-calving seasons on model beef cattle cow-calf operations in the fescue belt. Incorporating switchgrass increased profitability of tall fescue forage systems in both spring- and fall-calving herds, while adding bermudagrass increased profitability in spring-calving herds but not fall-calving herds. Spring-calving herds benefited the most from incorporating WSG, with profitability increases of $877 and $372 per hectare for switchgrass and bermudagrass, respectively, over the 100% tall fescue system. The order of profitability of forage systems did not change with randomly simulated decreases in rainfall and associated increased hay-feeding days, but with annual rainfall >88% of the long-term average, fall-calving 100% tall fescue was more profitable than fall-calving 70% tall fescue/30% bermudagrass. Of the scenarios modeled, the results of the simulation suggest that a profit-maximizing producer would utilize a 70% tall fescue/30% switchgrass forage system.

KEYWORDS

native warm-season grass, switchgrass, tall fescue, bermudagrass, forage, economics, profitability, complementary grazing

Profitability of most beef cattle operations is heavily influenced by forage cost, quality, and quantity (Keyser et al., 2016; Lowe et al., 2016). Within the tall fescue belt, forage production during hot summer months is limited, and animal productivity may be further compromised by fescue toxicosis (Stuedemann & Hoveland, 1988; Hoveland, 1993; Schmidt & Osborn, 1993; Smith et al., 2012). Tall fescue (hereafter fescue) is a perennial cool-season grass (CSG) with a long growing season that is well adapted to the Midsouth (Fribourg et al., 2009), and it is the primary forage grown across much of the southeastern United States (Keyser et al., 2011). However, during hot summer months, fescue becomes semidormant and has low productivity (Hannaway et al., 2009; Roberts et al., 2009). Additionally, grazing cattle on endophyte-infected fescue during the summer months can lower conception and calving rates, milk production, and rate of weight gain of growing animals (Stuedemann & Hoveland, 1988; Hoveland, 1993; Schmidt & Osborn, 1993; Smith et al., 2012). This has been estimated to result in losses of around $2 billion annually for the beef sector (Hoveland, 1993; Kallenbach, 2015). Incorporating perennial warm-season grasses (WSGs) into CSG systems could address these challenges with fescue pastures (Tracy et al., 2010; Kallenbach et al., 2012; Burns & Fisher, 2013; Keyser et al., 2016; Backus et al., 2017).

Profitability for cow herds grazing toxic fescue has also been reported to differ based on calving seasons. Caldwell et al. (2013) reported that fall-calving herds had greater calving rates and weaning weights than spring-calving herds in Arkansas. An economic analysis using data from Caldwell et al. (2013) reported that fall-calving herds were more profitable (Smith et al., 2012). Production and income for both calving seasons benefited from adding nontoxic, novel-endophyte fescue to toxic fescue-based grazing systems, but spring-calving systems benefited the most. In Tennessee, spring-born calves had higher average daily gain and weaning weights than fall-born calves (Campbell et al., 2013). In that study, fall-calving cows produced more calves, likely because they were bred during winter when the effects of fescue toxicosis were at a minimum, whereas spring cows were bred in late spring or early summer when the effects of fescue toxicosis were more pronounced (Campbell et al., 2013). Henry et al. (2016) expanded on the analysis of Campbell et al. (2013) by evaluating profitability and risk of both calving seasons as well as least-cost feed rations. They determined that fall calving was more profitable and risk-preferred and that greater prices for fall calves was the main factor in the difference.

The difference in profitability of fescue-based grazing systems with and without a perennial WSG component is not currently known. Information on profitability of different WSG options in such complementary grazing systems is also lacking, as is information on which calving season, spring or fall, will benefit the most, if at all, from incorporating a WSG into grazing systems. Nutritional needs of spring- and fall-calving cows peak at different times of the year. The nutritional needs of spring-calving cows more closely match WSG production curves, while fall-calving nutrient requirements match more closely with CSG production (Bagley et al., 1987). The objective of our research was to model the profitability of fescue-based grazing systems with and without a perennial WSG component and determine which perennial WSG—bermudagrass (*Cynodon dactylon*) or switchgrass (*Panicum virgatum*)—was most profitable while exploring the effect of calving season on profitability of these systems. This information will enable fescue belt beef cattle producers to make better-informed forage and calving-season decisions that increase profits.

METHODS

Assumptions

Enterprise budgets were constructed to compare net returns among three forage systems. Model beef cattle farms consisted of 40 hectares (ha) of pasture stocked at 0.81 ha/cow-calf pair. All pastures were assumed to consist of poor-condition fescue. Pastures were renovated and established to three forage systems that were modeled with both spring- and fall-calving commercial beef herds. The three systems modeled included 100% toxic endophyte-infected fescue/clover (TF100), 70% toxic endophyte-infected fescue/clover with 30% bermudagrass (BG30), and 70% toxic endophyte-infected fescue/clover with 30% switchgrass (SG30). Fescue and WSG components of forage systems were assumed to be established in separate pastures. The perennial WSG component of the latter two systems falls within the 10–35% range of WSG currently recommended for complementary grazing systems in the fescue belt (Keyser et al., 2012). Establishment techniques (e.g., seeding rate and technique, fertilizer, and lime amendments) and pasture management followed University of Tennessee guidelines (Bates et al., 2008; Savoy & Joines, 2009). Establishment and pasture costs (appendix, Table S1) were based on University of Tennessee forage budgets (University of Tennessee Department of Agricultural and Resource Economics, 2007) and May 2018 local prices for seed, fertilizer, and other inputs. Total annual pasture cost (US$/ha; annualized establishment + annual operational costs) was $366, $520, and $262 for fescue, bermudagrass, and switchgrass, respectively. Soil tests for phosphorous and potassium prior to seeding were assumed to be medium. Useful stand life was assumed to be 10 years.

During the establishment year, stocking rates on fescue were limited to 75% of the rate of 0.81 ha/cow-calf pair. No grazing occurred on switchgrass until the year following establishment. Stocking rates on bermudagrass are typically reduced during the establishment year. However, given the higher productivity of bermudagrass during summer relative to fescue, it was assumed to support 75% of the fescue rate (0.81 ha/cow-calf pair) during the establishment year. The same assumption was made for switchgrass for the year following establishment. Cattle grazed WSG from May 1 to September 1 for BG30 and SG30. We assumed that there was no calf death loss and that all replacement heifers were retained from the herd. Calves, open cows, and open replacement heifers were

Table 1. Calving Rates and Weaning Weights of Calves Used in Economic Simulation, by Calving Season and Forage System

	Calving Season	TF100[a]	BG30[b]	SG30[c]
Calving rate	spring	72%[d]	82%[e]	82%[e]
	fall	93%[f]	93%[g]	93%[g]
Weaning weight (kg)	spring	210[h]	228[h]	228[h]
	fall	215[i]	215[i]	215[i]

a. Tall fescue-only forage systems.
b. 70% tall fescue, 30% bermudagrass forage system.
c. 70% tall fescue, 30% switchgrass forage system.
d. Average of calving rates from Brown et al. (1992), Watson et al. (2004), Looper et al. (2010), Burns (2012), and Caldwell et al. (2013).
e. Average of calving rates from Brown et al. (1992) and Looper et al. (2010).
f. Average fall calving rate reported by Caldwell et al. (2013).
g. Average fall calving rate of toxic and nontoxic tall fescue treatments from Caldwell et al. (2013).
h. Average of spring-calving weaning weights from Peters et al. (1992), Burke et al. (2001), Watson et al. (2004), and Caldwell et al. (2013). There was insufficient data in peer-reviewed literature for spring-calving weaning weights for bermudagrass and switchgrass, so the average of the toxic fescue/nontoxic forage systems was used.
i. Caldwell et al. (2013). There was insufficient data in peer-reviewed literature for fall-calving weaning weights of toxic fescue/bermudagrass and toxic fescue/switchgrass systems, so the fall-calving weaning weight of 100% toxic fescue system was used.

marketed at weaning (September 1 and April 1 for spring- and fall-calving herds, respectively).

Calving rates (Table 1) were based on pertinent peer-reviewed literature. There is a lack of studies that provide data on calving rates for spring-calving cow herds grazing switchgrass and fall-calving herds grazing either bermudagrass or switchgrass. Therefore, we assumed that the SG30 spring-calving rate was the same as that for spring-calving BG30. For fall-calving BG30 and SG30 herds, we used the average of fall-calving rates for fescue and nontoxic fescue treatments (which did not differ) from Caldwell et al. (2013).

Similarly, weaning weights were also based on pertinent peer-reviewed literature (see Table 1). We did not find weaning weights for BG30 and SG30 in the literature for either calving season. Therefore, weaning weights from the 75% toxic/25% nontoxic fescue system from Caldwell et al. (2013) were used for the spring-calving herd. This assumption was made because spring-born calves on both complementary toxic-fescue/WSG and toxic-fescue/nontoxic fescue systems are pastured on nontoxic forages from May 1 to their weaning date on September 1. Because of a lack of studies with fall-calving weaning weights for BG30 and SG30, the average 205-d adjusted weaning weight of the 100% toxic fescue fall-calving herd from Caldwell et al. (2013) was used for all fall-calving herds, regardless of forage system. Cows and calves in fall-calving herds and complementary forage systems are on toxic fescue almost exclusively from birth to weaning, so using weaning weights from a 100% toxic fescue system was appropriate.

Daily nutritional requirements of cows (appendix, Table S2) and replacement heifers were estimated using the University of Nebraska Lincoln Extension BeefNRC macro, which is based on the *Nutrient Requirements of Beef Cattle* (National Academies of Sciences, Engineering, and Medicine, 2016). Requirements were based on month, animal class and lactation status, body weight, and reproductive status (appendix, Table S3). Spring-calving herds were bred on May 1 and calved beginning February 1, and calves were weaned on September 1. Fall-calving herds were bred on December 1 and calved beginning on September 1, and calves were weaned on April 1. Model cows were 60 months old, had condition scores of 5, and weighed 635 kilograms. Replacement heifer age and weight were adjusted on a monthly basis to determine nutritional requirements. The nutritional requirements of calves were estimated following Fox et al. (1988).

Early-bloom orchardgrass hay was used for all supplemental feed requirements. Nutrient content of orchardgrass hay (crude protein, 12.8% dry matter, and total dietary nutrition, 65% dry matter) and the amount of dry matter needed to fulfill an animal's daily nutritional requirements was based on the *Nutrient Requirements of Beef Cattle* (National Academies of Sciences, Engineering, and Medicine, 2016). Hay requirements were converted from dry matter to an as-fed basis for the simulation (appendix, Table S4). All hay was assumed purchased, and four months (December–March) of supplemental winter hay feeding was assumed necessary for all forage systems and calving seasons.

Length of summer hay-feeding periods were based on precipitation (appendix, Table S5). Precipitation levels were simulated based on 71 years (1948–2018) of historic monthly summer rainfall indices for Knoxville, Tennessee (United States Department of Agriculture Risk Management Agency, 2018). Based on the average index for this period for the months of July, August, and September, we assigned a duration (2–8 weeks) of supplemental summer hay feeding per forage system (see Table S5). No summer hay feeding was budgeted for any forage system if average summer rainfall was ≥100%. During winter and summer hay-feeding periods, we assumed that cattle received 100% of their nutritional requirements from hay.

Hay prices (see Table S4) were based on five-year averages of monthly winter and summer prices for USDA good-quality early-bloom orchardgrass in Harrisonburg, Virginia (USDA Virginia Department of Agriculture Market News, 2018). Cattle prices were based on the 17-year (2001–2017) average monthly sale prices for Tennessee (USDA Tennessee Department of Agriculture Market News, 2018), adjusted for inflation to 2017 prices. Spring- and fall-calving sale prices for steers, heifers, and cull cows were based on average prices in September, October, and November and April, May, and June, respectively. Open heifers that failed to breed were assumed to have the same market price ($/kg) as cull cows. Spring- and fall-calving sale prices ($/kg) were $1.48, $3.17, and $2.90 and $1.59, $3.35, and $3.02, respectively, for cull cows, steer, and heifers (USDA Tennessee Department of Agriculture Market News, 2018).

Profitability Analysis

The net present value (NPV) of annual net returns was calculated for spring- and fall-calving beef cow herds for each of the forage systems. Revenue for a cow-calf operation is generated through the sale of steers, heifers, and culled animals (open replacement heifers and cows). Costs for each system include land rent, pasture costs (annualized establishment and operational costs), and supplemental hay. A producer's expected annual net returns for a cow-calf operation with either a spring- or fall-calving herd grazing one of the three forage systems are determined by subtracting production costs from revenue and are expressed as

$$E[\pi_{ift}] = p^{s}_{ift} y^{s}_{ift}\left(\frac{CR_{if}}{2}\right) + p^{b}_{ift} y^{b}_{ift}\left(\frac{CR_{if}}{2} - RR_{ift}\right) + p^{c}_{ift} y^{c}_{ift}(RR_{ift}) + p^{ob}_{ift} y^{ob}_{ift}(HRR_{ift}) - PC_{ift} \quad (1)$$

Where π_{ift} is the expected annual net return ($/ha) for the i^{th} calving season (i = spring, fall) and the f^{th} forage system (f = TF100, BG30, SG30) in time period t ($t = 1, \ldots, 10$), p^{s}_{it} is the price of steer calves ($/kg), y^{s}_{ift} is the weight of steer calves (kg/head), CR_{if} is the calving rate , $0 \leq CR \leq 1$, p^{b}_{it} is the price of heifer calves ($/kg), y^{b}_{ift} is the weight of heifer calves (kg/head), RR_{ift} is the replacement rate of the cow herd $0 \leq RR \leq 1$, p^{c}_{it} is the price of culled animals ($/kg), y^{c}_{ift} is the weight of culled animals (kg/head), p^{ob}_{it} is the price of open heifers ($/kg), y^{ob}_{ift} is the weight of open heifers (kg/head), HRR_{ift} is the replacement rate of open heifers, and PC_{ift} is the annualized cost of production.

Annual net returns were discounted with the rate of 5% to find the NPV over the assumed 10-year useful stand life. NPV is expressed as

$$E[NPV_{if}] = \sum_{t=1}^{10} \pi_{ift}/(1+R)^{t} \quad (2)$$

where NPV_{if} is the sum of the discounted annual net returns and R is the discount rate.

Simulation

We used Simulation & Econometrics to Analyze Risk (Simetar©) (Richardson et al., 2008) to simulate NPV of each combination of calving season and forage system. Summer droughts reduce forage production, especially of CSG, and increase the amount of supplemental feeding required. Summer precipitation data was used to determine the number of summer hay-feeding days for each system, with rainfall data randomly bootstrapped with replacement. Hay prices were randomly drawn from a normal distribution, and cattle prices were drawn from a multivariate empirical distribution. A total of 5,000 NPV simulations were conducted for each combination of calving season and forage type.

Because of the limited published data on calving rates, our assumptions regarding these could be open to question, especially for spring-calving BG30 and SG30. A spring-calving herd with access to WSG may have higher calving rates than a similar herd with access to only CSG, regardless of endophyte infection status, because of increased WSG production and quality. Therefore, we conducted a sensitivity analysis for spring-calving BG30 and SG30 in which the assumed calving rate (0.82) was varied by ±10%. Results from simulations based on these adjustments to calving rates were compared to those generated using the baseline calving rate for the spring-calving TF100. Fall-calving herds were excluded from the sensitivity analysis because herds of all forage systems, including those assigned to systems with a WSG component, would be grazing dormant fescue, fed supplemental hay prior to and during the breeding season, or both.

The effect of hay feeding on annual net returns of each forage system within a calving season was isolated and explored by varying annual rainfall as a percent of the 71-year mean while holding all other independent variables constant at their means. The number of weeks of hay feeding in the simulation was determined by the average annual rainfall (see Table S5).

Many regional fescue pastures are in good condition. Therefore, NPV was also simulated assuming that existing fescue pastures were used for the forage systems. Under this scenario, no establishment cost was incurred for the 100% toxic endophyte-infected fescue/clover system (TF100-E). Total annual pasture cost for established fescue was US$279 per hectare. Establishment costs for the WSG components of the 70% toxic endophyte-infected fescue/clover with 30% bermudagrass (BG30-E) and 70% toxic endophyte-infected fescue/clover with 30% switchgrass (SG30-E) systems were the same as for the renovated fescue systems. Annual operational costs were the same for both scenarios (renovated and established fescue).

RESULTS AND DISCUSSION

Systems including WSG forages were more profitable than TF100 with the exception of the fall-calving BG30 system (Table 2). The SG30 system was more profitable than BG30 in both calving seasons. The most profitable calving season depended on the forage system. Fall calving was more profitable than spring calving for TF100, while spring calving was more profitable for BG30 and SG30 (see Table 2). Average NPV (pooled across calving seasons) of the TF100 system was $14,324

Table 2. Simulated Average Net Present Value (NPV) for Three Forage Systems and Two Calving Seasons

	Calving Season			
	Spring		Fall	
	NPV			
Forage System	Whole Farm	$/ha	Whole Farm	$/ha
TF100[a]	$3,279.12	$81.98	$25,368.46	$634.21
BG30[b]	$18,156.07	$453.90	$15,540.02	$388.50
ΔTF100	$14,876.94	$371.92	($9,828.43)	($245.71)
SG30[c]	$38,359.90	$959.00	$36,034.76	$900.87
ΔTF100	$35,080.78	$877.02	$10,666.31	$266.66

Note: Difference in NPV from incorporating warm-season grass (ΔTF100) is difference in NPV of WSG system (BG30 or SG30) and TF100.

a. Toxic endophyte-infected tall fescue.

b. Toxic endophyte-infected tall fescue with 30% bermudagrass.

c. Toxic endophyte-infected tall fescue with 30% switchgrass.

($358/ha), compared with $16,848 ($421/ha) and $37,197 ($930/ha) for BG30 and SG30, respectively. Average profitability of spring-calving herds increased with the addition of a WSG, and spring-calving SG30 was the most profitable system overall. Spring-calving herds grazing BG30 and SG30 had $372 and $877/ha greater NPV, respectively, than spring-calving TF100. In addition to WSG providing nontoxic forage, the production curve of WSG growth closely matches the increased nutritional demand of lactating spring-calving cows (Bagley et al., 1987). The fall-calving SG30 produced an increase (42%) in profitability over fall-calving TF100, but the fall-calving BG30 system was 39% less profitable than fall-calving TF100. Incorporating switchgrass increased profitability of fescue-based grazing systems due to increased calving rates (spring-calving only) (see Table 1), weaning weights (spring-calving only) (see Table 1), reduced hay demand during summer (see Table S5), and lower annual pasture cost. Despite greater pasture cost of BG30, greater calving rates and weaning weights resulted in higher profit for spring-calving herds relative to TF100. However, the only production advantage of BG30 over TF100 for fall-calving herds was reduced summer hay demand, which by itself did not result in great enough savings to offset the increased pasture cost.

NPV of spring-calving forage systems that included a WSG responded similarly to a 10% change in calving rate (Table 3). Profitability of both systems remained higher than TF100 when the calving rate was decreased and increased a similar amount when calving rate was increased 10%.

Profitability of all forage systems decreased as annual rainfall decreased and the number of hay--feeding days increased (Figure 1). For spring-calving herds, the order of profitability of the systems did not change over the range of average annual rainfall (Figure 1A). Notably, for the spring-calving herd, both BG30 and SG30 remained profitable regardless of drought severity. When hay was fed for four weeks, TF100 was no longer profitable. However, at annual rainfall levels ≥88% of the long-term average, fall-calving TF100 was more profitable than fall-calving BG30 (Figure 1B). All three systems remained profitable for fall-calving herds, regardless of summer hay-feeding requirements.

Profitability of all forage systems increased when existing fescue pastures were used (Table 4). However, the order of profitability among systems remained the same as for the systems with renovated fescue.

Spring-calving cows grazing toxic fescue during the breeding season are likely to experience reduced reproductive rates as the result of ingesting toxic fescue (Waller, 2009). Removing animals from toxic fescue pre- and postbreeding has been shown to increase reproductive rates (Burns, 2012; Caldwell et al., 2013). WSGs are generally ready to be stocked by the time the spring-calving breeding season begins. This enables spring-calving cows to be moved off toxic fescue and onto WSG pastures prior to and immediately subsequent to breeding, thus improving calving rates. Greater calving rates reduce the number of cows that must be culled and therefore the number of replacement heifers that must be retained and developed. Developing replacement heifers is one of the most expensive components of operating a cow-calf herd (McFarlane, 2018; McFarlane et al., 2018). Furthermore, higher calving rates result in increased revenue because more calves are produced and a greater proportion of calves are marketed.

Weaning weights for WSG systems in each calving season had to be estimated from studies comparing toxic fescue grazing systems to those that included either nontoxic fescue or another CSG. Spring-calving herds grazing WSG, as opposed to nontoxic CSG, prior to weaning calves may produce even greater weaning weights than those assumed in this study. Weaning weights of fall-born calves may also be greater on forage systems that include a WSG due to the ability to stockpile additional fescue going into winter. Increasing stockpiles of fescue for winter grazing has the additional benefit of reducing hay-feeding

Table 3. Simulated Net Present Values (NPV) of Spring-Calving Systems That Included a Warm-Season Grass at Three Calving Rates

	BG30		SG30	
Calving Rate	Farm	$/ha	Farm	$/ha
0.73	$12,223	$306	$26,920	$673
0.82	$18,156	$454	$38,360	$959
0.90	$27,514	$688	$48,181	$1,205

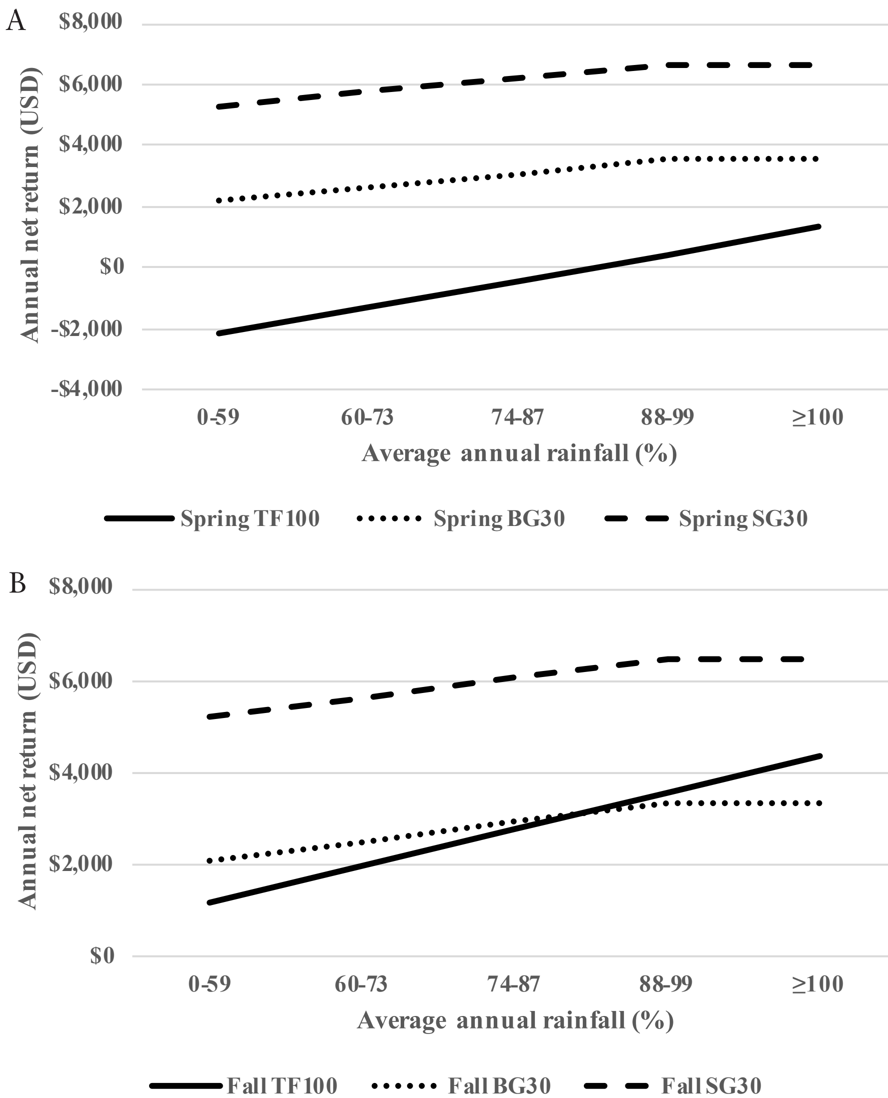

Figure 1. Annual Net Returns of Spring-Calving and Fall-Calving Beef Cow-Calf Herds on Model Forage Systems across the Range of Average Annual Rainfall

Note: Annual net returns of (A) spring-calving beef cow-calf herds grazing 30% bermudagrass/70% fescue (spring BG30), 30% switchgrass/70% fescue (spring SG30), and 100% fescue for 40-ha forage systems (spring TF100) and (B) fall-calving beef cow-calf herds grazing 30% bermudagrass/70% fescue (fall BG30), 30% switchgrass/70% fescue (fall SG30), and 100% fescue for 40-ha forage systems (fall TF100) across varying average annual rainfall (%) levels, with all other independent variables held constant at their means.

requirements, which reduces cost of production and, in turn, increases profitability.

Most fescue pastures are not pure stands. WSGs such as common bermudagrass are present in many fescue pastures as a result of feeding purchased hay. The amount of WSG in fescue pastures is highly variable. A limitation of this study is that we had no way to account for the influence of WSG already intermixed in fescue pastures. However, none of the assumptions or model parameters required

Table 4. Simulated Average Net Present Value (NPV) for Three Forage Systems and Two Calving Seasons

	Calving Season			
	Spring		Fall	
	NPV			
Forage System	Whole Farm	$/ha	Whole Farm	$/ha
TF100-E[a]	$31,337.98	$783.45	$53,240.88	$1,331.02
BG30-E[b]	$37,624.44	$940.61	$34,845.07	$871.13
ΔTF100-E	$6,286.46	$157.16	($18,395.82)	($459.90)
SG30-E[c]	$57,844.27	$1,446.11	$55,360.59	$1,384.01
ΔTF100-E	$26,506.29	$662.66	$2,119.70	$52.99

Note: Difference in NPV from incorporating warm-season grass (ΔTF100-E) is difference in NPV of WSG system (BG30-E or SG30-E) and TF100-E.

a. Toxic endophyte-infected tall fescue using existing fescue.

b. Toxic endophyte-infected tall fescue with 30% bermudagrass, using existing fescue.

c. Toxic endophyte-infected tall fescue with 30% switchgrass, using existing fescue.

pure stands of fescue. We assumed that parameters obtained from the literature were from representative fescue pastures.

Lowering production costs is important for small farms to be profitable (Lacy et al., 2012). The SG30 system ($335/ha) had the lowest production cost of the three forage systems, followed by TF100 ($366/ha) and BG30 ($413/ha). The lower production cost was the primary reason the NPV of SG30 was higher than TF100 for fall-calving herds. Lower cost of production is also why the NPV of SG30 was higher than BG30 in both calving seasons. The difference in annual pasture cost was driven by lower establishment and fertilizer costs for switchgrass (see Table S1). Bermudagrass establishment was more expensive because of higher seed cost and seeding rate relative to switchgrass. Annual input requirements were also greater for bermudagrass, with higher frequency of application and application rates of nitrogen, phosphorous, potassium, and lime. Profitability of forage systems still benefited from incorporating WSG even when existing fescue was in good condition. The exception was fall-calving herds on BG30 with higher establishment and operational costs. Spring-calving herds in particular benefited from adding switchgrass to existing fescue systems.

CONCLUSION

One of the systems with the lowest NPV, spring-calving TF100, is the most widely used in the fescue belt. Among the systems we evaluated, a profit-maximizing producer in the fescue belt would utilize a complementary forage system with 70% fescue and 30% switchgrass. Producers who prefer to maintain all-fescue forage systems can maximize profitability by utilizing a fall-calving season.

ACKNOWLEDGMENTS

We acknowledge Professor G. Bates, director of the UT Beef and Forage Center, University of Tennessee, Knoxville, for his assistance. A private donor, who wished to remain anonymous, funded this research.

REFERENCES

Backus, W. M., Waller, J. C., Bates, G. E., Harper, C. A., Saxton, A. M., McIntosh, D. W., Birckhead, J., & Keyser, P. D. (2017). Management of native warm-season grasses for beef cattle and biomass production in the Mid-South USA. *Journal of Animal Science 95*, 3143–3153.

Bagley, C. P., Carpenter Jr., J. C., Feazel, J. I., Hembry, F. G., Huffman, D. C., & Koonce, K. L. (1987).

Influence of calving season and stocking rate on beef cow-calf productivity. *Journal of Animal Science 64,* 687–694.

Bates, G. E., Harper, C. A., McClure, A., Raper, T., & Sykes, T. (2008). Forage and field crop seeding guide for Tennessee. PB 378. University of Tennessee Institute of Agriculture Extension.

Brown, M. A., Tharel, L. M., Brown Jr., A. H., Miesner, J. R., & Jackson, W. G. (1992). Reproductive performance of angus and brahman cows grazing common bermudagrass or endophyte-lnfected tall fescue. *Professional Animal Scientist 8*, 58–65.

Burke, J. M., Rorie, R. W., Piper, E. L., & Jackson, W. G. (2001). Reproductive responses to grazing endophyte-infected tall fescue by postpartum beef cows. *Theriogenology 56*, 357–369.

Burns, J. C. (2012). Timing of exposure to toxic tall fescue: Effects on beef cattle reproduction. Ph.D. dissertation, Clemson University, Clemson, SC.

Burns, J. C., & Fisher, D. S. (2013). Steer performance and pasture productivity among five perennial warm-season grasses. *Agronomy Journal 105*, 113–123.

Caldwell, J. D., Coffey, K. P., Jennings, J. A., Philipp, D., Young, A. N., Tucker, J. D., Hubbell, D. S., Hess, T., Looper, M. L., West, C. P., Savin, M. C., Popp, M. P., Kreider, D. L., Hallford, D. M., & Rosenkrans, C. F. (2013). Performance by spring and fall-calving cows grazing with full, limited, or no access to toxic Neotyphodium coenophialum-infected tall fescue. *Journal of Animal Science 91*, 465–476.

Campbell, B. T., Backus, W. M., Dixon, C. M., Carlisle, R. J., & Waller, J. C. (2013). A comparison of spring-and fall-calving beef herds grazing tall fescue. *Professional Animal Scientist 29*, 172–178.

Fox, D. G., Sniffen, C., & O'connor, J. (1988). Adjusting nutrient requirements of beef cattle for animal and environmental variations. *Journal of Animal Science 66*, 1475–1495.

Fribourg, H. A., Hannaway, D. B., & West, C. P. (Eds.). (2009). Tall fescue for the twenty-first century. Agronomy Monograph 53. ASA, CSSA, and SSA, Madison, WI.

Hannaway, D. B., Daly, C., Halbleib, M. D., James, D., West, C. P., Volenec, J. J., Chapman, D., Li, X., Cao, W., Shen, J., Shi, X., & Johnson, S. (2009). Development of suitability maps with examples for the United States and China. In H. A. Fribourg, D. B. Hannaway, & C. P. West (Eds.), *Tall fescue for the twenty-first century* (pp. 31–47). Agronomy Monograph 53. ASA, CSSA, and SSA, Madison, WI. doi:10.2134/agronmonogr53.c3

Henry, G. W., Boyer, C. N., Griffith, A. P., Larson, J., Smith, A., & Lewis, K. (2016). Risk and returns of spring and fall calving for beef cattle in Tennessee. *Journal of Agricultural and Applied Economics 48*, 257–278.

Hoveland, C. S. (1993). Importance and economic significance of the Acremonium endophytes to performance of animals and grass plant. *Agriculture, Ecosystems & Environment 44,* 3–12.

Kallenbach, R. L. (2015). Bill E. Kunkle Interdisciplinary Beef Symposium: Coping with tall fescue toxicosis; Solutions and realities. *Journal of Animal Science 93*, 5487–5495. doi:10.2527/jas.2014–8149

Kallenbach, R. L., Crawford Jr., R. J., Massie, M. D., Kerley, M. S., & Bailey, N. J. (2012). Integrating bermudagrass into tall fescue-based pasture systems for stocker cattle. *Journal of Animal Science 90*, 387–394.

Keyser, P. D., Bates, G. E., Waller, J. C., Harper, C. A., & Doxon, E. (2012). Grazing native warm-season grasses in the Mid-South. University of Tennessee Extension SP731-C, Institute of Agriculture, University of Tennessee, Knoxville.

Keyser, P. D., Harper, C. A., Bates, G. E., Waller, J. C., & Doxon, E. (2011). Native warm-season grasses for Mid-south forage production. University of Tennessee Extension SP731-A, Institute of Agriculture, University of Tennessee, Knoxville.

Keyser, P. D., Holcomb, E. D., Lituma, C. M., Bates, G. E., Waller, J. C., Boyer, C. N., & Mulliniks, J. T. (2016). Forage attributes and animal performance from native grass inter-seeded with red clover. *Agronomy Journal 108*, 373–383.

Lacy, R. C., Knight, C. H., & Mckissick, J. C. (2012). Profitable cattle marketing for the cow-calf producer. University of Georgia Cooperative Extension Bulletin 1078, University of Georgia, Athens.

Looper, M. L., Reiter, S. T., Williamson, B. C., Sales, M. A., Hallford, D. M., & Rosenkrans, J. C. F. (2010). Effects of body condition on measures of intramuscular and rump fat, endocrine factors, and calving rate of beef cows grazing common bermudagrass or endophyte-infected tall fescue1,2. *Journal of Animal Science 88*, 4133–4141.

Lowe, J., Boyer, C., Griffith, A., Waller, J., Bates, G., Keyser, P., Larson, J., & Holcomb, E. (2016). The cost of feeding bred dairy heifers on native warm-season grasses and harvested feedstuffs. *Journal of Dairy Science 99*, 634–643.

McFarlane, Z. D. (2018). Low-input heifer development using stockpiled native forages and protein supplementation. Ph.D. dissertation, University of Tennessee, Knoxville.

McFarlane, Z. D., Boyer, C. N., & Mulliniks, J. T. (2018). Profitability of developing beef heifers on stockpiled winter forages. *Journal of Applied Farm Economics 2*(2), 1–18.

National Academies of Sciences, Engineering, and Medicine. (2016). Nutrient requirements of beef cattle (8th rev. ed.). National Academies Press, Washington, DC.

Peters, C. W., Grigsby, K. N., Aldrich, C. G., Paterson, J. A., Lipsey, R. J., Kerley, M. S., & Garner, G. B. (1992). Performance, forage utilization, and ergovaline consumption by beef cows grazing endophyte fungus-infected tall fescue, endophyte fungus-free tall fescue, or orchardgrass pastures. *Journal of Animal Science 70*, 1550–1561.

Richardson, J. W., Schumann, K. D., & Feldman, P. A. (2008). Simetar©: Simulation and econometrics to analyze risk. Agricultural and Food Policy Center, Department of Agricultural Economics, Texas A&M University, College Station.

Roberts, C. A., Lacefield, G. D., Ball, D. M., & Bates, G. E. (2009). Management to optimize grazing performance in the Northern Hemisphere. In H. A. Fribourg, D. B. Hannaway, & C. P. West (Eds.), *Tall fescue for the twenty-first century* (pp. 85–99). Agronomy Monograph 53. ASA, CSSA, and SSA, Madison, WI. doi:10.2134/agronmonogr53.c6

Savoy, H. J., & Joines, D. (2009). Lime and fertilizer recommendations for the various crops of Tennessee: Chapter III. Forage, pasture, hay, silage crops. Department of Biosystems Engineering & Soil Science, University of Tennessee, Knoxville, TN.

Schmidt, S. P., & Osborn, T. G. (1993). Effects of endophyte-infected tall fescue on animal performance. *Agriculture, Ecosystems & Environment 44*, 233–262.

Smith, S. A., Caldwell, J. D., Popp, M. P., Coffey, K. P., Jennings, J. A., Savin, M. C., & Rosenkrans, C. F. (2012). Tall fescue toxicosis mitigation strategies: Comparisons of cow-calf returns in spring- and fall-calving herds. *Journal of Agricultural and Applied Economics 44*, 577–592.

Stuedemann, J. A., & Hoveland, C. S. (1988). Fescue endophyte: History and impact on animal agriculture. *Journal of Production Agriculture 1*, 39–44.

Tracy, B. F., Maughan, M., Post, N., & Faulkner, D. B. (2010). Integrating annual and perennial warm-season grasses in a temperate grazing system. *Crop Science 50*, 2171–2177.

United States Department of Agriculture Risk Management Agency. (2018). Pasture, Rangeland, Forage Support Tool. https://prodwebnlb.rma.usda.gov/apps/prf

University of Tennessee Department of Agricultural and Resource Economics. (2007). Tennessee forage budgets. University of Tennessee, Ag Econ Budgets, Knoxville.

USDA Tennessee Department of Agriculture Market News. (2018). Tennessee weekly livestock summary. https://www.ams.usda.gov/mnreports/nv_ls145.txt

USDA Virginia Department of Agriculture Market News. (2018). Virginia hay report. https://www.ams.usda.gov/mnreports/rh_gr310.txt

Waller, J. C. (2009). Endophyte effects on cattle. In H.A. Fribourg, D. B. Hannaway, & C. P. West (Eds.), *Tall fescue for the twenty-first century* (pp. 289–310). Agronomy Monograph 53. ASA, CSSA, and SSA, Madison, WI.

Watson, R., McCann, M., Parish, J., Hoveland, C., Thompson, F., & Bouton, J. (2004). Productivity of cow-calf pairs grazing tall fescue pastures infected with either the wild-type endophyte or a nonergot alkaloid-producing endophyte strain, AR542. *Journal of Animal Science 82*, 3388–3393.

APPENDIX

Table S1. Pasture Establishment and Annual Operational Costs for Tall Fescue (TF), Bermudagrass (BG), and Switchgrass (SG)

	TF	BG	SG
Pasture Costs		US$/ha	
Establishment costs			
Seed[a]	$109.58	$261.24	$140.85
Establishment[b]	$473.60	$573.11	$363.83
Risk of reestablishment	$58.32	$83.44	$50.47
Total	$641.50	$917.79	$555.15
Annualized establishment[c]	$87.15	$124.69	$75.42
Operational costs			
Fertilizer	$157.38	$300.43	$118.85
Herbicide	$9.64	$45.71	$18.29
Red and white clover seed	$8.08	—	—
Mowing (clipping)	$54.68	—	—
Land rent	$49.42	$49.42	$49.42
Total annual pasture cost	$366.36	$520.26	$261.98

a. Tall fescue seed includes tall fescue, red clover, and white clover seed. Seed varieties were KY-31, Cheyenne II, and "Alamo for tall fescue, bermudagrass, and switchgrass, respectively.
b. Other establishment costs include herbicide, fertilizer, custom applications, custom no-till planting, and land rent for establishment year.
c. Includes 5% annual interest.

Table S2. Dry Matter Intake (DMI) of Early-Bloom Orchardgrass Hay, Metabolized Protein (MP), and Energy (NEm) Requirements of 635-Kilogram Cows by Calving Season and Month

	Spring Calving Season			Fall Calving Season		
Month	DMI (kg/day)	MP (g/day)	NEm (mcal/day)	DMI (kg/day)	MP (g/day)	NEm (mcal/day)
December	13.3	570	11.7	15.4	1038	19.2
January	13.3	631	13.0	14.9	901	17.4
February	14.1	877	17.0	14.4	784	15.8
March	15.3	1177	21.1	14.1	696	14.6
Summer[a] (July–September)	13.9	659	13.5	13.6	693	13.9

Source: National Academies of Sciences, Engineering, and Medicine (2016).
a. Summer values are the average requirements of cows for the months of July through September.

Table S3. Straightbred Angus Animal Description Parameters Used in the Nutrient Requirements of Beef Cattle University of Nebraska Lincoln Extension Beef NRC Program to Develop Hay-Feeding Requirements for the Economic Simulation

		Spring-Calving Season					Fall-Calving Season				
Variables	Units	Dec	Jan	Feb	Mar	Summer	Dec	Jan	Feb	Mar	Summer
Age	months	60	60	60	60	60	60	60	60	60	60
Body weight	kg	635	635	635	635	635	635	635	635	635	635
Body Condition	value	5	5	5	5	5	5	5	5	5	5
Peak milk	kg/day	14	14	14	14	14	14	14	14	14	14
Production											
Calf birth weight	kg	36	36	36	36	36	36	36	36	36	36
Days pregnant	days	225	255	0	0	105[a]	15	45	75	105	160[a]
Days in milk	days	0	0	15	45	120[b]	105	135	165	195	5[b]

a. Mean of days pregnant for July, August, and September.
b. Mean of days in milk for July, August, and September.

Table S4. Monthly USDA Good-Quality Early-Bloom Orchardgrass Hay Prices in Harrisonburg, VA, and Amount of Hay Needed to Fulfill a 635-Kilogram Cow's Nutritional Requirements

[redacted]

Summer	$0.07	16.4	16.0

Source: USDA Virginia Department of Agriculture Market News (2018).

Table S5. Number of Weeks of Summer (July–September) Hay Feeding Given Monthly Precipitation in Simulation

Percent (%) Average Summer Monthly Rainfall[a]	Weeks of Hay Feeding	
	TF100	BG30 & SG30
0–59	8	3
60–73	6	2
74–87	4	1
88–100	2	0
>100	0	0

a. United States Department of Agriculture Risk Management Agency (2018).