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RESEARCH

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Emergency seeding of cool-season annuals into perennial grass after fall drought

Yedan V. Xiong[1] | **Renata L. G. Nave**[2] | **Andrew P. Griffith**[3] | **Marcia P. Quinby**[2] | **Gary E. Bates**[2] | **Michael D. Corbin**[2]

[1] Extension Kane County, Utah State Univ., Kanab, UT 84741, USA

[2] Dep. of Plant Sciences, Univ. of Tennessee, Knoxville, TN 37996, USA

[3] Dep. of Agricultural and Resource Economics, Univ. of Tennessee, Knoxville, TN 37996, USA

Correspondence

R. L. G. Nave, Dep. of Plant Sciences, Univ. of Tennessee, Knoxville, TN 37996, USA.
Email: rnave@utk.edu

Abstract

Spring establishment of cool-season annual grasses into poorly producing orchardgrass (*Dactylis glomerata* L) (OG) swards may improve forage production and nutritive value in the southeastern United States following a fall drought. A randomized complete block experiment was conducted where annual ryegrass (*Lolium multiflorum* Lam.) (AR) or forage oat (*Avena sativa L.*) (FO) was interseeded into an existing OG stand over three seeding dates with (+) or without (–) a burndown herbicide (BD) treatment and compared with an OG monoculture (control). In 2017, after a warm and wet winter, the OG monoculture (control) was able to produce sufficient forage mass (FM) without significant reduction in nutritive value as compared with OG interseeded with AR or FO. In 2018, OG had approximately 2,600 lb acre^{-1} less FM than in 2017, suggesting that recurrent fall drought with unfavorable winter conditions resulted in long-term damage to the perennial sward. Meanwhile, treatments without BD did not show higher FM in the beginning of the season. Burndown treatment in general increased FM and nutritive value. An economic analysis of the study also revealed results suggesting that interseeding AR and FO in the spring is not economically viable, as it may cost up to 10 times as much as the control.

1 | INTRODUCTION

Drought can be defined as a "prolonged weather pattern when precipitation is <75% of the long-term average" (Bedell, 1989). Thus, drought periods during fall can result in reduced forage yield in perennial pastures, especially in the subsequent winter and spring (Sosebee et al., 2012). Recent drought conditions in the southeastern United States have forced producers to seek alternative options and management plans to overcome reduced productivity by improving the stability and resiliency of their forage production systems (Gates et al., 2003).

Livestock producers rely on hay feeding and supplementation during the winter; however, this is usually not the most economic option. Overseeding cool-season annual grasses into existing pastures can provide a more economically viable alternative for livestock feeding while increasing forage availability and nutritive value during winter and spring.

Most forage production systems in the Mid-South are composed of cool-season perennial grass pastures, and livestock production systems in the region are highly dependent on the productivity of these grasses (Gates et al., 2003). Annual cool-season grasses can provide additional forage resources during times when perennial pastures are semi-dormant, such as early

Abbreviations: AR, annual ryegrass; BD, burndown herbicide; CP, crude protein; FM, forage mass; FO, forage oat; ID, interseeding date; MTREC, Middle Tennessee AgResearch and Education Center; NDF, neutral detergent fiber; OG, orchardgrass.

TABLE A Useful conversions

To convert Column 1 to Column 2, multiply by	Column 1 suggested unit	Column 2 SI unit
0.304	foot, ft	meter, m
2.54	inch	centimeter, cm (10^{-2} m)
0.405	acre	hectare, ha
0.405×10^3	acre	square meter, sq m
454	pound, lb	gram, g

Core Ideas

- Poor orchardgrass stand productivity can be improved by interseeding cool-season annual grasses.
- Cool-season annual grasses treated with burndown improved forage productivity during spring.
- Spring seeding of cool-season annual grasses into orchardgrass may not be economically viable.

spring and late fall (Ball et al., 2015; Kennelly et al., 2003). However, there is limited information evaluating the potential to establish cool-season annual grasses into weakened swards of cool-season perennial grasses that were compromised by adverse environmental conditions, such as drought.

Most cool-season annual grasses have the potential to produce high yields with nutritive value suitable to sustain dry and lactating cows throughout their growing season (Bagley et al., 1988). Annual ryegrass (AR) has excellent cold tolerance, a long growing season, and produces high quality forage primarily during the spring (Beck et al., 2007). Although it does not provide as high a forage mass (FM) as other cool-season annual grasses (West et al., 1988), AR's extensive growing period normally peaks in May and ends in June (Kennelly et al., 2003). Forage oat (FO) is also cold tolerant and grows rapidly, producing palatable livestock forage from fall through spring (Ball et al., 2015; Marten et al., 1975).

Evaluating complementary forage crops that can be established into perennial grass swards can increase overall FM and quickly improve nutritive value during periods of shortages. Therefore, the objective of this study was to determine which combinations of planting date, species, and burndown treatment resulted in greatest FM and quality of orchardgrass (OG) stands interseeded with either AR or FO following a fall drought.

2 | SITE DESCRIPTION

This study was conducted at the Middle Tennessee AgResearch and Education Center (MTREC) in Spring Hill, TN (35.68° N, 86.91° W, 810 ft elevation). A 2-yr field experiment was conducted from February to June of 2017 and 2018. The soil at the location was a Maury silt loam (fine, mixed, active, mesic Typic Paleudalf) (NRCS, 2018). Initial pH was 6.0, and Melich 3-extractable minerals were P = 222 lb acre^{-1}, K = 124 lb acre^{-1}, Ca = 2086 lb acre^{-1}, and Mg = 148 lb acre^{-1}. Weather was monitored on site at the MTREC weather station.

The OG (cultivar unknown) sward used for this study was planted (10 lb seed acre^{-1}) in September 2015. Hay was harvested in October 2016. No fertilizer was applied between the hay harvest and experiment initiation in early 2017. Post-haying visual observations indicated that sward conditions were declining as a result of reduced groundcover with moderate grass and broadleaf weed competition.

The experimental design was a randomized complete block. Treatments included all combinations of two annual species (AR or FO) interseeded into OG, three interseeding dates (IDs), and two burndown herbicide (BD) levels [presence (+) or absence (–)], plus an untreated control of OG only. Three replications of these 13 treatments resulted in 39 experimental units.

Burndown herbicide [Gramoxone (1,1′-Dimethyl-4,4′-bipyridinium dichloride; Syngenta)] when present, was applied at each ID at a rate of 32 oz acre^{-1} with a 1% non-ionic surfactant to plots measuring 5 by 20 ft. Annual ryegrass (cultivar Wax Marshall) and FO (cultivar Jerry) were interseeded at 30 and 150 lb acre^{-1}, respectively, using a Hege 1000 no-till plot drill (Hege Company) to depths of 0.5 and 1.5 inches, respectively. In 2017, interseeding occurred on 17 February, 9 March, and 24 March. Forage was sampled and FM was determined on 4 April and 11 May. In 2018, plots were rerandomized and interseeding occurred on 21 February, 4 March, and 15 March, respectively. Sampling for determination of FM occurred on 15 May and 11 June. Sampling occurred at two consecutive dates to determine yield and nutritive value changes across the season. Plots remained unharvested up until completion of the growing season each year, where all plots were then terminated by mowing.

2.1 | Measurements

Total aboveground FM was measured in each plot by randomly placing two 1-ft^2 quadrats. Samples were hand-clipped above a 3-inch stubble height and dried to constant weight at 140 °F. After determination of dry matter (DM) FM, samples were ground through a 0.04-inch (1-mm) screen in a Wiley mill (Thomas-Wiley Laboratory Mill Model 4, Arthur H. Thomas Co.) prior to determination of forage nutritive value. Crude protein (CP) and neutral detergent fiber (NDF) were predicted by means of near infrared spectroscopy (FOSS 5000, FOSS NIRSystems) using Win ISI II supplied by Infrasoft International. Equations for the CP and NDF were standardized and checked for accuracy with the 2019 Mixed Hay Equation developed by the NIRS Forage and Feed Consortium (NIRSC). The Global H statistical test compared the samples against the model and samples from distinct data sets within the database for accuracy, in which all forage samples fit the equation (H < 3.0) and are reported accordingly (Murray et al., 2004).

2.2 | Production cost

A partial budget was constructed for each treatment combination to compare cost differences on a FM and CP basis. Input prices (i.e., chemical, fertilizer, machine use, and custom applications) were obtained from local agricultural equipment dealers at the time of the study. Forage mass cost (US$ ton^{-1}) was calculated by dividing the per acre production cost by total FM summed across all harvests. Similarly, CP cost ($ lb^{-1} CP) was calculated by dividing the production cost per acre by the total pounds of CP per acre.

2.3 | Statistical analyses

Data were collected for two consecutive years, 2017 and 2018. For the purpose of statistical inference, years and sampling dates were analyzed individually. Forage mass, CP, and NDF were analyzed using a mixed model analysis of variance (PROC GLIMMIX, SAS 9.4) to test the fixed effects of interseeding dates, forage species, and BD treatment (presence or absence) and their three-way interactions with the random effect of block (replications). When interactions were found, the main effects were separated and their two-way interactions based on the interseeding date, forage species, and BD treatment. Given that the control was the untreated existing monoculture with no interseeding dates, the analysis with the control had fixed effects of forage species and BD, and their two-way interactions with random effects of block. Least-square means adjustments were performed using Tukey's HSD to control for Type 1 error. Level of significance was determined at $\alpha = .05$.

Cost data were analyzed using PROC MIXED in SAS 9.4 adjusted for Tukey's method for least square means separation with year and replication being random parameters.

3 | RESULTS AND DISCUSSION

3.1 | Weather

In 2016, there was a severe fall drought in Spring Hill, TN, as well over much of the southeastern United States (Figure 1). Cumulative precipitation from early September to late November totaled 2.4 inches, which was 4.8 inches below the 30-yr average for the same period. Drought was accompanied by greater than average monthly temperatures (Figure 1). The total fall precipitation was inadequate to recharge the soil profile or to support fall regrowth of OG, given that adequate moisture is crucial for driving critical carbohydrate accumulation and storage (Sepaskhah et al., 1979). Precipitation in winter (January–March), spring (April–June), and summer (July–September) of 2017 was generally greater than the 30-yr average.

A slight drought, coupled with greater-than-average temperatures, occurred in November 2017 (Figure 1), resulting in another period of water deficit. However, in contrast to the 2016 fall, October and November of 2017 did provide good conditions for fall regrowth. Abundant precipitation in December was followed by a 40-d drought period with lower-than-average temperatures (Figure 1).

3.2 | Forage mass

In April 2017, BD– treatments averaged across all ID treatments for both AR and FO showed greater FM than BD+ treatments (Table 1, P = .001). However, if interseeding occurred in February (ID1) there were no differences in FM between BD+ and BD– treatments. The control treatment had greater FM as compared with the AR and FO treatments for the March (ID2) BD+ (Table 1, P = .005). There were no differences in FM among species (AR, FO, and control) for treatments BD– across all IDs. These results suggest that in the early stages of vegetative growth, BD treatment eliminated a substantial amount of aboveground FM which was likely composed of mostly weeds (data not collected). In May 2017, FM generally did not differ between IDs and BD treatments, with the exception of ID3 BD+, where AR had less FM than FO and the control (Table 1, P = .03).

The experimental site received more than adequate precipitation during spring (Figure 1), generating more than 45 days of growth. These results also suggest that drought effects from the previous fall were minimized with similar FM production for the control and all BD– treatments. The warm and moist winter in 2017 (Figure 1) replenished soil moisture and allowed OG to produce sufficient forage even after

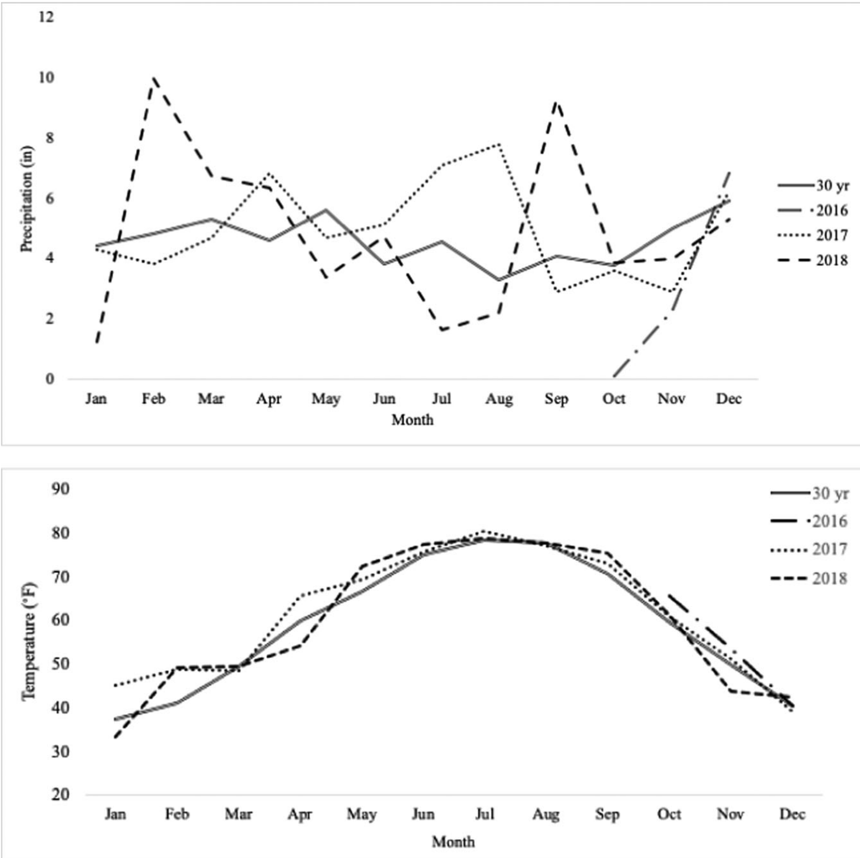

FIGURE 1 Average precipitation and temperature from October 2016 to May 2018 in Spring Hill, TN

TABLE 1 Forage mass of an orchardgrass sward interseeded with cool-season annual forages in 2017 in Tennessee

		Forage mass					
		April			May		
ID	Species	BD+	BD–	$\bar{x}$ ID	BD+	BD–	$\bar{x}$ ID
		lb acre^{-1}					
1	FO	1,067	703	NS	4,473	2,737	NS
	AR	853	867		2,983	3,270	
	Control	1,050	1,050		3,833	3,833	
2	FO	320B	873	NS	3,543	3,720	NS
	AR	240B	1,090		2,653	3,263	
	Control	1,050A	1,050		3,833	3,833	
3	FO	197	777	NS	2,930A	2,753	NS
	AR	NA	917		1,240B	3,083	
	Control	1,050	1,050		3,833A	3,833	
ID × BD	1	960a	785a		–	–	
	2	280b	981a		–	–	
	3	103b	823a		–	–	
Species	FO	–	–		–	–	
	AR	–	–		–	–	
BD		448b	866a				

Note. AR, annual ryegrass; BD, burndown treatment; BD+, presence of burndown treatment; BD–, absence of burndown treatment; FO, forage oat; ID, interseeding date; NA, not applicable; NS, not significant. Uppercase letter differs within column, lower case letters differ within rows based on Tukey's test ($\alpha \leq .05$). When interaction is detected, letter comparisons are among all variables from the interaction.

TABLE 2 Forage mass of an orchardgrass sward interseeded with cool-season annual forages in 2018 in Tennessee

		Forage mass					
		May			June		
ID	Species	BD+	BD–	x̄ ID	BD+	BD–	x̄ ID
		lb acre^{-1}					
1	FO	810	803	NS	3,197	2,437	NS
	AR	680	513		2,007	1,683	
	Control	1,275	1,275		1,216	1,216	
2	FO	763B	777	NS	3,730	2,040	NS
	AR	520B	840		3,060	1,857	
	Control	1,275A	1,275		1,216	1,216	
3	FO	450B	780B	NS	3,087	2,357	NS
	AR	206B	820B		2,537	1,627	
	Control	1,275A	1,275A		1,216	1,216	–
ID × BD	1	745a	658a		–	–	–
	2	641a	808a		–	–	–
	3	328b	800a		–	–	–
Species	FO	–	–		2808A	–	
	AR	–	–		2128B	–	
BD		–	–		2936a	2000b	

Note. AR, annual ryegrass; BD, burndown treatment; BD+, presence of burndown treatment; BD–, absence of burndown treatment; FO, forage oat; ID, interseeding date; NS, not significant. Uppercase letter differs within column, lower case letters differ within rows based on Tukey's test ($\alpha \leq .05$). When interaction is detected, letter comparisons are among all variables from the interaction.

undergoing a fall drought. During winter, cool-season grasses generally have a low evapotranspiration demand due to colder air temperatures and winter dormancy. Precipitation during this period is generally sufficient to sustain OG sward maintenance. Recent studies have shown that OG can produce sufficient forage after drought periods while productivity of other species such as timothy (*Phleum pratense* L.) may be greatly impacted following drought (Frank et al., 2015; Sanada et al., 2010). In addition, BD+ may slow down germination and establishment of FO and AR shortly after seeding, but in most instances productivity can be restored subsequently.

An interaction between ID and BD (P = .02) occurred in May 2018. When averaged across forage treatments, ID3 BD+ treatments had lowest FM. When averaged across BD treatments, no differences in FM were observed between forage treatments for ID1. For ID2 and ID3 with BD+, the control treatment showed greater FM than both FO and AR (P = .003 and P = .009, respectively). The only difference in FM in BD– treatments occurred where the control had greater FM than both FO and AR at ID3 (P = .04). In June 2018 (Table 2), there were no differences among annual species and the control treatment at neither IDs nor BD treatments. However, there were detected species differences between FO and AR, with FO showing greater FM than AR overall (P = .006). Meanwhile, there were also differences between overall BD treatments, with BD+ showing greater FM than BD– (P = .0003, Table 2). Given that the last sampling occurred in June, all species had the same opportunity to establish (in the case of annual grasses), grow and reach maturity, which can explain the lack of differences among ID, and among annual species and the control treatment.

In 2018, the first forage sampling occurred approximately 2 mo after the last planting due to a slow establishment and growth of the annual species. In addition, the existing OG sward received sufficient precipitation in the fall 2017 that preceded the 2018 growing season, as well as early spring of 2018, which likely benefited OG productivity as compared with the newly established annual grass swards.

3.3 | Nutritive value

In April 2017 (Table 3), there were CP differences between BD treatments, where swards BD+ showed higher CP content than BD– (P = .002). This is likely due to less weed competition that can consequently reduce CP content of the sward. When comparing ID among annual species, ID2 showed greater CP content than ID1, while ID3 did not differ from either (P = .002). Meanwhile when comparisons are made with the control treatment, the CP content was higher for the control treatment than AR interseeded in February for BD– (P = .04, Table 3). Although some differences in

TABLE 3 Forage nutritive value (crude protein [CP] and neutral detergent fiber [NDF]) of an orchardgrass sward interseeded with cool-season annual forages in 2017 in Tennessee

		CP						NDF					
		April			May			April			May		
ID	Species	BD+	BD–	x̄ ID	BD+	BD–	x̄ ID	BD+	BD–	x̄ ID	BD+	BD–	x̄ ID
		%						%					
1	FO	18.4	19.9AB	19.3B	9	9.1	NS	44.7	46.4	NS	63	59.7 B	NS
	AR	20.2	17.3B		10.5	11		41.1	41.2		57.2	60.8 B	
	Control	20.3	20.3A		10.4	10.4		44.9	44.9		66.3	66.3A	
2	FO	25.7	19.2	22.2A	10.5	10.4	NS	39.7	44.8	NS	54.8B	63.1B	NS
	AR	23.8	20.3		13.5	9.7		43.4	46.8		52.6B	66.6A	
	Control	20.3	20.3		10.4	10.4		44.9	44.9		66.3A	66.3A	
3	FO	21.2	20	20.2AB	12.4A	10.2	NS	44.6	44.9	NS	50.1B	63.2	NS
	AR	NA	19.5		13.4A	10.4		–	45.1		42.4C	65.6	
	Control	20.3	20.3		10.4B	10.4		44.9	44.9		66.3A	66.3	
ID × BD	1	–	–		9.8b	10.1b		–	–		59.9a	60.1a	
	2	–	–		12.1a	10.1b		–	–		53.6b	64.7a	
	3	–	–		12.9a	10.3b		–	–		46.1c	64.3a	
Species	FO	–	–		10.3B	–		–	–		–	–	
	AR	–	–		11.4A	–		–	–		–	–	
BD		22a	19b		–	–		–	–		–	–	

Note. AR, annual ryegrass; BD, burndown treatment; BD+, presence of burndown treatment; BD–, absence of burndown treatment; FO, forage oat; ID, interseeding date; NA, not applicable; NS, not significant. Uppercase letter differs within column, lower case letters differ within rows based on Tukey's test ($\alpha \leq .05$). When interaction is detected, letter comparisons are among all variables from the interaction.

CP were observed, nutritive value of all treatments would have exceeded nutrient requirements of all classes of livestock (NRC, 2016), which is to be expected of vegetative growth. There were no differences in neutral detergent fiber (NDF) among treatment levels nor interactions in April 2017 (Table 3).

In May 2017, there was an observed main effect of species with FO showing lower CP content than AR (P = .01, Table 3). These results suggest that FO reduced nutritive value due to a shift from vegetative to reproductive stage reflected in advanced maturity. Additionally, there was an interaction between ID x BD in CP content, with the highest CP observed in BD+ of ID2 and ID3 (P = .02, Table 3). When comparisons were made with the control treatment, annual species interseeded in late March (ID3) BD+ showed greater CP content than the control treatment (P = .03). These plants were established later with low weed competition and still had immature vegetative material as compared with other IDs (Table 3).

An interaction between ID x BD was also observed for NDF averaged across species in May 2017 (P < .0001), with the lowest NDF concentration shown on ID3 BD+ (Table 3). Meanwhile, when compared with the control treatment, both AR and FO on ID1 BD– (P = .04) and FO on ID2 BD– showed lower NDF than the control (P = .02). For BD+ interseeded in March, the control showed greater NDF concentration as compared with the annual species (ID2 and ID3, P = .0009 and .0004, respectively) (Table 3).

Overall, CP of all treatments decreased from April to May 2017, while NDF increased. This is expected due to advanced maturity in the swards. At the end of the growing season, annual grasses show an increase in stem lignification and decrease in the leaf/stem ratio, which are correlated with the decrease in overall nutritive value.

In May 2018, there was an interaction between ID x BD (P = .01) with the greatest CP observed in ID3 BD+ averaged across species (Table 4). When compared with the control treatment, differences in CP content were observed for annual species interseeded in March with BD+ (ID2 and ID3, P = .02 and .001, respectively), where the control treatment consistently showed lower CP. No differences were observed among control treatments and annual grasses BD–. Meanwhile, NDF concentration showed a main effect of species (P = .002) with FO showing greater NDF than AR. There was also a main effect of BD (P = .001), with BD– showing greater NDF than BD+ (Table 4). When comparisons are made with the control treatment, annual grasses treated with BD+ consistently show lower NDF concentration than the control treatment in all ID1 (P = .01), ID2 (P = .008) and ID3 (P = .004) (Table 4).

In June 2018, no differences were observed in CP or NDF between FO and AR in both BD+ and BD– when averaged across ID treatments (Table 4). When compared with the control, annual species on ID2 BD+ showed lower CP than the control (P = .02); however, no differences were observed for NDF content at any level of comparison (Table 4). As AR and FO matured between the first and second sampling date, there was likely increased proportion of stems and lignification, resulting in reduced forage nutritive value. Overall, the nutritive value of perennial grasses such as OG and its response to water deficit differ from cool-season annual forages (Frank et al., 2015). Annual grasses are likely to advance maturity at a higher pace during drought, especially at the end of its growing season; whereas perennial grasses are in general less susceptible to changes in maturity under the same circumstances.

3.4 | Changes in forage mass and nutritive value

All treatments showed significant increases in FM from April to May of 2017 (Table 1), which supports the conclusion that sufficient winter precipitation can promote FM production despite a previous fall drought. Meanwhile, the CP content of all treatments decreased, and the NDF of all treatments increased (Table 3), reflecting the overall reduction in nutritive value. These results are expected given that a decline in forage quality comes from advancing maturity (Balde et al., 1993).

In 2018 (Table 2), the FM of AR and FO increased from May to June, while the control treatment did not show changes in FM over the course of the season. Meanwhile, inconsistent changes in CP occurred from May to June for all treatments, where most of the time CP content remained the same. However, there was a significant increase in NDF for all treatments from May to June 2018.

The control treatment produced one-third less FM in the first data collection month of 2018 as compared with 2017 and did not show a significant increase in the following month, as was seen in 2017. This was likely due to drier and cooler conditions of the previous winter. In addition, critical conditions at the first 2 mo of fall (October and November) during two consecutive years (2016 and 2017) has the potential to restrict carbohydrate replenishment, damage the root system, and ultimately weaken the sward conditions.

3.5 | Cost analysis

The control treatment had the lowest expected cost based on FM and CP ($5.35–$5.90 ton^{-1} and $0.02–0.03 lb^{-1} CP, Table 5). Though the control was not found to have a significant lower cost than all other treatments on a FM and CP basis, results would suggest interseeding AR and FO in the spring is cost prohibitive in this study, as it may cost up to 10x as much as the control.

TABLE 4 Forage nutritive value (crude protein [CP] and neutral detergent fiber [NDF]) of an orchardgrass sward interseeded with cool-season annual forages in 2018 in Tennessee

		CP						NDF					
		May			June			May			June		
ID	Species	BD+	BD–	x̄ ID	BD+	BD–	x̄ ID	BD+	BD–	x̄ ID	BD+	BD–	x̄ ID
		%						%					
1	FO	12.2	11.6	NS	8.1	10.6		40.3B	48.6		67.8	65.7	
	AR	9.4	12.4		10.1	9.5	NS	32.5C	39.9	NS	63.5	65.4	NS
	Control	10.5	10.5		12.1	12.1	–	53.9A	53.9		62.3	62.3	–
2	FO	13.5A	12	NS	8.4B	10.2		36.3B	48.9		67.2	65.7	
	AR	13.7A	12.5		7.9B	9.8	NS	32.9B	48.4	NS	67.3	62.2	NS
	Control	10.5B	10.5		12.1A	12.1	–	53.9A	53.9		62.3	62.3	–
3	FO	15.2B	12.9	NS	10.2	10.6		39.3B	49		67.1	63.8	
	AR	18.1A	11.7		11.1	10.8	NS	35.9B	47.3	NS	60.1	64.6	NS
	Control	10.5C	10.5		12.1	12.1	–	53.9A	53.9		62.3	62.3	
ID × BD	1	10.8c	11.9bc		–	–	–	–	–		–	–	
	2	13.6b	12.3bc		–	–	–	–	–		–	–	
	3	16.6a	12.3bc		–	–	–	–	–		–	–	
Species	FO	–	–		–	–	–	44.2A	–		–	–	
	AR	–	–		–	–	–	39.5B	–		–	–	
BD		–	–		–	–		36.7b	47.0a		–	–	

Note. AR, annual ryegrass; BD, burndown treatment; BD+, presence of burndown treatment; BD–, absence of burndown treatment; FO, forage oat; ID, interseeding date; NS, not significant. Uppercase letter differs within column, lower case letters differ within rows based on Tukey's test ($\alpha \leq .05$). When interaction is detected, letter comparisons are among all variables from the interaction.

TABLE 5 Cost of interseeding annual ryegrass and forage oat into an orchardgrass sward based on forage mass and crude protein

Treatment	Forage mass cost 2017	Forage mass cost 2018	Crude protein cost 2017	Crude protein cost 2018
	US$ ton^{-1}		$ lb^{-1}	
Control[a]	5.90b	5.35b	0.02b	0.03b
AR – ID1 BD+	38.38b	50.75ab	0.15b	0.26a
AR – ID1 BD–	23.88b	45.37ab	0.10b	0.23ab
AR – ID2 BD+	47.69b	41.74ab	0.17ab	0.25ab
AR – ID2 BD–	23.46b	36.80ab	0.09b	0.18ab
AR – ID3 BD+	142.56a	64.54a	0.56a	0.27a
AR – ID3 BD–	27.14b	41.22ab	0.11b	0.19ab
FO – ID1 BD+	39.98b	57.87a	0.19ab	0.32a
FO – ID1 BD–	54.60b	63.04a	0.30ab	0.29a
FO – ID2 BD+	60.46ab	50.16ab	0.25ab	0.27a
FO – ID2 BD–	42.74b	73.77a	0.17ab	0.35a
FO – ID3 BD+	70.50ab	64.79a	0.28ab	0.30a
FO – ID3 BD–	57.99ab	62.52a	0.23ab	0.29a

Note. AR, annual ryegrass; BD+, presence of burndown treatment; BD–, absence of burndown treatment; FO, forage oat; ID1, first interseeding date; ID2, second interseeding date; ID3, third interseeding date.

[a]Control with untreated existent orchardgrass sward.

3.6 | Implications

Where adapted in the southeastern United States, OG is very competitive because of its favorable FM and nutritive value (Burner, 2003; Clark, 2009; Jones & Tracy, 2018; Sanada et al, 2010; Smith & Saylor, 2012). In this study, warm and wet winter immediately after the 2016 fall drought probably mitigated the drought effects by maintaining adequate FM in the 2017 growing season. Orchardgrass under these conditions is capable of producing leaves at its standard rate with rapid response to water (Saeidnia et al, 2016), therefore it does not necessarily require planting of an emergency crop to overcome drought when only considering the FM production. However, the subsequent rapid intermittent fall drought, along with a cold and dry winter as observed in January 2018 could have intensified the effects of the previous drought on perennial pastures, which can be devastating for cool-season grasses when trying to recover from dormancy (Frank et al., 2015). On top of the unfavorable weather condition, the low-height defoliations (3 inches) of OG sward in the previous season could also negatively impact ground coverage and productivity due to the poor persistence of OG (Saeidnia et al, 2016). The decline of ground cover of OG pasture due to drought and low cutting height has been widely observed and addressed (Clark, 2009; Smith & Saylor, 2012). A study on persistence and productivity of OG conducted in Virginia (Jones & Tracy, 2018) concluded that harvest at a 2-inch height showed significant ground coverage decline, while harvest height at 4 inches or above did not. If frequent drought periods continue to occur in the Southeast, especially during fall and winter, along with the poor persistence of OG, there would be an increased demand for a fast-growing and reliable emergency forage crop to be established. If the goal for the emergency crop is increased FM, FO with BD+ was shown to be more productive then AR with BD+. In support of these results, Maloney et al. (1999) also observed higher FM of FO as compared with AR in the spring.

4 | CONCLUSIONS

The effects of drought can eventually shorten the life of OG by thinning the sward, which can result in greater weed invasion. A warm and wet winter can mitigate the effects of a previous fall drought, resulting in little need for emergency forage crop. If spring seeding annuals is desired, both AR and FO can be established anytime from mid-February to late March and should be accompanied by a BD+ to increase FM and nutritive value. Depending on the demand and purpose for the pasture, FO has the potential to increase FM later in the season, with a reduction in CP content and increased NDF as the plant matures. Alternatively, AR treated with BD+ maintained high nutritive value. However, results from this study indicate that emergency seeding of annual forages into OG swards is not economical.

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AUTHOR CONTRIBUTIONS

Yedan Xiong: Data curation; Formal analysis; Validation, Writing-original draft; Writing-review &; editing. Renata Nave: Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Project administration; Resources; Supervision; Validation; Visualization; Writing-original draft; Writing-review & editing. Andrew Griffith: Formal analysis; Validation; Writing-original draft; Writing-review & editing. Marcia Quinby: Data curation; Formal analysis; Writing-review & editing. Gary Bates: Conceptualization; Funding acquisition; Methodology; Resources; Visualization. Michael Corbin: Conceptualization; Investigation; Methodology; Visualization.

CONFLICT OF INTEREST

The authors report no conflict of interest.

ORCID

Yedan V. Xiong https://orcid.org/0000-0002-4028-8905
Renata L. G. Nave https://orcid.org/0000-0002-6872-8079

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