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# Forage mass, nutritive value, and economic viability of cowpea overseeded in tall fescue and sorghum-sudangrass swards

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**Abstract**

Cowpea (*Vigna unguiculata* L. Walp) (CW) is being considered as an alternative feed source in the southern U.S. Legume–grass mixtures are known to provide greater forage mass compared with unfertilized grass monocultures; however, research is needed to evaluate alternatives for increasing forage availability during the summer. The objective of this study was to quantify forage mass, nutritive value, and economic viability of CW overseeded in tall fescue [*Schedonorus arundinaceus* (Schreb.) Dumort.] (TF) and sorghum × sudangrass hybrid [*Sorghum bicolor* (L.) Moench × *Sorghum sudanese* (P.) Stapf] (SS) swards seeded at different rates. Two experiments were established in Spring Hill, TN, one with TF and the other with SS, from June to September of 2016 and 2017. Inoculated CW seeds were drilled into TF and SS plots at 25, 50, or 75 lb acre$^{-1}$ and compared with control treatments that were without CW. There were no differences in total and average forage mass of TF or SS with the addition of CW, regardless of the seeding rate, likely due to the competitiveness of the grasses. No differences among seed rates were observed in the concentration of crude protein (CP) for TF swards mixed with CW in either year while in vitro dry matter digestibility (IVDMD) was less for the control treatment in 2017. Meanwhile, the nutritive value of the SS and CW mixture was improved as the CW seeding rate increased in both years. Data from this study suggest that the addition of CW to TF or SS does not justify its cost given the minimal benefit provided.

## 1 | INTRODUCTION

Cow-calf operations in the southeastern U.S. depend on forage production through the use of cool-season grasses, mostly TF. However, the total forage mass of these cool-season forage grasses, including TF, is limited during the summer months.

Annual warm-season grasses, such as SS, are useful for summer forage production, due to their ability to quickly accumulate forage mass. Therefore, integrating these annual species into forage systems can be especially beneficial to producers in the southeastern USA and regions with similar climate features (Gelley, Nave, & Bates, 2016).

Legume–grass mixtures are known to provide a more consistent forage mass across a wide range of environments compared with unfertilized grass monocultures (Sleugh, Moore, George, & Brummer, 2000). Legumes also have greater forage nutritive value, generally having greater digestibility and crude protein concentration than grasses. In addition, legumes can fix atmospheric nitrogen (N), reducing the need for N fertilization (Bélanger et al., 2015).

Cowpea is a high-protein forage legume that is adapted to hot, dry weather (Summerfield, Huxley, & Steele, 1974). It has historically been used as a cover crop for soil conservation and soil fertility improvement or planted for wildlife feed or

**Abbreviations:** CP, crude protein; CW, cowpea; DM, dry matter; IVDMD, in vitro dry matter digestibility; SS, sorghum-sudangrass; TF, tall fescue.

habitat (Muir, 2002). Most recently, CW has been evaluated as an alternative feed source, especially in the southern U.S. where most of the CW is grown. However, data on the use of CW as a forage source are limited in this region.

Research is needed to evaluate alternative forage crops to potentially increase overall mass and nutritive value of forages during summer months and thus extend the grazing season for beef production. Corbin, Nave, Bates, Butler, & Hawkins, 2018, studying alternatives to conventional N fertilization, showed that mixtures of TF and 50 lb acre$^{-1}$ of CW resulted in the greatest forage mass. The same study also reported greater CP concentration in early summer compared with mixtures of TF and other forage legumes. They suggested future studies should consider different seeding rates for planting CW into mixtures with grasses. Therefore, the objective of this study was to quantify forage mass, nutritive value, and economic viability of TF and SS mixed with CW planted at different seeding rates.

**Core Ideas**

- Forage mass of both grasses was not affected by overseeding cowpea.
- Few nutritive value changes occurred for both grasses when mixed with cowpea.
- From a cost perspective, the benefit provided by cowpea was minimal.

## 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 altitude). Two experiments were conducted: one with TF, and the other with SS, from June to September 2016 and 2017. The experimental design for each experiment was a randomized complete block with four treatments and four replications per treatment ($n$ = 16). For both experiments, treatments were as follows: (1) control, no cowpea (CW0); (2) cowpea overseeded at a low rate of 25 lb acre$^{-1}$ (CW25); (3) cowpea overseeded at recommended rate of 50 lb acre$^{-1}$ (CW50); and (4) cowpea overseeded at a high rate of 75 lb acre$^{-1}$ (CW75). Cowpea when planted as a monoculture is recommended to be seeded at a rate of 50 lb acre$^{-1}$ (Quinn, 1999); therefore, this study aimed to use half the recommended rate (considered low, 25 lb acre$^{-1}$), the full recommended rate of 50 lb acre$^{-1}$, and one and a half the recommended rate (considered high, 75 lb acre$^{-1}$). Individual plots for both experiments measured 15 × 25 ft.

The soil type at the location was a Maury silt loam (fine, mixed, active, mesic Typic Paleudalfs) (NRCS, 2018). Initial soil condition and nutrient levels on the experimental site were pH = 5.6, P = 143 lb acre$^{-1}$, K = 147 lb acre$^{-1}$, Ca = 1562 lb acre$^{-1}$, and Mg = 122 lb acre$^{-1}$. Weather was monitored on site at the MTREC weather station.

## 3 | TALL FESCUE

On 14 Oct. 2015, the TF experimental area was sprayed with Gramoxone (Paraquat dichloride) at 32 oz acre$^{-1}$ in preparation for planting. On 15 Oct. 2015, TF cultivar Kentucky 31 was drilled at seeding rate of 15 lb acre$^{-1}$ using a no-till 7-ft Tye drill. On 9 Mar. 2016, ammonia sulfate was applied to all TF plots at a rate of 84 lb N acre$^{-1}$ to ensure proper growth. Prior to planting, TF plots were mowed to a 8-inch stubble height, and CW seeds, cultivar Iron & Clay, were inoculated with N-Dure (Verdesian, Cary, NC) premium peanut rhizobium inoculant at a rate of 5 oz per 100 lb of seeds and then no-till-drilled into designated TF plots at 0, 25, 50, or 75 lb acre$^{-1}$. Inoculated CW was overseeded into TF plots on 1 June utilizing a Hege 1000 series plot drill (Hege Company, Waldenburg, Germany). In 2017, inoculated CW was overseeded on 11 May utilizing the same Hege plot drill, maintaining the same randomization of plots from 2016.

## 4 | SORGHUM-SUDANGRASS

On 11 May 2016, the SS experimental area was sprayed with Gramoxone at 48 oz acre$^{-1}$ in preparation for planting. On 1 June 2016, SS cultivar FSG208BMR was drilled at seeding rate of 30 lb acre$^{-1}$ utilizing the no-till 7-ft Tye drill model, and simultaneously, inoculated CW seeds were no-till-drilled into designated SS plots at 0, 25, 50, or 75 lb acre$^{-1}$. No fertilizers were applied to SS plots. On 24 Apr. 2017, 1.5 qt acre$^{-1}$ of Cornerstone Plus herbicide was applied to the experimental area, and 41% of that amount contained the active ingredient glyphosate, [N-(phosphonomethyl) glycine]. On 8 May, a second chemical application was conducted to these plots to ensure proper establishment of SS and CW with 1 qt acre$^{-1}$ of Gramoxone and 12.8 oz acre$^{-1}$ of a non-ionic surfactant. Then, on 11 May, SS and inoculated CW seeds were drilled utilizing the same Hege plot drill into the same plots (according to 2016 plot randomization assignment) following the same seeding rates described above.

### 4.1 | Measurements

Forage samples for both experiments were collected at an 8-inch stubble height from a 1-ft$^2$ area selected at random within each experimental unit on a monthly basis monthly during the entire growing season from June to September. Immediately following monthly sampling, all plots were mowed to an 8-inch height, and the cut forage was removed. In 2016, forage sampling for both experiments occurred on 27 June, 22 July, 16 August, and 8 September. In 2017, samples were collected on 21 June, 21 July, 22 August, and 20 September for both experiments. All samples collected were separated into three categories: grass, legume, and weed for botanical composition determination. No weeds were present in the plots. Samples were then dried at 140°F to a constant weight (~ 72 h), and forage mass (lb dry matter acre$^{-1}$) was determined for each component and summed to provide the total dry weight of each sample collected. The botanical components from each experimental unit were recombined and ground through a 1-mm sieve with a Wiley Mill Grinder (Thomas Scientific, Swedesboro, NJ) for laboratory analyses. Crude protein (CP) and in vitro dry matter digestibility (IVDMD) were predicted by means of near-infrared spectroscopy (FOSS 5000, FOSS NIRSystems, Laurel, MD). Equations for the forage nutritive value analyses were standardized and checked for accuracy with the 2013 Mixed Hay Equation developed by the NIRS Forage and Feed Consortium (NIRSC, Hillsboro, WI). Software used for NIRS analysis was Win ISI II supplied by Infrasoft International (State College, PA). The Global *H* statistical test compared the samples against the model and samples from distinct data sets within the database for accurate results, in which all forage samples fit the equation with $H < 3.0$, and are reported accordingly (Murray & Cowe, 2004).

## 4.2 | Production cost

A partial budget was constructed for each treatment on a per-acre basis to compare cost differences on a forage mass and CP basis. A prorated TF establishment cost was included in the annual production budget assuming a six-year stand life. Input prices (i.e., seed, chemical, fertilizer, tractor use, and custom applications) were obtained from local dealers at the time of the study. Production cost on a forage mass basis was calculated by dividing the per-acre cost from the partial budget by total forage mass summed across all four harvests. Similarly, production cost on a CP basis was calculated by dividing the per-acre cost from the partial budget by total pounds of CP by forage mass.

## 4.3 | Statistical analyses

Differences between least square means of treatments were evaluated for forage mass, CP, IVDMD, species, and production cost on a total forage mass basis and on a CP basis using the PROC GLIMIX procedures, adjusted for Tukey's method for least square means separation, of SAS (SAS for Windows V 9.4, SAS Institute, Cary, NC). Response variables were considered dependent, year and treatment × sampling date were considered fixed effects, and blocks were considered random effects. There were significant year × treatment interactions ($P < .0001$) for most dependent variables. Therefore, results of each experiment are displayed separately by year for all variables showing this interaction with the exception of TF forage mass, TF production cost difference on a forage mass basis, and production cost difference on a CP basis for both TF and SS. Differences between least square means by treatments for botanical composition variables of legume and grass were tested for each species using the PROC GLIMIX procedures adjusted for Tukey's method for least square means separation of SAS.

# 5 | RESULTS AND DISCUSSION

## 5.1 | Weather

The mean air temperature during the growing season in 2016 (April through September) was 4% greater than the 30-yr average and 6% greater in 2017 (Figure 1). In 2016, monthly rainfall averaged 3.5-inches, which was 21% below the 30-yr average (Figure 1). These values were lesser during early spring in April and May 2016 with an average of 1.8 inches each month. In 2017, rainfall during the same period (April through September) averaged 5.7 inches each month, which was 30% above the 30-year average (Figure 1).

## 5.2 | Tall fescue

### 5.2.1 | Forage mass

There were no differences between years ($P = .89$) for total forage mass of CW and TF mixed swards per monthly harvests; therefore, years were combined (Table 1). Also, there were no treatment differences within months in both years ($P = .82$). There was no interaction between treatment and monthly harvests ($P = .68$); however, there was an overall month effect ($P < .01$, statistical differences data not shown in the table), with September having greater forage mass than previous months, independent of seeding rate treatments.

In a recent study evaluating alternatives to N fertilization on TF swards, it was shown that unfertilized TF did not differ from a treatment of TF mixed with CW (50 lb acre$^{-1}$) during two consecutive years (Corbin et al., 2018), which agrees with findings from our study. Corbin et al. (2018) also showed that TF mixed with CW resulted in the lesser total forage mass and nutritive value than mixtures with other legume species such as white and red clover. However, Corbin et al. (2018) also showed that TF and CW mixtures had the greatest forage mass early in the summer compared with other legumes. Our

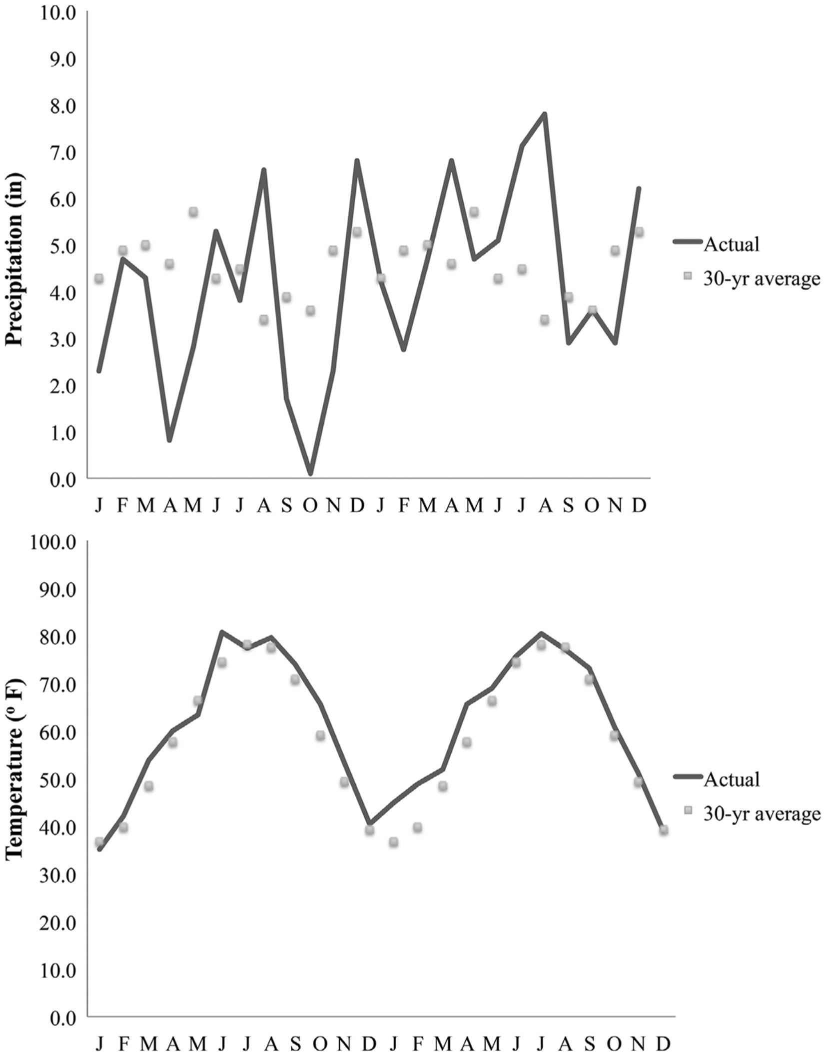


**FIGURE 1** Weather for Spring Hill, TN, reported as monthly averages based on daily records including the 30-yr average for 2016 and 2017

present study, however, showed that overseeding CW into a recently established TF sward at a greater-than-recommended seeding rate resulted in the same forage mass as TF alone probably due to TF competitiveness.

Precipitation was below average during the 2016 growing season (Figure 1), however, it was average or above average during most of the CW growing season. In 2017, precipitation was also above average during the experimental period. Cowpea, normally established in late May in the southern U.S., is considered a drought-tolerant warm-season legume (Ball, Hoveland, & Lacefield, 2007). However, the above-normal precipitation conditions allowed TF swards to be highly competitive, not allowing CW to thrive. Foster et al. (2009) observed that CW as a monoculture performed favorably during drought conditions in Florida.

### 5.2.2 | Botanical composition

There were differences in CW percentage between years ($P < .0001$); therefore, years are shown separately (Table 2).

**TABLE 1** Monthly and total forage mass of a tall fescue sward overseeded with cowpea at different seeding rates per monthly harvest at the Middle Tennessee AgResearch and Education Center (MTREC). Values reported are the means of two consecutive growing seasons (2016 and 2017)

| | June | July | August | September | Total |
|---|---|---|---|---|---|
| Treatment | Forage mass, lb DM acre$^{-1}$ | | | | |
| CW0[a] | 1652 | 1623 | 2132 | 2132 | 7539 |
| CW25 | 1575 | 1537 | 1940 | 2372 | 7424 |
| CW50 | 1652 | 1594 | 1594 | 2458 | 7298 |
| CW75 | 1652 | 1901 | 1978 | 2286 | 7817 |

[a]CW0, CW25, CW50, and CW75 are 0, 25, 50 and 75 lb cowpea acre$^{-1}$, respectively.

Also, there were treatment differences across monthly harvests in both years ($P < .01$ in 2016 and $P < .01$ in 2017). In 2016, CW75 had the greatest percentage of CW in June and July although in July, it did not differ from CW50 (Table 2). There were no differences among treatments later in the season (August and September). In 2017, CW75 had a

**TABLE 2** Percentage of cowpea overseeded into a tall fescue sward at different seeding rates per monthly harvest for two consecutive growing seasons in 2016 and 2017 at the Middle Tennessee AgResearch and Education Center (MTREC)

| | | June | July | August | September |
|---|---|---|---|---|---|
| Year | Treatment | Cowpea, % | | | |
| 2016 | CW0[a] | 0b | 0c | 0 | 0 |
| | CW25 | 1b | 2bc | 0 | 0 |
| | CW50 | 2b | 5ab | 1 | 0 |
| | CW75 | 14a | 7a | 1 | 0 |
| 2017 | CW0 | 0b | 0b | 0b | 0b |
| | CW25 | 4b | 22a | 11b | 8ab |
| | CW50 | 38a | 9ab | 6b | 8ab |
| | CW75 | 32a | 27a | 44a | 24a |

[a]CW0, CW25, CW50, and CW75 are 0, 25, 50 and 75 lb cowpea acre$^{-1}$, respectively.
Means within a column per year without a common letter differ ($P < .05$), based on Tukey's test.

**TABLE 3** Concentration of crude protein (CP) and in vitro dry matter digestibility (IVDMD) of a tall fescue sward overseeeded with cowpea at different seeding rates averaged across four monthly harvests for two consecutive growing seasons in 2016 and 2017 at the Middle Tennessee AgResearch and Education Center (MTREC)

| | | CP | IVDMD |
|---|---|---|---|
| Year | Treatment | % | |
| 2016 | CW0[a] | 11.8 | 74.1 |
| | CW25 | 11.4 | 74.2 |
| | CW50 | 11.0 | 73.5 |
| | CW75 | 11.6 | 74.1 |
| 2017 | CW0 | 10.2 | 66.8c |
| | CW25 | 10.5 | 70.5b |
| | CW50 | 10.1 | 70.2b |
| | CW75 | 10.5 | 73.7a |

[a]CW0, CW25, CW50, and CW75 are 0, 25, 50 and 75 lb cowpea acre$^{-1}$, respectively.
Means within a column per year without a common letter differ ($P < .05$), based on Tukey's test.

consistently greater percentage of CW throughout the entire growing season; however, it did not differ from CW50 or CW25 with the exception of the month of August (Table 2).

In 2016, for the CW50 treatment, there was no more than 5% CW during the entire experimental period, and for the CW75 treatment, the greater percentage of CW found was 14% shortly after establishment (Table 2). In 2017, there was a greater percentage of CW shortly after establishment for treatments CW50 and CW75 (38 and 32%, respectively), and these percentages remained high for CW75 for the remainder of the season (Table 2). These results can explain why there were no differences in forage mass (Table 1) for TF mixed with CW due to the low and inconsistent amount of CW present in the sward. In addition, in 2016, a significant drought affected early establishment of CW seedlings as it was undetected for all treatments two months after planting. In 2017, above-average precipitation allowed CW to establish well early in the season; however, when temperature started to drop, TF growth was accelerated, outcompeting CW in the field. Corbin et al. (2018) observed that CW in a mixture with TF performed better when TF was stressed by drought conditions; however, in our study, CW did not establish well, and its drought tolerance characteristic was not observed.

### 5.2.3 | Forage nutritive value

Crude protein and IVDMD differed between years for both variables ($P < .01$); therefore, years were analyzed separately (Table 3). In 2016 and 2017, there were no treatment differences for CP averaged throughout the growing season ($P = 0.28$ and $P = 0.61$, respectively). Similarly, a study evaluating TF swards mixed with different forage legumes showed that concentration of CP was least for mixtures with CW and did not differ from TF as a monoculture for two consecutive years (Corbin et al., 2018). Poor CW stands allowed TF to be very competitive, thereby affecting the ability of CW to thrive and consequently increasing average CP in the mixture. Another study comparing CP concentration of sorghum forage with different warm-season annual legumes showed that the addition of CW did not change CP concentration compared with a sorghum forage monoculture, probably due to the fact that CP proportion in the mixture was very low (Contreras-Govea, Lauriault, Marsalis, Angadi, & Puppala, 2009). These results agree with findings from our study. Even though the percentage of CW was greatest for CW75 in 2017 (Table 2), it did not differ from other treatments containing CW in most instances, explaining the lack of differences in the concentration of CP in the mixture.

In 2016, there were no treatment differences for IVDMD averaged throughout the growing season ($P = .79$) (Table 3). These results were expected since CW establishment was poor in 2016 and percentage of CW was very low for all treatments (Table 2), which likely influenced the lack of forage nutritive value differences. In 2017, there were seeding rate differences ($P < .01$) for IVDMD averaged across the growing season. Differences were as expected with the greatest IVDMD observed for CW75 and the least for CW0 (Table 3). Percentage of CW was consistently greater for CW75 as opposed to the control treatment, which resulted in increased IVDMD. Average IVDMD for TF pastures in the southeastern U.S. ranges from 61 to 65% (Nave, Barbero, Boyer, Corbin, & Bates, 2016), whereas IVDMD of CW ranges from 83 to 92% (Foster et al., 2013). These values agree with findings from our study where there was an increase in

**TABLE 4** Monthly and total forage mass of a sorghum-sudangrass sward overseeded with cowpea at different seeding rates per monthly harvest for two consecutive growing seasons in 2016 and 2017 at the Middle Tennessee AgResearch and Education Center (MTREC)

| | | June | July | August | September | Total |
|---|---|---|---|---|---|---|
| Year | Treatment | Forage mass, lb DM acre$^{-1}$ | | | | |
| 2016 | CW0[a] | 580 | 2264 | 1146 | 1359 | 5349 |
| | CW25 | 584 | 3042 | 1075 | 1249 | 5950 |
| | CW50 | 736 | 2197 | 1087 | 1376 | 5396 |
| | CW75 | 663 | 1899 | 855 | 1120 | 4537 |
| 2017 | CW0 | 1927 | 2672 | 953 | 1655 | 7107 |
| | CW25 | 1212 | 2871 | 1017 | 897 | 6691 |
| | CW50 | 1841 | 2412 | 1287 | 1124 | 6664 |
| | CW75 | 1452 | 2867 | 1287 | 1584 | 7190 |

[a]CW0, CW25, CW50, and CW75 are 0, 25, 50 and 75 lb cowpea acre$^{-1}$, respectively.

IVDMD concentration with an increased percentage of CW in the mixed sward. Warm-season legumes used for forage will generally result in lower forage mass but will provide forage with greater digestibility (Biederbeck et al., 1993).

## 5.3 | Sorghum sundangrass

### 5.3.1 | Forage mass

There were year differences in forage mass of SS mixed with CW ($P < .01$); therefore, years were analyzed separately (Table 4). Meanwhile, there were no treatment differences within harvest months in either year ($P = .71$ and $P = .59$ for 2016 and 2017, respectively). Neely et al. (2018) studied legume intercropping with sorghum and found that there were no forage mass differences between sorghum as a monoculture or intercropped with CW for two consecutive years, results that agree with the current study. Cowpea tends to utilize moisture very efficiently and fairly deep in the soil profile, which makes it very competitive when grown with warm-season annual grasses. Even though it reduces grass forage mass, it is capable of maintaining high forage mass in the mixture while increasing CP concentration (Neely et al., 2018).

Similarly to TF, there was an overall month effect in both years ($P < .01$, statistical differences data not shown in the table). For SS, July showed the greatest forage mass accumulation compared with other months, independent of seeding rates. Gelley et al. (2016) investigated forage mass accumulation of SS, and similar to our study, concluded that the greatest accumulation occurred in July. This is due to the fact that SS is an annual warm-season grass, which accumulates forage mass quickly but is mostly useful for short-term forage production during the summer.

**TABLE 5** Percentage of cowpea overseeded into a sorghum-sudangrass sward at different seeding rates per monthly harvest for two consecutive growing seasons in 2016 and 2017 at the Middle Tennessee AgResearch and Education Center (MTREC)

| | | June | July | August | September |
|---|---|---|---|---|---|
| Year | Treatment | Forage mass, lb DM acre$^{-1}$ | | | |
| 2016 | CW0[a] | 0c | 0b | 0 | 0 |
| | CW25 | 2c | 9ab | 6 | 0 |
| | CW50 | 42b | 23a | 14 | 0 |
| | CW75 | 65a | 25a | 7 | 0 |
| 2017 | CW0 | 0b | 0b | 0b | 0c |
| | CW25 | 16b | 9ab | 39a | 28b |
| | CW50 | 19b | 28a | 55a | 40ab |
| | CW75 | 43a | 27a | 50a | 57a |

[a]CW0, CW25, CW50, and CW75 are 0, 25, 50 and 75 lb cowpea acre$^{-1}$, respectively.

Means within a column per year without a common letter differ ($P < .05$), based on Tukey's test.

### 5.3.2 | Botanical composition

There were differences in the percentage of CW between years ($P < .01$); therefore, year results are shown separately (Table 5). In addition, there were treatment differences across months in both years ($P < .01$ in both 2016 and 2017). In 2016, CW75 had the greatest percentage of CW in June with 65% of the sward composed of CW. In July 2016, SS accumulated forage at a rapid rate (Gelley et al., 2016); therefore, all treatments seeded with CW had a similar percentage of CW. By August and September, SS outcompeted CW plants and no differences were found among treatments (Table 5).

In 2017, a similar pattern occurred, with a greater percentage of CW occurring in June for CW75, followed by a lack of differences among treatments containing CW in July. However, in August and September 2017, a sudden increase in percentage of CW occurred (Table 5), and that was likely due to a severe drought that occurred in August 2017 (Figure 1). While SS can withstand drought, it does not accumulate mass at the same rate during these events (SARE, 2007). Nave and Corbin (2018) studied warm-season legumes intercropped with corn for silage and showed that the addition of CW did not increase dry matter yield of corn, results that agree with the current study.

### 5.3.3 | Forage nutritive value

There were year effects on forage nutritive value of SS mixed with CW ($P < .01$) (Table 6). In 2016, there were seeding rate differences for CP ($P < .01$), with CW75 and CW50 showing greater CP concentration as compared with CW0. These results were expected, given that a greater

**TABLE 6** Concentration of crude protein (CP) and in vitro dry matter digestibility (IVDMD) of a sorghum-sudangrass sward overseeded with cowpea at different seeding rates averaged across four monthly harvests for two consecutive growing seasons in 2016 and 2017 at the Middle Tennessee AgResearch and Education Center (MTREC)

| Year | Treatment | CP | IVDMD |
|---|---|---|---|
| 2016 | CW0[a] | 9.3c | 76.5c |
| | CW25 | 9.9bc | 78.3b |
| | CW50 | 11.5ab | 81.0a |
| | CW75 | 11.7a | 80.2a |
| 2017 | CW0 | 7.3b | 68.6b |
| | CW25 | 7.3b | 70.4b |
| | CW50 | 9.5a | 73.5a |
| | CW75 | 9.6a | 74.7a |

[a]CW0, CW25, CW50, and CW75 are 0, 25, 50 and 75 lb cowpea acre$^{-1}$, respectively.
Means within a column per year without a common letter differ ($P < .05$), based on Tukey's test.

**TABLE 7** Production cost differences between treatments of tall fescue and sorghum-sudangrass swards overseeded with cowpea at different seeding rates on a forage mass basis during the growing season in 2016 and 2017 at the Middle Tennessee AgResearch and Education Center (MTREC)

| Year | Treatment | Cost difference | $P > \|t\|$ |
|---|---|---|---|
| 2016–2017 | Tall fescue | \$ ton$^{-1}$ | |
| | CW0 – CW25[a] | –12.29 | .01 |
| | CW0 – CW50 | –21.30 | <.01 |
| | CW0 – CW75 | –28.05 | <.01 |
| | CW25 – CW50 | –9.01 | .01 |
| | CW25 – CW75 | –15.76 | <.01 |
| | CW50 – CW75 | –6.75 | .01 |
| 2016 | Sorghum-Sudangrass | | |
| | CW0 – CW25 | –6.19 | .64 |
| | CW0 – CW50 | –24.77 | .09 |
| | CW0 – CW75 | –46.69 | .01 |
| | CW25 – CW50 | –18.58 | .18 |
| | CW25 – CW75 | –40.49 | .01 |
| | CW50 – CW75 | –21.91 | .12 |
| 2017 | | | |
| | CW0 – CW25 | –15.00 | .22 |
| | CW0 – CW50 | –28.25 | .04 |
| | CW0 – CW75 | –24.10 | .06 |
| | CW25 – CW50 | –13.25 | .27 |
| | CW25 – CW75 | –9.10 | .45 |
| | CW50 – CW75 | 4.15 | .72 |

*Note*: Data presented as a mean of 2016–2017 for tall fescue and by year for sorghum-sudangrass.
[a]CW0, CW25, CW50, and CW75 are 0, 25, 50 and 75 lb cowpea acre$^{-1}$, respectively.

percentage of CW was shown for these treatments early in the season. Similar results were observed for IVDMD in 2016 ($P < .01$) with greater IVDMD attributed to CW75 and CW50 (Table 6).

In 2017, there were differences in concentration of CP and IVDMD averaged throughout the growing season ($P < .0001$ for both variables). However, these differences were less pronounced with CW75 and CW50 having greater concentration of CP and IVDMD than CW25 and CW0 (Table 6). In general, the CP concentration for SS monoculture (CW0) is comparable to past studies where these values ranged from 7 to 12% (Gelley et al., 2016). However, mixtures of SS with CW appear to be lesser during both years. Research on intercropping CW with warm-season grasses has shown values ranging from 11 to 19% when 75% of the sward was composed of CW (Contreras-Govea et al., 2009; Neely et al., 2018). Sorghum-sudangrass tends to accumulate mass quickly after establishment, which increases the amount of stems early in the season (Gelley et al., 2016). High stem/leaf ratio can dramatically decrease forage nutritive value in general, and this decline can be even more prominent when growing annual warm-season forages due to their shorter growing season.

## 5.4 | Economic viability of cowpea interseeded in tall fescue and sorghum-sudangrass swards

Production cost differences of each treatment for TF and SS on a forage mass basis are shown on Table 7. Tall fescue and CW0 was the least expensive from a forage mass standpoint among TF treatments. Tall fescue with CW25 cost \$12.29 per ton more to produce than CW0. Similarly, CW50 cost \$9.01 per ton more than TF with CW25 while CW75 cost \$6.75 per ton more than CW50.

Sorghum-sudangrass treatments were highly variable across years and could not be grouped (Table 7). In 2016, the cost of producing SS with CW0 was not found to be different from SS with CW25. However, SS with CW0 was found to cost \$24.77 less per ton than SS with CW50 and \$46.69 per ton less than SS with CW75. Sorghum-sudangrass with CW25 cost \$40.49 per ton less to produce than SS with CW75 in 2016. Somewhat similar results were observed in 2017 for SS with CW0 costing \$28.25 less per ton than SS with CW50, and \$24.10 per ton less than SS with CW75.

Table 8 reports results of production cost differences for each treatment for TF and SS on a protein content basis. Tall fescue with CW0 was \$0.056 per pound of protein less expensive than TF with CW25, \$0.103 per pound of protein less expensive than TF with CW50, and \$0.127 less expensive than TF with CW75. Increasing the seeding rate of CW mixed in TF subsequently increased the cost of production on a

**TABLE 8** Production cost differences of tall fescue and sorghum-sudangrass swards overseeded with cowpea at different seeding rates on a crude protein (CP) basis, averaged during the growing season in 2016 and 2017 at the Middle Tennessee AgResearch and Education Center (MTREC)

| Treatment | Cost difference | *P* > \|*t*\| |
|---|---|---|
| Tall fescue | $/lb CP | |
| CW0 – CW25[a] | –0.056 | <.01 |
| CW0 – CW50 | –0.103 | <.01 |
| CW0 – CW75 | –0.127 | <.01 |
| CW25 – CW50 | –0.047 | 0.01 |
| CW25 – CW75 | –0.071 | <.01 |
| CW50 – CW75 | –0.024 | 0.01 |
| Sorghum-Sudangrass | $/ton | |
| CW0 – CW25 | –0.075 | 0.20 |
| CW0 – CW50 | –0.108 | 0.08 |
| CW0 – CW75 | –0.131 | 0.04 |
| CW25 – CW50 | –0.033 | 0.55 |
| CW25 – CW75 | –0.056 | 0.32 |
| CW50 – CW75 | –0.023 | 0.68 |

*Note*: Data presented as a mean of 2016–2017.
[a]CW0, CW25, CW50, and CW75 are 0, 25, 50 and 75 lb cowpea acre$^{-1}$, respectively.

protein basis relative to lower rates of CW seed (Table 8). In the SS treatments, the only differences in cost were in the SS without CW compared with SS with CW50 and CW75. In these comparisons, SS without CW was $0.108 per pound of protein less than SS with CW50 and $0.131 per pound of protein less than SS with CW75.

From a cost of production perspective, there appears to be no advantage from a forage mass or CP concentration standpoint to adding CW to a stand of TF or SS. The addition of CW to TF and SS appears to have a greater marginal cost than the marginal benefit provided by the CW.

## 6 | CONCLUSIONS

Forage mass of TF and SS was not affected by overseeded CW independently of the seeding rate even though these mixtures had variable CW percentage. The percentage of CW in the sward varied across monthly harvests for both experiments. The CW percentage was greater in the SS stands while in TF stands, CW percentage was lesser and inconsistent. These differences in the legume/grass ratio did not affect overall forage mass, indicating that when accumulation of CW increases, it decreases the forage mass of the grass at the same rate.

Crude protein concentration of TF mixed with CW did not change, but IVDMD increased when the CW percentage increased in the sward. For SS, both CP and IVDMD were affected by CW seeding rates, indicating that overall forage nutritive value of an annual warm-season grass may be improved with the addition of CW. However, data from this study suggest that the addition of CW to either TF or SS does not justify its cost given the minimal benefit provided by CW.


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