Enhancing the adoption of stockpiling tall fescue and managed grazing

Sharon Freeman[1], Matthew Poore, and April Shaeffer

Department of Animal Science, North Carolina State University, Raleigh, NC 27695

ABSTRACT: One of the primary goals of extension is to encourage and support adoption of improved technologies. Managed grazing and stockpiling forage are two such technologies. The goal of this project was to encourage adoption of these practices by providing on-farm demonstrations of the technologies. We also collected forage and soil data and held workshops at each of the demonstration sites. Host producers were selected, given a basic kit of temporary fencing supplies for use during the demonstration, and instructed on their proper use during the winter stockpiling season. Forage yield and quality data were collected and soil tests made to show the economic advantages of proper fertilization and grazing fresh forage in contrast to feeding stored forage and concentrate. The nutritive value of the forage stockpiled in September through November (67% total digestible nutrients [TDN] and 14% crude protein, CP) exceeded the needs of the cattle and was greater than the nutrient content of hay present on the farms (59% TDN and 11% CP, $P < 0.01$). The mean quantity of available forage (2,856 ± 164 kg dry matter per hectare) provided an average of 260 (±81.8) standard cow (545 kg) grazing days per hectare of stockpiled forage. Taking into account the higher nutritive value of the fresh forage when compared with hay and the savings of time and equipment costs by grazing, we estimated that grazing stockpiled forage saved $1.28 per standard cow per day. The grazing management skills gained during this project and the temporary fencing technology were adopted by 93% of the demonstration farms that responded to our follow-up survey (78% of demonstration sites), and the area managed with these technologies increased on these sites more than 350%. Having the hosts share personal experiences played an important role in encouraging their peers to adopt the technologies.

Key words: adoption, managed grazing, stockpiled forage, temporary fencing, workshops

Transl. Anim. Sci. 2019.3:1099–1105
doi: 10.1093/tas/txz086

INTRODUCTION

All phases of agriculture seek to minimize costs to maximize profitability. Cost-saving efforts become a priority when inputs, such as fuel, feed, and fertilizer, rise drastically in price. Among the savings options available to beef farmers in the fescue belt are stockpiling tall fescue (*Festuca arundinacea* Schreb.) in the late fall for subsequent winter grazing and improved grazing management. Despite readily available temporary fencing equipment options and well-developed recommendations to facilitate these practices (Hancock and Josey, 2014; Castillo et al., 2018), many beef farmers continue to use the same forage management techniques used for decades, namely continuous grazing combined with feeding stored forage in the form of hay for an extended winter feeding period (Hanson, 1995), which typically begins in December and ends in late February or March.

Several factors have been found to impact adoption of available technologies on farms

[1]Corresponding author: sfreeman@ncsu.edu
Received March 21, 2019.
Accepted June 6, 2019.

including farm size (number of cows), ownership of the land, education, and region of the country (Pruitt et al., 2012). In the southeastern area of the United States, an area included in the "fescue belt" where herd size is small, adoption rates were lower than in other parts of the United States. Economies of scale would have had less impact on farms with fewer cattle, possibly influencing adoption decisions. Gillespie et al. (2007) found that perceived nonapplicability and unfamiliarity were the most and second most commonly cited reasons for nonadoption of technologies, respectively. Somewhat in contradiction with Pruitt et al. (2012), farms with the largest beef herds viewed rotational grazing as non-applicable. Farms which maintained contact with personnel from United States Department of Agriculture-Natural Resources Conservation Service were more likely to adopt this practice. Knowing the potential benefits stockpiling forage and adaptive grazing could offer beef farmers in North Carolina (Poore et al., 2000), the goals of this project were to (i) encourage adoption of strip grazing (one facet of adaptive grazing) in conjunction with stockpiling tall fescue; (ii) document pasture composition, yield, and nutritive value over the grazing season; (iii) collect cost data to determine the value of these practices when compared with continuous grazing and feeding hay; (iv) assess long-term adoption of these technologies by the demonstration farmers; and (5) provide a demonstration and workshop template that may be adapted to other locations.

MATERIALS AND METHODS

These demonstrations were conducted on research stations and private farms across North Carolina. Demonstrations at research stations were conducted with approval of the Animal Care and Use Committee at North Carolina State University (Protocol #10-131-A). Animal care met or exceeded the standards described in the Guide for the Care and Use of Agricultural Animals in Research and Teaching (FASS, 2010) at private farms.

Farm Selection, Expectations, On-Farm Data Collection, and Scheduling

The project was designed as a series of on-farm technology demonstrations and involved partnership with North Carolina Cooperative Extension county extension agents and associated local conservation agency staff [Natural Resources Conservation Service (NRCS) and Soil and Water Conservation District]. The demonstrations and accompanying workshops were conducted in the 2010, 2011, and 2012 grazing seasons as part of, "Amazing Grazing", an interdisciplinary program aimed at expanding the use of adaptive grazing management. Agents collaborated with local conservation staff to consider the farmers in their counties and to pick several who tended to be early technology adopters and who were well regarded within their local area. The agents reached out to these farmers, invited them to participate in the project, and explained the expectations. Each would stockpile a pasture of tall fescue, use strip grazing (frontal grazing) when allowing cattle to consume the stockpiled forage, host a workshop during the grazing period, and be willing to candidly share their thoughts regarding the implementation of the showcased technologies. Farmers also kept records of basic information including pasture area and fertilizer applications, including costs; grazing dates including start, stop, and animal movement days; time spent moving animals or fences and supplying feed; equipment usage (type and time used); and amounts of supplemental feed offered (hay, minerals, and/or energy supplements) and associated costs of the supplements.

In exchange for their participation and to facilitate strip grazing, each farmer was provided with a "grazing kit" containing the necessities for managed grazing (Figure 1). The use of a standardized temporary fence kit ensured that fencing equipment would be high quality and appropriate for existing conditions. Participating farmers were expected to complete a soil test and apply lime and/or other nutrients according to the test prior to the demonstration. They were also required to supply at least 53 kg N per hectare in early fall to promote tall fescue growth during the fall growth period (September to November, depending on location) and then hold off grazing the growth ("stockpile") until early winter, when other forage sources were depleted (Poore and Drewnowski, 2010). They were asked to move their cattle no less frequently than every 3 d.

Host farms also received support from their local Extension, NRCS, or the Soil and Water Conservation District staff and detailed information to help them better understand their forage resources. These data were supplied back to the farmer, to his or her extension agent, and to those attending the workshop. Data from forage samples, collected monthly by the county extension agents, allowed participants to follow forage nutritive value throughout the grazing season and compare it with stored forage they had on hand.

Farmers' time was valued at $12 per hour for all calculations and equipment operation at $15 per hour (estimated with Edwards, 2016; not including labor).

Workshops were scheduled to allow attendees to observe the cattle grazing the stockpiled forage at each location (December or January). They were open to the public, advertised by the local advisory teams, and allowed attendees to communicate directly from the host farmer about his/her experiences using strip grazing of stockpiled forage. A questionnaire was mailed to the host farmers in 2014 to determine longevity of adoption. They were given space to comment on the impact the technologies had on their respective farm operations.

Forage Sampling and Analysis

Prior to each workshop, project staff visited the site to make measurements of forage yield by means of falling plate measurements according to Drewnoski et al. (2007) with the modification of clipping to a residual height of 5 cm instead of to the ground. Individual tall fescue tillers (minimum of 25) were collected and sent to the North Carolina Department of Agriculture and Consumer Services laboratory for determination of endophytic infection rate by the plant tissue stain test according to Association of Official Seed Analysts rules for testing seed. Samples of forage were collected from each pasture for analysis of sward botanical composition as described by Drewnoski et al. (2007). Forage grab samples for nutrient analysis were collected monthly during the grazing season and sent to the North Carolina Department of Agriculture Forage Analysis laboratory (Raleigh, NC) where dry matter (DM) was determined according to Shreve et al. (2006; NFTA procedure 2.1.4). Forages were also analyzed for crude protein (CP; AOAC, 2010), neutral detergent fiber (Van Soest et al., 1991), acid detergent fiber (ADF; Ankom Method 12), total digestible nutrients (TDN = 92.5135 − (0.7965 × ADF), and mineral concentrations (AOAC, 2010).

Statistical Analysis

Data from forage samples collected for nutrient analysis were analyzed with SAS Proc Mixed (v. 9.4, SAS, Cary, NC) to detect differences between hay and fresh forage samples. The model included forage type (hay or fresh forage) as the fixed effect, and harvest date was used as the random effect. Data from sward composition samples and endophytic infection rates were analyzed with SAS Proc Means to determine mean sward composition and infection rate across farms.

Figure 1. Grazing kit supplied to workshop hosts to promote managed grazing on farms that showcased stockpiling tall fescue including (100) tread-in temporary fence posts (#1); (10) 7/8 in diameter fiberglass posts for use as temporary corners or gate posts (#2); (1) post driver (#3); (2) nongeared fence reels with polywire and handles (#4); (2) geared fence reels with polywire and handles (#5); and (1) "fault finder" fence tester (#6). Equipment was purchased from Pasture Management Systems (Mt. Pleasant, NC).

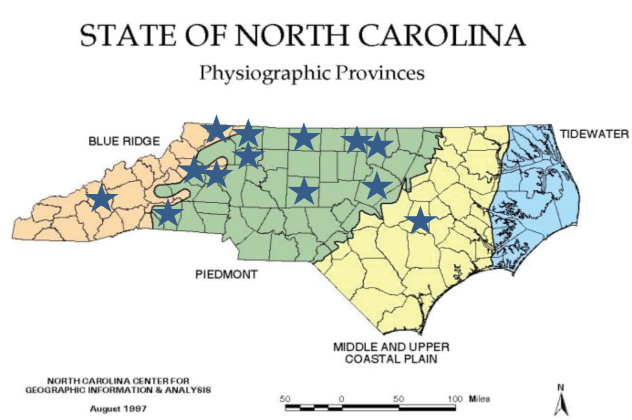

Figure 2. North Carolina counties that hosted on-farm workshops that showcased stockpiling tall fescue and managed grazing.

RESULTS AND DISCUSSION

On-Farm Demonstrations and Workshops

Twenty-two sites in 13 NC counties across the state (Figure 2) were identified to participate in demonstrations and host workshops. Of these, 18 were privately owned farms, and four were research stations. Over 300 participants attended the workshops with individual workshop attendance ranging from 10 to 85. Turnout varied primarily with weather conditions at or around the time of the workshop. Pastures used for the workshops included a total of 174 ha and supported 525 cattle (5.8 ± 1.1 ha per site with 25 ± 17.1 animals). Because cattle size varied, cow body weight was standardized on the basis of 544 kg for calculations ("standard cow", e.g., if a cow actually weighed 500 kg, she became 500/544 = 0.92 standard cow). With this adjustment, there was an average of 22.8 standard cows per farm.

Based on the results of the soil tests conducted at each site, soil pH averaged 6.4 ± 0.16. Relatively few farms required lime application as a result. Over the 3-yr period of the workshops, lime costs remained fairly consistent at $33 per ton applied. The cost of N-P-K applications, however, increased annually from $504 per t applied in the fall of 2009 to $547 and then $778 per t applied in 2010 and 2011, respectively. With the increase in fertilizer cost, producers became more judicious with applications so that application rates dropped from an annual mean of 68 kg N per hectare in 2009 to 58 and 57 kg N per hectare in 2010 and 2011, respectively. Nitrogen applications averaged 61 kg N per hectare and met project requirements at all sites. Mean P and K were 38.7 and 16.5 kg/ha, respectively. Application rates varied greatly because of differences in soil test results (SEM = 54.7 and 32.3 kg/ha for P and K, respectively). The result was a mean per hectare cost for fertilization of $162, $96, and $200 for 2009, 2010, and 2011, respectively. Phosphorus and potassium were applied according to soil test and, on average, at rates of 30 and 16 kg per ha, respectively. Total fertilizer and lime cost averaged $37.05 per standard cow per year for the duration of the project.

Mean yield of grazable forage (Table 1) was 2,856 kg DM per hectare (±164.1) and fell within the range of yields found in the literature (Kallenbach et al., 2003; Teutsch et al., 2005; Lyons et al., 2016). With this amount of available forage, farmers were able to achieve an average of 260 (±81.8) standard cow grazing days per ha of stockpiled forage.

Forage nutritive value was fairly consistent from year to year (Figure 3), but declined slowly over the course of each winter. This pattern agreed with the literature (Kallenbach et al., 2003; Poore et al., 2006; Drewnoski et al., 2007). Fresh forage consistently had greater nutritive value for the cattle (greater CP and TDN with less ADF, $P < 0.01$) than available hay and it exceeded NRC requirements for lactating beef cows or developing heifers (National Research Council (NRC), 2000). The mean CP, TDN, and ADF (Table 1) were typical of values previously reported (Poore et al., 2000). Tall fescue contributed the greatest amount of DM to the swards (Table 1); however, these "tall fescue pastures" were only 2/3 tall fescue and had considerable bluegrass, crabgrass, and other forage plants. Testing for the presence of endophytic fungus in the fescue showed that 89% of the tillers (±5.3%) were infected across farms.

Economic Comparison of Grazing to Feeding Hay

The winter grazing season averaged 63 d (±3.2), beginning about December 15 and ending about February 16 (Table 2). Participating farmers spent an average of 0.47 h per move (±0.05) shifting cattle to fresh pasture allocations. Each move required setting up a new, temporary fenceline (using the equipment provided) to allow cattle access to fresh pasture and taking down the previous day's fenceline. Farmers moved their animals an average of 54.6 times (±13.4) during the demonstration period resulting in a total expenditure of 25.7 h over the course of the grazing season. Most moved their cattle daily and used either a pickup truck or all-terrain vehicle as transportation. Equipment and labor costs for giving cattle forage allocations were $649.46 or $28.45 per standard cow per year (±$8.11).

Table 1. Summary of forage quality, grazing days achieved, and grazing cost

Parameter, units	3-yr mean (standard deviation)
Grazable forage dry matter, kg/ha	2,855 (405)
Crude protein, % of DM	14.4 (2.5)
Total digestible nutrients, % of DM	67.8 (3.3)
Acid detergent fiber, % of DM	31.0 (4.0)
Fescue, % of DM	66.8 (18.7)
Green fescue, % of DM	45.4 (19.8)
Other grass, % of DM	13.5 (8.7)
Clover, % of DM	0.51 (1.0)
Other plant, % of DM	19.6 (11.0)
Grazing days (standard cow days/ha)	260.2 (81.8)
Cost of grazing ($/standard cow/d)	$1.26 ($0.71)

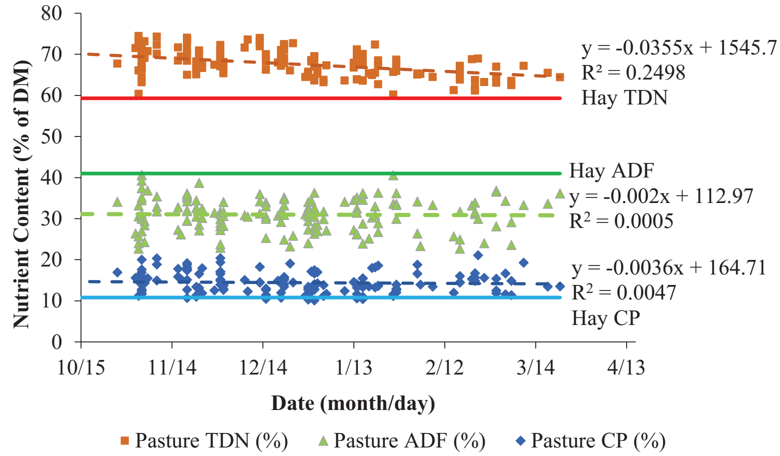

Figure 3. Forage nutritive value for the duration of the winter grazing period on farms that showcased stockpiling tall fescue and managed grazing when compared with the quality of stored hay.

Table 2. The economics of grazing stockpiled forage when compared with feeding hay over 3 yr of demonstration workshops (U.S. dollars per standard cow over the winter grazing season unless otherwise noted)

Parameter	Grazing	Feeding hay
Winer grazing season, d	63	63
Standard cows present (545 kg)	22.6	22.6
Fall fertilizer including equipment and labor	$37.05	—
Allocating forage, equipment and labor	$28.45	—
Feeding hay including equipment and labor	$8.45	$120.33
Trace minerals	$2.94	$2.94
Energy/protein supplements including equipment and labor	$2.84	$37.17
Total cost	$79.73	$160.44
Total cost per standard cow per day	$1.26	$2.54

The need to feed hay was minimal and resulted in an average of only five bales (±3.1) per farm being fed per year. Hay was offered only when snow and ice made grazing too difficult for cattle to meet their nutritional needs on their own. Hay cost averaged $83.36 per ton (±$21.01) and it took the farmers 0.36 h (± 0.07) to feed each bale resulting in an expenditure of $192.94 (±$145.70) including equipment operation costs. This was $8.45 per standard cow per year during the demonstration period.

Because the nutritive value of the stockpiled forage was adequate for the cattle being grazed, very little supplemental feed was needed other than free-choice mineral. Farmers spent $64.74 per year on energy/protein supplements ($2.84 per standard cow ± $4.66) and $67.12 per year on minerals for their cattle ($2.94 ± $0.58 per standard cow) and supplied the supplements as needed when they moved their animals so no additional labor time or equipment costs were accrued in supplying these feeds. The total amount (fertilizer, feed, labor, and equipment costs) participating farmers spent per standard cow was $79.73 per year or $1.26 per grazing day. The range in costs varied from $0.22 to $2.84 per standard cow per day.

By contrast, the farmers had chosen to continue their former practice of feeding hay and concentrate during the same period, costs would have been considerably greater under the economic conditions that existed during the period of the workshops. Assuming a standard cow eats 2.5% of body weight on a dry basis with 20% waste, she would need 16.3 kg DM per day as hay. Hay was valued at $83.36 per ton based on the cost of the hay per bale and actual bale weights reported which equates to $1.36 per standard cow per day. Mean bale weight from participating farms was 290 kg, so 1.3 bales per day would be needed to meet the cows' needs or about nine bales per week. Labor and equipment costs for feeding hay would be estimated to be $0.55 per standard cow per day (nine bales needed per week, 0.36 h per bale to feed it). Total cost for supplying hay was $120.33 per standard cow for the grazing season (Table 2)

The hay at the farms that hosted workshops was lower than the available pasture in TDN [59.3 (SEM = 0.48) vs. 67.3% (SEM = 0.35) for hay and fresh forage, respectively; $P < 0.01$] and CP [10.8% (SEM = 0.26) vs. 14.3% (SEM = 0.20) for hay and forage, respectively; $P < 0.01$]. To provide an equivalent plane of nutrition to that provided by fresh forage, the cattle would have been required 1.4 kg per day energy/protein supplement. Concentrate costs would have been $176 per t or $0.24 per standard cow per day. If we assume feeding concentrate to the average herd would mean one daily trip to the feeding area (0.3 h), associated labor and equipment costs are $0.35 per cow per day. Mineral costs would have been similar in both systems ($0.05 per standard cow per day). The total daily cost of feeding a standard cow hay and concentrate is therefore estimated to be $2.54, as compared with $1.26 per standard cow day in the grazing system, representing a savings of $1.28 per standard cow per day.

On our average farm, over a 63-dgrazing period involving 23 standard cows, grazing saved $1,855 as compared with feeding stored feed. Changes in fertilizer and hay prices would certainly impact this figure. At the time of this comparison, fertilizer prices were relatively high. Hay costs, based on what producers indicated they had paid, were relatively low. Raising hay costs would further increase the advantage of grazing (Teutsch et al., 2005). The cost of supplemental feed would also have an impact on the relative advantage of grazing.

Value of On-Farm, Hands-On Demonstrations

Encouraging a hands-on atmosphere and the sharing of personal experiences by the host farmers proved to be valuable teaching tools during the demonstrations. One of the hands-on exercises developed during the first year of the workshops of greatest utility was a "reel race" during which two workshop participants, one with a geared reel and one with a nongeared reel, tried to retract equal lengths of outstretched polywire. The time and energy saving advantage of the geared reel became obvious for most participants. As the project progressed and interest in temporary fencing increased, more reels were added to the race as more workshop participants wanted to try different reels. Allowing workshop attendees to watch the host producer move his or her animals to a fresh strip of pasture demonstrated the simplicity of strip grazing and encouraged adoption of the technology. No follow-up was conducted with attendees to see if any adopted the technologies demonstrated at the workshops; however, anecdotal reports from county extension agents were that many farms had adopted these valuable tools as a result of the workshops.

Follow-Up Surveys to Host Farmers

Follow-up surveys were mailed to the 18 cooperating farmers in 2014 to determine longevity of technology adoption. Of the 15 respondents, 14 have continued to use stockpiling and managed grazing on their farms. The single person who stopped using the technologies was an elderly widow who cited "unreliable labor" as her reason for stopping. One farmer was renovating his fescue pastures at the time of the follow-up survey and could now stockpile as a result. He indicated, however, that he would resume when renovations were complete and that he continued using managed grazing in his other pastures.

The farmers reported using 58.5 ha as pasture at the time of the demonstrations and they committed 11.7 ha per farm (20% of their pasture) for use in the demonstrations. The completed follow-up surveys indicated the area grazed under managed grazing had increased to an average of 42.1 ha per farm (72% of pastures). This represents a 278% increase in area. Reduced expenses (feed, fuel, and equipment) was the most commonly cited advantage of managed grazing followed by calmer livestock and improved soil quality.

We received several positive comments back on the follow-up survey. Among them were:

- "Best project ever completed on farm to increase income and reduce expenses!"
- "Stockpiling and managed grazing helped farm family receive conservation family of the year for 2014".
- "Better body condition on the cows through winter and calves wean 50 lb heavier."

Only one negative comment was received:

- "(We) had 3 calves cut legs on polywire in 2013–14 and had to put one down."

Despite this negative experience, however, this farm continues to use the technologies and is managing accordingly. This comment shows the importance of maintaining a high level of power on the temporary fence to avoid teardowns of the fence and the potential injuries that can result.

IMPLICATIONS

The results of the follow-up survey coupled with the anecdotal reports of additional farms using stockpiled fescue and managed grazing suggested that the technique we used to promote these practices, namely on-farm, hands-on demonstrations with associated workshops, was successful in encouraging adoption. Supplying the farmers with a basic supply of the tools they needed, giving them hands on instruction on how to use them, and then allowing them to freely share their experiences with other farmers proved to be a valuable way of encouraging the adoption of these desirable practices on other farms. The format is easily adapted to promote the use of other cost saving or sustainability oriented technologies.

Conflict of interest statement. None declared.

LITERATURE CITED

Association of Analytical Chemists (AOAC). 2010. Method 985.01. In: G.W. Latimer, Jr, editor, Official methods of analysis of AOAC International. 19th ed. Rockville, MD: Association of Analytical Chemists.

Castillo, M. S., J. C. Burns, and S. Sosinski. 2018. Production and utilization of stockpiled tall fescue: understanding the basic concepts. North Carolina State Extension. https://content.ces.ncsu.edu/show_ep3_pdf/1542644004/24185/

Drewnoski, M. E., M. H. Poore, E. J. Oliphant, B. Marshall, and J. T. Green, Jr. 2007. Agronomic performance of stockpiled tall fescue varies with endophyte infection status. Forage Grazinglands 5. doi:10.1094/FG-2007-1217-03-RS

Edwards, W. 2016. Machinery cost calculator. [accessed November 8, 2017]. http://www.extension.iastate.edu/Publications/PM710.pdf.

Federation of Animal Science Societies (FASS). 2010. Guide for the use and care of agricultural animals in research and teaching, 3rd ed. Champaign (IL): Federation of Animal Science Societies. [accessed April 29, 2019]. https://www.aaalac.org/about/ag_guide_3rd_ed.pdf

Gillespie, J. E., S-A. Kim, and K. Paudel. 2007. Why don't producers adopt best management practices? An analysis of the beef cattle industry. Agric. Econ. 36:89–102. doi:10.1111/j.1574-0862.2007.00179.x

Hancock, D. W. and R. W. Josey. 2014. Stockpiling tall fescue for fall and winter grazing. University of Georgia Extension Circular 920. [accessed November 10, 2018]. https://secure.caes.uga.edu/extension/publications/files/pdf/C%20920_4.PDF

Hanson, G. D. 1995. Adoption of intensive grazing systems. Journal of Extension, 33(4), Article 4RIB3. [accessed November 10, 2018]. https://www.joe.org/joe/1995august/rb3.php

Kallenbach, R. L., G. J. Bishop-Hurley, M. D. Massie, G. E. Rottinghaus, and C. P. West. 2003. Herbage mass, nutritive value, and ergovaline concentration of stockpiled tall fescue. Crop Sci. 43:1001–1005. doi:10.2135/cropsci2003.1001

Lyons, S. E., A. D. Shaeffer, M. E. Drewnoski, M. H. Poore, and D. H. Poole. 2016. Effect of protein supplementation and forage allowance on the growth and reproduction of beef heifers grazing stockpiled tall fescue. J. Anim. Sci. 94:1677–1688. doi:10.2527/jas.2015-9969

National Research Council (NRC). 2000. Nutrient requirements of beef cattle, 7th revised ed., update., Washington, DC: National Academies Press.

Poore, M. H., G. A. Benson, M. E. Scott, and J. T. Green. 2000. Production and use of stockpiled fescue to reduce beef cattle production costs. J. Anim. Sci. 79:1–11. doi:10.2527/jas.00.079ES1001i

Poore, M. H. and M. E. Drewnoski. 2010. Review: utilization of stockpiled tall fescue in winter grazing systems for beef cattle. Prof. Anim. Scientist. 26:142–149. doi: 10.15232/S1080-7446(15)30573–8

Poore, M. H., M. E. Scott, and J. T. Green, Jr. 2006. Performance of beef heifers grazing stockpiled fescue as influenced by supplemental whole cottonseed. J. Anim. Sci. 84:1613–1625. doi:10.2527/2006.8461613x

Pruitt, J. R., J. M. Gillespie, R. F. Nehring, and B. Qushim. 2012. Adoption of technology, management practices, and production systems by U.S. beef cow-calf producers. J. Agric. Appl. Econ. 44:203–222. doi:10.1017/S1074070800000274

Shreve, B., N. Thiex, and M. Wold. 2006. National Forage Testing Association (NFTA) reference method: dry matter by oven drying for 3 hours at 105°C. NFTA reference methods. Omaha, NB: NFTA. [accessed December 11, 2018]. www.foragetesting.org.

Teutsch, C. D., J. H. Fike, G. E. Groover, and S. Aref. 2005. Nitrogen rate and source effects on the yield and nutritive value of tall fescue stockpiled for winter grazing. Online. Forage and Grazinglands 3. doi: 10.1094/FG-2005-1220-01-RS

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