Chapter 5

Potential for Use of a Perennial C_3 Grass in a Warm-Temperate Region with Pastures Dominated by C_4 Grasses

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Abstract

Tall fescue is a perennial cool-season forage grass utilized over an extensive area of the USA; however, adaptation is limited across the Coastal Plain region of the southeastern states including Louisiana. Stands of the original variety, Kentucky 31, from early plantings either failed to persist or were replaced as adverse effects on grazing livestock by an ergot alkaloid toxin from an association of tall fescue with an endophytic fungus were recognized. Management approaches can moderate the adverse effects allowing productive use of existing tall fescue pastures. Endophyte removal from tall fescue allowed development of useful cultivars for the primary tall fescue growing area, but these endophyte-free cultivars proved to be less persistent in marginal areas such as Louisiana. Recently available varieties with novel, nontoxin-producing endophytes have shown potential in northern Louisiana with stand persistence for 4 years on some sites. Cool-season perennial grass pastures can be realistic components of forage systems in areas such as northern Louisiana. Existing remnant stands can be beneficial with appropriate management, and, as indicated by ongoing research, new novel-endophyte varieties may prove useful on selected sites.

Keywords: pastures, cool-season grasses, tall fescue, adaptation, plant persistence, grazing management, fescue toxicosis

1. Introduction

Across northern Louisiana USA, perennial grass pastures support beef cattle production on sites ranging from fertile bottomlands to leached sandy uplands. This area lies within 32–33°N and 91–94°W providing a long summer growing season for warm-season grasses and a winter dormant period for these grasses of about 5 months each year. The warm-season, perennial grasses bermudagrass (*Cynodon dactylon*) and bahiagrass (*Paspalum notatum*) are well adapted and provide the forage base for livestock production. Dormant season forage has typically been provided by hay and/or cool-season annual forages overseeded each autumn on dormant sod of the warm-season pasture grasses. To the north of this area, just above about 35°N, the cool-season perennial grass, tall fescue (*Lolium arundinaceum*; synonym *Schedonorus arundinaceus;* formerly *Festuca arundinacea*) dominates as the primary pasture grass. From about 1945, the area of use of tall fescue in the United States expanded greatly with development of the variety Kentucky 31 as a widely adapted pasture plant [1]. By the 1960s, tall fescue was recognized as a useful perennial cool-season pasture plant on bottomland soils of northern Louisiana [2]. On sandy loam upland soils of northern Louisiana, evaluations of tall fescue varieties in repeatedly clipped plots resulted in yields of Kentucky 31 of 4400 kg/ha per growing season over a 4-year period for a 1955 planting [3]. Average annual production over a 4-year period for Kentucky 31 from a 1958 planting was 5930 kg/ha. Stands from a 1967 planting of eight tall fescue varieties persisted for only 2 years with average annual yields for Kentucky 31, which was one of the two most productive varieties, of 9130 kg/ha. Failure to survive the summer period following repeated clipping to an 8-cm stubble height for a period of two to four growing seasons was a common result of the field plot evaluations [3]. Remnant tall fescue stands on sandy loam soils in the area, especially along the bottoms of the often strongly sloping landscape, have survived under grazing for decades. These stands are considered to be predominately of Kentucky 31, which was the primary variety available in the area when most of the tall fescue pasture planting occurred. As tall fescue pastures were developed, toxicity problems were increasingly recognized in the 1970s as documented for the neighboring state, Arkansas [4]. With recognition of this toxicity as a limitation to both calf-crop percentages and weaning weights in addition to the infrequent severe toxicity symptoms, use of tall fescue as a pasture plant in Louisiana decreased to only remnant stands. Management of these remnant tall fescue stands continues to present recurring management questions.

Recent contacts with area cattle producers regarding existing tall fescue in pastures have ranged from a desire to eliminate the plants to an interest in management approaches to improve existing partial stands. Observation of toxicity symptoms in one instance and lack of detectable negative effects in another of close proximity led to assessments of ergot alkaloid levels and seed head suppression in existing tall fescue stands. Ergovaline levels in seed heads of tall fescue in Missouri in late June of 1–5 mg/kg contrast with levels of 0.3–0.5 mg/kg for all other plant parts [5]. Thus, reproductive tillers with maturing seed heads can produce very high concentrations of alkaloid toxins. Use of plant growth regulators to seasonally decrease stem development has been identified as a management approach for control of fescue toxicity [6–8]. Applications of metsulfuron-containing herbicides to vegetative and boot-stage tall fescue in the spring substantially reduced seed head production [6]. The herbicide

Chaparral®™ suppressed tall fescue seed head emergence, reduced severity of fescue toxicosis [7], and contributed to a higher rate of gain by steers grazing herbicide-treated tall fescue compared to those grazing nontreated pastures [8].

Discovery of the detrimental effects of the endophyte alkaloids on the rate of gain by young growing cattle [9, 10] led to development of cultivars identified as endophyte free. Subsequently, reduced competitiveness and decreased plant persistence were found to be associated with reduced endophyte levels of tall fescue pastures in stressful environments [11]. As an approach to provide a useful cool-season perennial pasture option for the lower southeastern USA, Georgia-5 and Jesup were selected for superior persistence and released [12, 13] in the 1990s as cultivars with the endemic, toxin-producing endophyte contributing to stand survival. Following initial results in Louisiana verifying the endophyte effects [14], evaluations of these varieties along with their endophyte status and potential management approaches for northern Louisiana were evaluated.

Interest in the novel-endophyte tall fescue varieties in Louisiana increased with marketing of cultivars with the Max Q endophyte resulting in evaluations of Jesup Max Q. Recently, availability of several cultivars of tall fescue with novel, nontoxin-producing endophytes from the commercial seed industry along with marketing of these cultivars led to renewed interest in potential for persistent cool-season pastures in Louisiana. Positive results from evaluations of initial novel endophyte varieties in Louisiana [14] and the lack of negative effects reported for animal responses [15] further justified the continuing assessment of the available varieties of novel endophyte tall fescue.

2. Materials and methods

2.1. Alkaloid levels

At two farms in northern Louisiana where responses of grazing cattle to tall fescue forage differed, tillers were dug from just below the soil surface with individual tillers removed from the plant crown. When reproductive tillers were present, separate samples of vegetative and reproductive tillers were collected. At each farm, samples were collected from two distinct pasture areas. Each sample collected consisted of 20 individual tillers. Samples were immediately placed on ice and then frozen upon arrival at the lab. For assessment of ergot alkaloid effects, ergovaline, the widely recognized predominant alkaloid associated with fescue toxicosis [5, 16], which has been widely used as a measure of fungal endophyte toxin level in tall fescue, was analyzed. Analysis of ergovaline and its stereoisomer, ergovalinine, was by high-performance liquid chromatography fluorescence as described by Yates and Powell [17] and modified by Carter et al. [18].

2.2. Seed head suppression

Two locations in a large pasture in Claiborne Parish, Louisiana, USA, where fescue toxicosis symptoms had been observed, were selected for evaluation of effects of Chaparral herbicide on tall fescue seed head emergence. The pasture was stocked continuously with crossbred beef cattle during the evaluation period. Paired comparisons with and without application of the herbicide were made at each of the two locations within this pasture. Each of the four experimental units was 0.1 ha in size. Chaparral herbicide was applied to one 0.1 ha experimental unit in each of the two pairs of plots on April 22, 2016. Application rate was 1.46 ml ha^{-1} plus 0.25% nonionic surfactant in 187 L water ha^{-1}. The number of seed heads was counted within a 0.25 m^2 frame at five locations within each experimental unit. Height of mature inflorescences within each frame was also determined. Tillers were obtained from each experimental unit for determination of ergot alkaloid concentration as described above.

2.3. Endophyte status and grazing management

Potential for the tall fescue varieties Georgia-5, Jesup, and Kentucky 31 to persist as perennial pasture species in northern Louisiana was evaluated over 3 years from a 1988 drill seeding into a dormant bermudagrass sod. A split-plot treatment arrangement consisted of main plots of grazing management combinations differing during the cool and warm seasons. A factorial combination of either continuous or rotational stocking in the cool season and warm-season management of continuous stocking, rotational stocking, or hay production resulted in six main plot treatments. Each was split into six subplots of the factorial combination of three tall fescue varieties with either the endemic endophyte or no endophyte. These were established in a randomized complete block design with four replications. Warm-season treatments were applied from June through September each year. Cattle numbers were adjusted to maintain a minimal 6 cm forage stubble height. Stands were assessed each January by determining presence or absence of fescue plants every 3 cm along a 3-m transect in each plot.

2.4. Jesup grazing management

Plantings of Jesup Max Q tall fescue on a seasonally waterlogged Latanier clay soil in northwest Louisiana and a Gigger silt loam soil in northeast Louisiana were subjected to grazing treatments. The planting in northwest Louisiana was drill-seeded in the autumn of 2008, while the northeast Louisiana stand was from a 2006 planting that had been lightly grazed periodically. Treatments imposed were a factorial combination of two spring grazing termination dates (May 1 and June 1) with grazing treatments of no summer grazing and periodic summer grazing to harvest growth of associated warm-season grass, primarily summer annuals dominated by crabgrass (*Digitaria sanguinalis*). Fertilization of tall fescue in this factorial arrangement of treatments was at 38 kg/ha of nitrogen each spring. In addition, three control treatments of no nitrogen fertilizer and 76 kg/ha of nitrogen with the periodic summer grazing and a continuously grazed treatment with 38 kg/ha of nitrogen fertilizer were also imposed. Cool-season grazing was from October through May in 2009–2010 and 2010–2011. Periodic tall fescue stand assessments were made by counting the number of 0.1 × 0.1 m cells containing the grass in a 1-m^2 divided sample quadrat. Stands were evaluated on March 22, 2010 and January 31, 2012 with herbage mass sampled on November 30, 2009.

2.5. Tall fescue variety/novel endophyte evaluation

On October 29, 2013, five commercially available novel-endophyte inoculated varieties of tall fescue were planted near the site of the Jesup grazing evaluation in northwest Louisiana.

Along with the varieties DuraMax Gold tall fescue with Armor®™ endophyte, Estancia tall fescue with ArkShield®™ Technology endophyte, Martin 2 tall fescue with Protek®™ endophyte, Texoma tall fescue with Max Q II®™ endophyte, and Tower tall fescue with Protek®™ endophyte, Kentucky 31 with the naturally occurring (endemic), toxin-producing endophyte was included as a check. Plantings were in a randomized complete block design with three replications of plots each 12 × 80 m on an area dominated by Moreland silty clay loam soil with a substantial area of Latanier clay across much of one replication. The area was grazed periodically as forage was available over the next 4 years with grazing restricted to the cool season. To compare potential productivity among varieties, an area of 1 m^2 was clipped to an 8-cm stubble height from each plot in a selected area with a dense stand on January 31, 2018 before grazing was initiated. Ratings of stand density were made on March 13, 2018 following an early season grazing period. Visual ratings of tall fescue stand density across only the Moreland soil area of each plot were based on a scale of 0 for no tall fescue to 9 for a complete, dense stand with no competing vegetation present.

3. Results and discussion

3.1. Alkaloid levels

Ergovaline concentrations in vegetative tillers from these Louisiana pastures ranged from a low of 0.08 mg/kg in April of 2017 to a high of 1.61 mg/kg in October of 2015 (**Figure 1**). Both of these divergent samples were from the pasture location where no fescue toxicity symptoms were observed. Ergovalinine concentration was consistently lower than that of ergovaline but followed a generally similar pattern of fluctuation throughout the sampling period. The average ergovaline concentrations of 0.65 and 0.70 mg/kg for the two pastures exceeded the highest level of 0.464 mg/kg reported by Belesky et al. [19] for tall fescue grown at Watkinsville, Georgia, USA. From evaluations at three Georgia locations during 2 years [20], only samples from Athens, Georgia in one of the 2 years produced a higher average ergovaline concentration than that of the Louisiana samples. Ergovaline concentration can be affected by environmental and management conditions including season of the year, nitrogen fertilizer, and moisture deficit [5, 19–21]. Defoliation intensity can also affect production of this toxin [22]. As illustrated in **Figure 1**, substantial variation in ergot alkaloid concentration occurred among sampling dates and between locations in the two Louisiana pastures. In contrast to the distinct seasonal pattern with peak ergovaline concentrations in spring and autumn reported by Belesky et al. [19], the variation in Louisiana pasture samples revealed no distinct seasonal pattern. Variation in ergot alkaloid production in these pastures is perhaps primarily influenced by the rather drastic weather conditions and stocking management which resulted in substantial variation in available forage and plant growth.

Consumption of ergovaline was estimated to range from 4.2 to 6.0 mg/day during June in a Missouri evaluation before decreasing to a range of 1.1–2.8 mg/day in August [16]. Forage concentrations of ergovaline in Kentucky 31 tall fescue forage providing these daily intake levels ranged from 0.154 to 0.506 mg/kg. Although clinical symptoms of toxicosis were not reported, reductions in milk production, calf gain, and cow body weight were reported, as

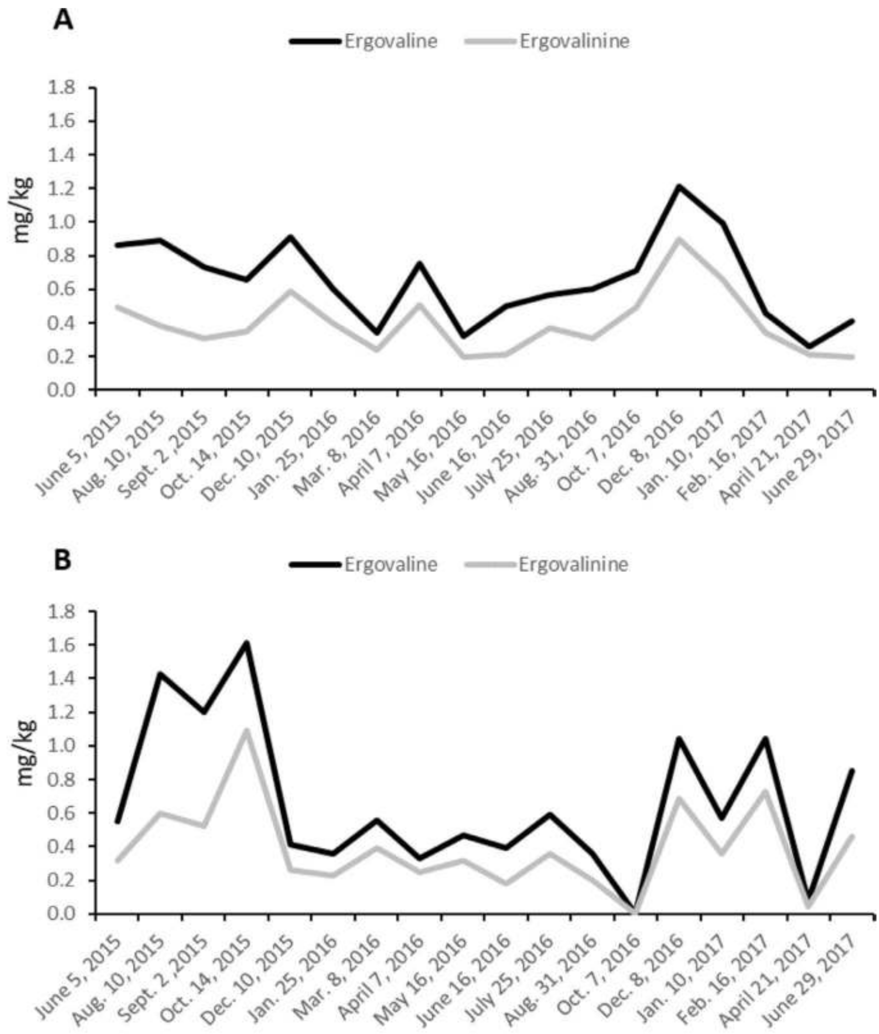

Figure 1. Ergot alkaloid concentrations in vegetative tillers from remnant tall fescue stands in (A) central and (B) southern locations in Claiborne Parish, Louisiana, USA.

well as reduced forage intake in August, in comparison to cattle grazing endophyte-free tall fescue pastures [16]. Some questions have been presented about the adequacy of ergovaline as the sole measure of ergot alkaloid concentration in tall fescue. Different patterns of concentration of ergovaline and total ergot alkaloids in distribution within a tall fescue canopy and with forage conservation methods have been reported [23, 24] with Roberts et al. [23] suggesting that ergovaline alone may not fully reflect animal performance responses to the endophyte. Rogers et al. [25] further determined that management to reduce effects of ergot alkaloids on livestock performance depended upon whether ergovaline or total alkaloids are the primary causative agents of fescue toxicosis. Potential for synergistic effects of multiple ergot alkaloid compounds on vasoconstriction was also reported [26]. Foote et al. [27] reported that vasoconstriction, a primary animal response to the toxin, was primarily a result of ergovaline concentration of forage consumed by grazing livestock. Levels of ergovaline and ergovalinine detected in both Louisiana pastures were at least periodically high enough to produce fescue toxicosis symptoms, even though other effective alkaloids may also have been present. The lack of visual toxicosis symptoms at one of the locations was not associated with lack of toxic alkaloid concentrations in the tall fescue forage, even though additional toxic alkaloid compounds may have been present.

With alkaloid levels periodically high in both Louisiana pastures and animal effects in only one of these, further assessment is needed. One location involved leased land which had not been recently grazed and tall fescue growth was mature and rank. This tall fescue forage was essentially the only grazing available during the initial cool season for these cattle, which were also alkaloid toxin-naïve (not previously exposed to such toxic forage). In addition, cattle in the pasture not visually affected by toxicity symptoms were crossbred cattle with a substantial proportion of Brahman breeding, while the herd where symptoms were observed was of less uniform breeding and generally less Brahman composition. Brahman cattle have been suggested to provide less susceptibility to fescue toxicosis associated with their greater heat tolerance [28, 29]. Thus, both cattle aspects and pasture condition may have contributed to differences in toxicity symptoms observed. This is consistent with observations in Arkansas where "fescue foot" symptoms were reported in cattle stocked on previously ungrazed "soil-bank program" land being returned to production, even though these symptoms were not frequently observed in most tall fescue pastures in the area [4].

3.2. Seed head suppression

Evaluations of Chaparral treatment of tall fescue produced visible decreases in tall fescue seed head emergence (**Table 1**) and changes in plant species composition of mixed tall fescue stands with diverse broadleaf weeds and bahiagrass, which were substantially reduced by the herbicide. In addition to the substantial reduction in number of seed heads emerging following treatment, height of seed heads was also reduced (**Table 1**) with greatly reduced production of stem material. Ergot alkaloid concentrations were similar between the two treatments in both vegetative and reproductive tillers (**Table 2**) but the reduction in number of reproductive tillers by herbicide application should reduce the amount of alkaloid ingested

		Range of seed head stem heights	
	Seed head	**Low**	**High**
	No./m²	**cm**	
Chaparral®™	42a*	14a	32a
Not treated	126b	26b	69b

Chaparral®™ (Trademark of the Dow Chemical Company) was applied on April 22, 2016 at the rate of 146 ml ha^{-1} + 0.25% nonionic surfactant in 187 L water ha^{-1}.*Means within a column followed by a common letter do not differ significantly ($P < 0.05$).

Table 1. Effect of Chaparral®™ herbicide on tall fescue seed head formation and development.

	Vegetative tillers		Reproductive tillers	
Treatment	Ergovaline	Ergovalinine	Ergovaline	Ergovalinine
Chaparral®™	0.42	0.27	0.54	0.29
Not treated	0.41	0.21	0.49	0.29

Chaparral®™ (Trademark of the Dow Chemical Company) was applied on April 22, 2016 at the rate of 146 ml ha^{-1} + 0.25% nonionic surfactant in 187 L water ha^{-1}.

Table 2. Ergot alkaloid concentrations (mg/kg) in response to Chaparral®™ herbicide application to tall fescue pasture (no significant differences between treatments, $P > 0.05$).

by grazing livestock. At an additional northern Louisiana location with a dense, ungrazed tall fescue stand, seed head density was reduced by this herbicide treatment of plants primarily in the boot stage. Seed heads were, however, still prevalent in the stand indicating that adequate opportunity for livestock consumption of toxin may persist in tall fescue pasture treated at this stage and allowed excessive deferment from grazing even with such seed head suppression.

3.3. Endophyte status and grazing management

At the end of 3 years, it was obvious that endophyte infection was necessary for stand persistence of the varieties Georgia-5, Jesup, and Kentucky 31 on this site as the endophyte-free varieties provided less than 10% stand survival. For the endophyte-infected varieties, both Georgia-5 and Jesup were more persistent than Kentucky 31 (**Figure 2**), with Jesup providing the highest level of persistence at a little more that 50% stand survival. Continuous stocking of endophyte-infected tall fescue during the summer period provided the best stand survival (**Figure 3**), although considerable stand loss occurred in all treatments. Continuous stocking was beneficial during the warm season because little grazing of tall fescue occurred and warm-season grass was highly competitive during periods without grazing. Warm-season grass height of 15–20 cm during the summer before each rotational grazing period or hay harvest resulted in substantial shading of the tall fescue, which produced only minimal growth during this period. Grazing management, either continuous or rotational stocking, during other periods of the year did not substantially affect tall fescue survival.

Even though both of the endophyte-infected varieties provided better persistence than did Kentucky 31 and Kentucky 31 had persisted for years on some sites, widespread use of these varieties did not occur, even on more favorable sites. Establishment difficulties were found to be limitations for plantings into existing warm-season grass sod under less-than-optimal conditions. Selection of the more moist Coastal Plain sites, management of competition, and soil fertility, particularly phosphorus, were reported to be critical aspects for establishment of Georgia 5 on sandy Coastal Plain sites in Louisiana [30]. Despite the potential for Georgia-5 and Jesup to fill a gap in pasture systems on appropriate sites in the region, these cultivars were not widely planted in Louisiana.

3.4. Jesup grazing management

At initiation of grazing in autumn 2009, the experimental areas at both locations were essentially complete stands of tall fescue with similar fescue growth between locations and among

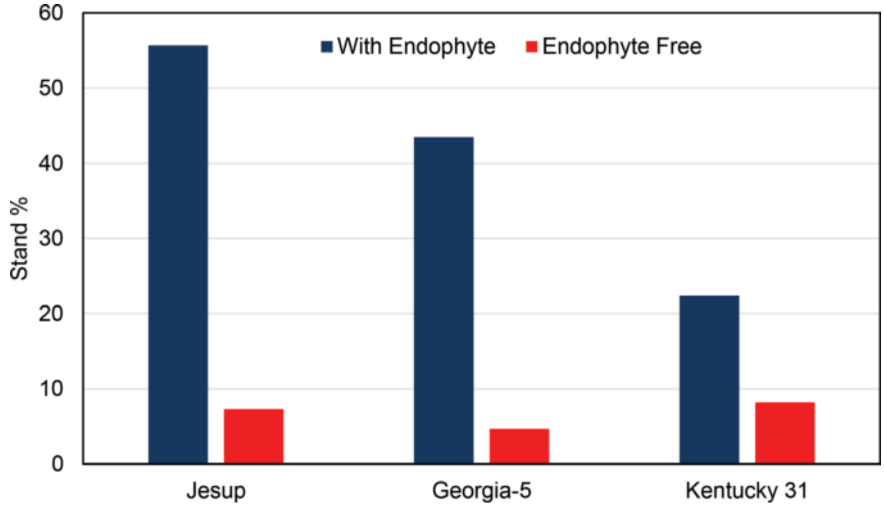

Figure 2. Effect of endophyte infection on stands of tall fescue varieties planted in a perennial warm-season grass sod and subjected to various grazing and hay management practices during the previous 3 years.

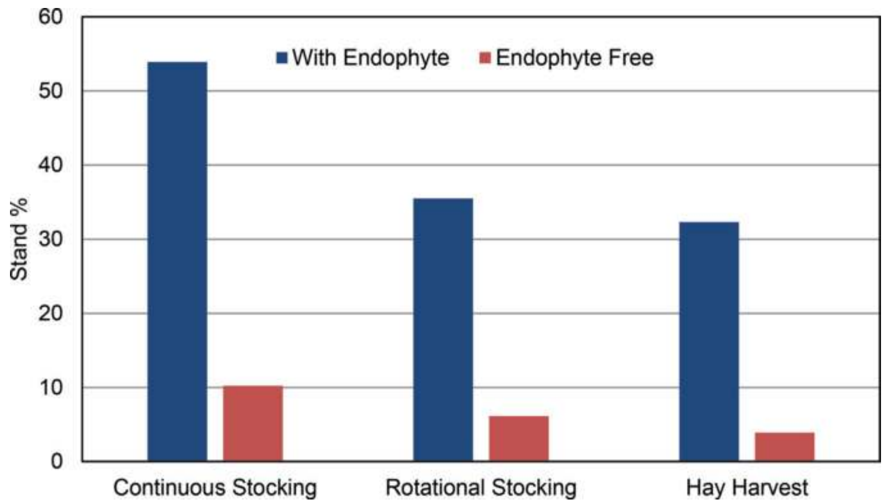

Figure 3. Effect of 3 years of light continuous stocking, rotational stocking, or hay harvests during the summer periods on stands of tall fescue planted in a perennial warm-season grass sod.

plots (**Table 3**). By March of 2010, very little change had occurred in these stands with no difference among treatments, which ranged from 95 to 98% tall fescue. Tall fescue stands decreased markedly at both locations during the relatively dry summer of 2011. Stands at the northwest location ranged from only 6 to 25% tall fescue at the end of January 2012, even though no grazing occurred after September 2011. Both treatments at this location with grazing terminated on May 1 had lower tall fescue cover percentages (6%) than did similar

Spring N (kg/ha)	Spring grazing terminated	Summer grazing*	Location (Louisiana, USA)	
			NW	NE
			Forage mass (kg/ha)**	
0	1-Jun	Periodically stocked	4915	5038
38	1-Jun	None	5698	4955
38	1-Jun	Periodically stocked	4960	4840
38	1-May	None	4719	4726
38	1-May	Periodically stocked	4905	4761
38	None	Continuously stocked	4950	5237
76	1-Jun	Periodically stocked	5918	5314

*Summer grazing describes grazing during the summer period (June–September). Periodically stocked refers to light stocking during various times to graze volunteer annual summer forages but minimize grazing of tall fescue.

**No significant differences ($P > 0.05$) in forage mass between locations or among grazing treatments.

Table 3. Forage dry matter production by late November from Jesup MaxQ tall fescue at two locations in Louisiana.

treatments with grazing terminated on June 1 (average of 19% cover). The numerically highest tall fescue cover of 25% was on the ungrazed control treatment. Whether or not warm-season grass was grazed during the summer, the early grazing termination date was detrimental rather than beneficial as expected. Grazing until June 1 may have reduced competition from early growth of warm-season grass more than any adverse effects on the tall fescue during the month of May. None of the treatments evaluated provided sufficient stand survival at either location to indicate adaptation of Jesup Max Q tall fescue to these sites. No survival response was detected over the range of 0–76 kg/ha of nitrogen fertilizer annually.

3.5. Tall fescue variety/novel endophyte evaluation

Visual observation over the years indicated substantial stands of all entries of tall fescue persisting across most of the planted area. By the summer of 2017, a visually distinct demarcation of the boundary of the two soil types was apparent with all varieties persisting on the Moreland silty clay loam, except in some nondrained depressional areas, and very little of any variety persisting on the Latanier clay. Thus, both lack of drainage in depressional areas and the water-logging prone Latanier clay appear to provide unacceptable sites for tall fescue. This clay soil limitation may have been a key aspect of lack of survival by Jesup Max Q in the earlier evaluation of grazing and nitrogen fertilization treatments at this location.

Herbage mass available for grazing in January 2018 ranged from 1485 kg/ha for Tower to 1970 kg/ha for DuraMax; however, substantial variability among replications resulted in no significant difference among varieties (**Table 4**). It is noteworthy that the variety producing the numerically highest yield, DuraMax Gold, was developed from the winter-productive cultivar AU Triumph [31]. AU Triumph produced twice as much forage during the winter growth period on the Alabama gulf coast as did Kentucky 31 in early trials [32]. Thus, the

Tall fescue variety	Endophyte	Forage mass		Stand rating*	
		Jan. 31, 2018		Mar. 13, 2018	
		kg/ha			
DuraMax Gold	Armor®™	1970	a**	7.7	a
Estancia	ArkShield®™	1510	a	6.7	ab
Kentucky 31	Naturally occurring	1635	a	7.5	a
Martin 2	Protek®™	1593	a	7.0	a
Texoma	MaxQ II®™	1593	a	8.0	a
Tower	Protek®™	1485	a	5.5	b

*Stand ratings were on a scale of 0 for no tall fescue to 9 for a complete, dense stand.
**Means within a column followed by a common letter do not differ significantly ($P < 0.05$).

Table 4. Forage mass and stand ratings of novel endophyte tall fescue varieties in early 2018 from a 2013 planting on bottomland soil in northwest Louisiana.

indication of potentially superior cool-season productivity for DuraMax requires further evaluation. As with herbage mass, Tower provided the lowest stand rating (5.5) on March 13, 1018 (**Table 4**). Four entries, DuraMax Gold, Kentucky 31, Martin 2, and Texoma, were similar in stand rating averaging 7.5. Estancia was intermediate with a stand rating of 6.7. The numerically highest stand rating for Texoma is also consistent with selection of this cultivar for persistence in a marginal environment for the species [33] with further evaluation of this planting expected to provide further detection of differences in persistence among varieties.

Fiber components and CP were similar among varieties from the January 2018 herbage samples (**Table 5**) indicating that forage quality is generally similar for these varieties. Increased Mg levels in herbage has been suggested as a possible means to reduce grass tetany potential, and HiMag Tall Fescue Germplasm was developed as a cool-season pasture option to reduce

Variety*	Endophyte	CP	ADF	NDF	Mg
		%			
DuraMax Gold	Armor®™	12.9	33.41	60.84	0.29
Estancia	ArkShield®™	13.1	33.52	59.79	0.34
KY31	Endemic	12.8	34.02	60.11	0.30
Martin2	Protek®™	13.8	32.10	57.60	0.32
Texoma	MaxQ II®™	12.7	34.44	60.38	0.32
Tower	Protek®™	13.5	32.58	57.79	0.32

*No significant differences ($P > 0.05$) in forage quality parameters were detected among varieties.

Table 5. Forage quality parameters of tall fescue varieties with novel endophytes from a winter harvest at the northwest Louisiana location.

grass tetany hazard [34]. Estancia was developed from the HiMag germplasm [31], and was highest in Mg ranking among the varieties. Despite lack of statistically significant differences among varieties in Mg levels from our single harvest of growth, the limited results justify further evaluation.

4. Implications for use of tall fescue in a warm-temperate environment

While existing areas of tall fescue with potential to produce toxic alkaloid compounds provide distinct limitations for livestock production, management approaches for effective use of such pastures are available. Aiken and Strickland [22] provided several strategies to minimize adverse effects of such pastures. These include use of heavy grazing intensities, chemical suppression of seed head emergence, use of these pastures in seasons other than late spring and summer, and dilution of dietary alkaloids by interseeding clovers or feeding supplements. Variations of these strategies are perhaps the reason that adverse effects on grazing livestock from the few remaining Kentucky 31 pastures across northern Louisiana are only rarely observed. Thus, with appropriate management, existing pastures of Kentucky 31 tall fescue in the region can be productive components of pasture systems, even though improved options appear to be available for new plantings of perennial cool-season pasture on selected sites.

Endophyte-free tall fescue varieties have proven to be insufficiently adapted for planting as perennial pasture plants even on the better sites in Louisiana. Among the varieties with toxin-producing-endophytes, better adapted varieties than Kentucky 31 have been developed, but planting of these varieties has been very limited. In contrast to the recommendations for the primary tall fescue growing area not to graze tall fescue pastures during summer to reduce effects of the toxin-producing endophyte [22], in northern Louisiana, light stocking is beneficial because tall fescue growth is minimal and stocking rate can be managed to reduce competition from preferentially grazed warm-season grasses. The novel, nontoxin-producing endophytes appear to provide improved options for development of tall fescue varieties adapted to northern Louisiana.

Current information indicates that several varieties of tall fescue with different novel endophytes may provide useful options, at least on selected sites. Whether any of these varieties may be as persistent over periods of decades as Kentucky 31 has been on the most favorable sites has not been determined. Both drought-prone sandy uplands and seasonally waterlogged clay bottomlands do not appear to be suitable sites for tall fescue in this region. Loss of stands in clipping evaluations of several early varieties including Kentucky 31 on upland soils and subsequent survival of Kentucky 31 from plantings in nearby pastures indicate that both site and extent of defoliation may be important determinants of stand survival. With plantings planned for only a few years of productive life, such as may be appropriate for cropping systems including a soil health building phase, selection among appropriate varieties for yield potential would be useful. For long-term pasture plantings with no planned termination date, selection for persistence may be more beneficial than short-term differences in productivity among the generally productive varieties. Developing forage systems with perennial grass pastures available for grazing in both the warm season and cool season in this region appear to be realistic goals with selection of appropriate sites and the best adapted tall fescue variety. Several of the recently available novel-endophyte varieties provide promise but require additional evaluation.

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