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# Establishment of Bahiagrass and Bermudagrass with Annual Warm-Season Grasses as Companion Crops

## Abstract

Bahiagrass (BH, *Paspalum notatum*) and bermudagrass (BG, *Cynodon dactylon*) are warm-season perennial grasses (PWSG) commonly grown in the southern United States. The objective of the study was to determine the establishment of PWSG using warm-season annual forages as a nursery crop. The study was a split-plot design replicated three times. The main plots were BH, and BG established at seeding rates of 20 and 10 lb of pure live seed (PLS) per acre, respectively. The subplots were three-annual warm-season annual grasses (AWSG) [‘AF7401’forage sorghum (FS), ‘Prime 180’ pearl millet (PM), ‘Green Grazer V’ sorghum-sudan hybrid (SS)], established at 10, 15, and 20 lb PLS/ac, respectively, and monocultures of BH and BG. All treatments received 100 lb N/ac in split applications after AWSG germination and following the first AWSG harvest. Treatments were harvested using a Wintersteiger Cibus F harvester (Wintersteiger AG, Austria) when plants reached 48 in height. Biomass subsamples were analyzed for nutritive value using a Foss DS2500 NIR instrument (Foss North America, Eden Prairie, MN) and the 2021 mixed grass hay equation from the NIRS Forage and Feed Testing Consortium (Berea, KY). Data were analyzed in the PROC GLIMMIX of SAS at $\alpha = 0.05$. Bahiagrass and BG establishment and productivity were not affected by AWSG. Total biomass production was 18% greater for the BH treatments compared to BG. The yield index of adding FS, PM, and SS were 108, 38, and 25%, respectively, when compared to PWSG monocultures. During the first harvest in 2020, CP, WSC, and IVTDMD concentrations were not different among AWSG treatments.

**Abbreviations:** BH = Bahiagrass; BG = Bermudagrass; AWSG = annual warm-season grass; PWSG = perennial warm-season grass; PLS = pure live seed; CP = crude protein; NDF = neutral detergent fiber; ADF = acid detergent fiber; IVTDMD = *in vitro* dry matter digestibility; WSC = water-soluble carbohydrates; LSD = least significant difference.

**Keywords:** bahiagrass, bermudagrass, establishment, companion crops, annual grass

## Introduction

Bahiagrass (*Paspalum notatum*) and bermudagrass (*Cynodon dactylon*) are the predominant warm-season perennial grasses (PWSGs) used for cow-calf production in the southern USA. Although these grasses are very productive once they are established, their yields are often hindered during the establishment year due to slow germination rates and weed competition. Weed competition can be related to the slow germination of bahiagrass and bermudagrass and the limitation of available herbicides during the establishment phase. On the other hand, warm-season annual grasses tend to get established quicker and close the canopy to limit weed germination, To avoid loss in forage production during the establishment year, there is an opportunity to incorporate warm-season annual grasses (AWSGs) such as forage sorghum (*Sorghum bicolor*), pearl millet (*Pennisetum glaucum*), and sorghum x sudan hybrids (*Sorghum bicolor x S. bicolor*). These AWSGs provide a valuable forage crop capable of producing supplemental production from late June through September (Tracy et al, 2010).

Forage sorghum is a coarse, upright-growing grass adapted to fertile, well-drained soils with good water-holding capacity, and a soil pH ranging from 5.5 to 6.5 (Teutsch, 2009).

*Sorghum-sudangrass hybrids* have relatively coarser stems, taller growth habits, and higher yields compared to forage sorghum (Beck et al., 2007). Pearl millet has smaller stems and tends to be leafier than forage sorghum and sorghum-sudangrass hybrids. It is adapted to more acid soils with lower water holding capacity (Rostamza et al., 2011). Annual warm-season grasses should be planted when the soil temperature has reached at least 64°F. Pearl millet, forage sorghum, and sorghum-sudan hybrids can accumulate nitrates but only the latter two contain prussic acid. Cultivars of each species are available that contain the brown midrib (BMR) trait which gives the plant brown vascular tissue because of reduced lignin content and improved digestibility.

Prior studies have focused on the establishment of native warm-season grasses with annuals. Hintz et al. (1998) successfully established big blue stem (*Andropogon gerardii*) and switchgrass (*Panicum virgatum*) with corn (Z*ea maize*) as a companion crop despite corn density or harvest date. Anderson et al. (2016) successfully established switchgrass with corn as a companion crop. Cossar and Baldwin (2002) found that switchgrass plant density and sorghum x sudangrass seeding rates had an inverse relationship. However, Horton et al. (2004) reported no difference in switchgrass biomass yield with increasing sorghum x sudangrass seeding rates. Likewise, brown top millet did not affect the establishment of big blue stem or switchgrass as a companion crop while helping offset production losses (Richwine et al., 2020).

Perennial warm-season grasses (bahiagrass and bermudagrass) are essential for livestock production in the southern USA. As a forage option, these perennial warm-season grasses are valued for their efficient biomass production and moderate nutritive value with typical management. However, establishing perennial warm-season grasses is difficult because of reduced first-year yields due to slow germination and aggressive competition from weeds when the seedbed is not properly prepared. The use of warm-season annual grasses as companion crops during the establishment of PWSGs can be a viable alternative allowing producers to mitigate forage production loss during the establishment year. However, there is limited information on the success of this practice in reducing the time a pasture may remain out of production in the southern USA. Producers need to consider the high cost of annual grass establishment and the increased risk of stand failure due to variable rainfall in late spring and early summer. The objective of the study was to determine the establishment of PWSGs using warm-season annual forages as companion crops at different seeding rates to evaluate production and nutritive value during the establishment of warm-season perennial grasses.

## Methods

A preliminary study was conducted at the Henry H. Leveck Animal Research Farm at Mississippi State University. The soil type is a Marietta fine sandy loam (Fine-loamy, siliceous, active, thermic Fluvaquenti Eutrudepts) with a 2 to 5% slope. Soil samples were collected at a six-inch depth before planting to determine nutrient concentrations and make recommended soil fertility adjustments. All plots were adjusted for pH, P, and K based on soil testing recommendations. To minimize weed competition, the land was prepared four weeks ahead of planting, and plots were treated with a glyphosate application (2 pt/ac) 10 d before planting. The experimental design was a split plot replicated three times. The main plots were ‘Tifton 9’ bahiagrass (BH, 20 lb PLS $ac^{-1}$), and ‘Cheyenne II’ bermudagrass (BG, 10 lb PLS $ac^{-1}$) established at 20 and 10 lb PLS/ac, respectively. The subplots were a factorial combination of three warm-season annual grasses (AWSG) established at three seeding rates (10, 15, and 20 lb PLS/ac). The AWSGs included ‘AF7401’ forage sorghum (FS), ‘Prime 180’ pearl millet (PM), and ‘Green Grazer V’ sorghum-sudan hybrid (SS). The subplots also included a monoculture (MC) of bahiagrass and bermudagrass for the establishment and forage biomass comparison. The plots were established on June 5, 2020, using an ALMACO plot drill (ALMACO, Nevada, IA) and the plot size was 6 ft x 10 ft. All treatments received 100 lb N/ac in split applications using urea ammonium sulfate (33-0-0) after AWSG germination (June 5) and following the first AWSG harvest (July 25). Treatments were harvested using a Wintersteiger Cibus F harvester (Wintersteiger AG, Austria) when plants reached 48 in height on July 21 and 12 inches on October 14. A subsequent first harvest of bahiagrass and bermudagrass was conducted on June 4,

2021. Biomass subsamples were dried at 140°F for 72-h and ground to pass a 1-mm screen. Biomass subsamples were analyzed for crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), 48-h *in vitro* dry matter digestibility (IVTDMD), and water-soluble carbohydrates (WSC) using a Foss DS2500 NIR instrument (Foss North America, Eden Prairie, MN). Samples were analyzed using the 2021 mixed grass hay equation from the NIRS Forage and Feed Testing Consortium (Berea, KY).

Data were analyzed using harvest frequency as a repeated measure for each of the dependent variables. Data were tested and normality and homogeneity of variance were subjected to ANOVA using SAS PROC GLIMMIX procedure of SAS (SAS 9.4) and the least significant difference was used to determine treatment differences at $\alpha = 0.05$.

## Results

### Climatic conditions

Total precipitation from September 2020 to August 2020 was very similar to the 30-year normal (Table 1). However, precipitation deficits greater than one inch was observed in August and November 2020 and January and February 2021. June of 2021 was a wet month with a 163% increase in precipitation compared to the long-term normal. The average temperature for the growing season was very similar to the long-term normal. Warmer temperatures than normal were observed in November 2020 and January and March 2021. Total growing degree days (GDD) were only 1.5 greater than normal. Larger fluctuations in GDD were observed with a significant decrease in GDD for December 2020 and an increase for November and March 2020 and March 2021. This large decrease in GGD in December could usually be related to an increase in cloud cover.

### Forage biomass

The seeding rates of warm-season annual grasses (AWSGs) did not affect the establishment of bahiagrass (BH) and bermudagrass (BG). Total biomass production was 18% greater for the BH treatments compared to BG alone. Using AWSGs as

Table 1. Precipitation, temperature, and growing degree days (GDD) along with 30-yr normal and deviation during the preliminary evaluation of alfalfa planting date at Starkville, MS from September 2020 to August 2021 (NOAA, 2022).

| | **Precipitation (in)** | | | | **Temperature (°F)** | | | | ***GGD***$_{50}$* | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Month*** | 2020-21 | 30-yr | Dev | | 2020-21 | 30-yr | Dev | | 2020-21 | 30-yr | Dev |
| *Jun* | 5.4 | 4.4 | 1.0 | | 79.6 | 79.6 | 0.0 | | 894 | 910 | -16 |
| *Jul* | 4.2 | 5.2 | -0.9 | | 83.0 | 82.1 | 0.9 | | 1032 | 998 | 34 |
| *Aug* | 3.1 | 4.7 | -1.6 | | 81.4 | 81.8 | -0.4 | | 982 | 1004 | -22 |
| *Sep* | 4.4 | 3.4 | 1.0 | | 77.6 | 76.8 | 0.8 | | 834 | 780 | 54 |
| *Oct* | 4.1 | 3.7 | 0.3 | | 67.6 | 66.3 | 1.3 | | 550 | 620 | -70 |
| *Nov* | 2.4 | 4.3 | -1.9 | | 59.5 | 55.3 | 4.2 | | 306 | 132 | 174 |
| *Dec* | 4.5 | 5.1 | -0.6 | | 49.1 | 49.5 | -0.4 | | 81 | 364 | -283 |
| *Jan* | 4.0 | 5.4 | -1.4 | | 50.9 | 47.0 | 3.9 | | 124 | 73 | 51 |
| *Feb* | 3.3 | 5.0 | -1.7 | | 52.5 | 50.7 | 1.8 | | 144 | 115 | 29 |
| *Mar* | 4.9 | 5.7 | -0.8 | | 66.5 | 58.0 | 8.5 | | 518 | 359 | 159 |
| *Apr* | 5.4 | 5.9 | -0.5 | | 64.1 | 64.8 | -0.7 | | 431 | 414 | 17 |
| *May* | 4.8 | 4.4 | 0.4 | | 71.6 | 72.9 | -1.3 | | 675 | 675 | 0 |
| *Jun* | 11.6 | 4.4 | 7.2 | | 79.6 | 79.6 | 0.0 | | 894 | 910 | -16 |
| *Total/ Mean* | 62.0 | 61.6 | -- | | 67.9 | 66.5 | -- | | 7465 | 7354 | -- |

*Growing degree days (GDD) base 50.

companion crops increased forge biomass production when compared to establishing BH or BG as monocultures (Fig. 1). Most of the biomass production was earlier in the season while the second harvest was mainly BH and BG. Comparison of AWSGs to BH and BG monocultures indicated a significant increase in the yield index with forage sorghum (FS) proving a greater advantage earlier in the season (Fig. 2). The yield index of adding FS, PM, and SS was 108, 38, and 25% when compared to PWSG monocultures. However, greater biomass production had an impact on the subsequent yield later in the season. Using AWSGs as companion crops did not influence biomass production in the following spring of the establishment year (Fig 3). The results suggest that summer annual grasses are ideally suited as a companion crop when establishing bahiagrass and bermudagrass pastures. They demonstrate the importance of selecting a companion crop that is compatible with the forage crop of interest to achieve attainable forage production. Therefore, the choice of AWSG intercrop species and their symbiotic success are strongly influenced by the species' growing season and the adaptation of crops to differing environments.

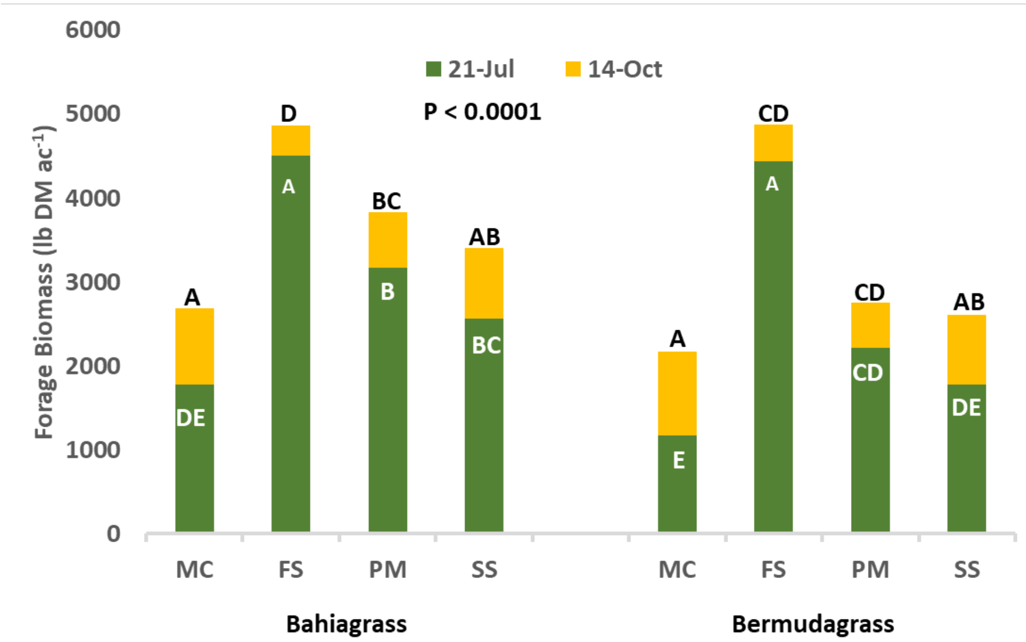


Figure 1. Forage biomass production of bahiagrass and bermudagrass when established as monoculture (MC) or with three annual warm-season grasses as companion forage crops. Letters are for comparison of mean differences among treatments within the sampling date at α=0.05.

### ***Nutritive value***

Nutritive values across all the treatments were affected ($P < 0.001$) by a sampling date x treatment interaction (Table 2). During the first harvest of 2020, CP, WSC, and IVTDMD mean concentrations were not different among AWSG treatments. Crude protein levels were greater during the October 14 sampling compared to July 21. This was likely due to the restricted growth of the BH and BG that led to greater concentrations of nutrients in the biomass. The same pattern was observed for ADF and NDF with lower percentages and greater IVTDMD and WSC.

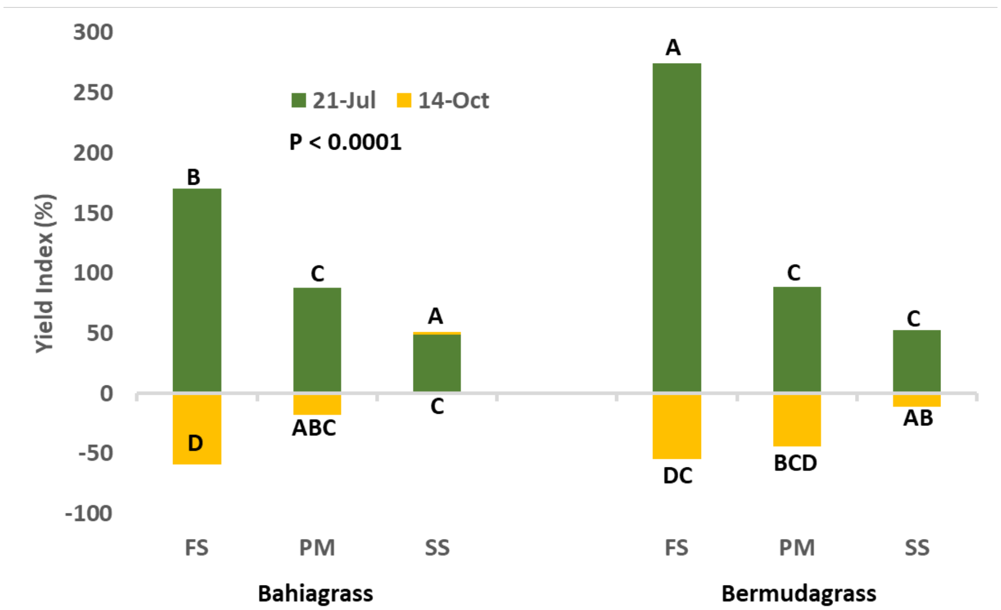


Figure 2. Biomass yield index of bahiagrass and bermudagrass when established with three annual warm-season grasses as companion forage crops. The yield index was determined by subtracting the biomass of the BH and BG in combination with the AWSG from the monoculture of BH and BG and expressed as a percentage. Letters are for comparison of mean differences among treatments within the sampling date at α=0.05.

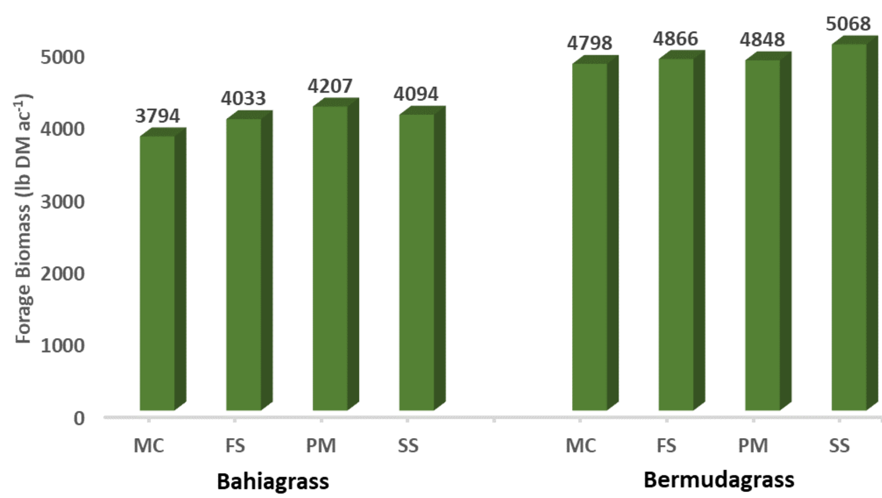


Figure 3. Forage biomass production of bahiagrass and bermudagrass on June 4, 2021, after being established as monoculture (MC) or with three annual warm-season grasses as companion forage crops in 2020.

Table 2*.* Influence of sampling date on crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), *in vitro* dry matter digestibility (IVTDMD), and water-soluble carbohydrates of bahiagrass (BH) and bermudagrass (BG) established as monoculture (MC) or with [Forage Sorghum (FS), Pearl Millet (PM), and Sorghum-sudan (SS)] as companion forage crops.

| | | Sampling Dates | | | | | |
|---|---|---|---|---|---|---|---|
| | | **21-Jul** | **14-Oct** | | **21-Jul** | **14-Oct** | |
| | | **CP** | | **$LSD_{0.05}$** | **IVTDMD** | | **$LSD_{0.05}$** |
| | | ---------- % DM ---------- | | | | | |
| **BH** | **MC** | 13.0 | 16.3 | 0.7 | 65.6 | 73.5 | 3.4 |
| | **FS** | 12.4 | 18.6 | 1.0 | 72.1 | 72.0 | NS |
| | **PM** | 12.6 | 19.0 | 1.0 | 71.0 | 77.5 | 1.8 |
| | **SS** | 12.7 | 17.1 | 1.1 | 68.3 | 74.9 | 2.2 |
| **BG** | **MC** | 13.5 | 18.3 | 1.0 | 72.0 | 73.6 | NS |
| | **FS** | 12.6 | 21.4 | 1.0 | 72.0 | 77.0 | 2.6 |
| | **PM** | 13.9 | 21.7 | 1.5 | 71.6 | 77.2 | 4.3 |
| | **SS** | 13.8 | 20.3 | 1.0 | 69.2 | 75.3 | 2.4 |
| | **$LSD_{0.05}$** | 0.8 | 1.1 | - | 2.8 | 3.2 | - |
| | | **ADF** | | **$LSD_{0.05}$** | **WSC** | | **$LSD_{0.05}$** |
| **BH** | **MC** | 43.5 | 35.5 | 1.9 | 5.2 | 8.4 | 0.7 |
| | **FS** | 42.2 | 35.4 | 1.8 | 5.2 | 7.6 | 0.6 |
| | **PM** | 41.0 | 32.6 | 1.3 | 6.0 | 8.5 | 0.4 |
| | **SS** | 42.9 | 34.3 | 1.4 | 5.3 | 8.5 | 0.5 |
| **BG** | **MC** | 39.8 | 31.0 | 1.5 | 5.5 | 6.8 | 1.1 |
| | **FS** | 42.4 | 29.0 | 1.9 | 5.3 | 7.2 | 0.6 |
| | **PM** | 40.0 | 29.0 | 2.8 | 5.6 | 7.3 | 0.5 |
| | **SS** | 41.6 | 29.9 | 1.9 | 4.9 | 7.1 | 0.8 |
| | **$LSD_{0.05}$** | 2.0 | 2.1 | - | NS | 0.6 | - |
| | | **NDF** | | **$LSD_{0.05}$** | | | |
| **BH** | **MC** | 66.4 | 56.8 | 1.7 | - | - | - |
| | **FS** | 67.9 | 55.0 | 1.9 | - | - | - |
| | **PM** | 66.0 | 52.2 | 1.7 | - | - | - |
| | **SS** | 67.0 | 55.0 | 2.0 | - | - | - |
| **BG** | **MC** | 63.1 | 53.7 | 1.4 | - | - | - |
| | **FS** | 68.1 | 50.4 | 2.2 | - | - | - |
| | **PM** | 64.6 | 50.2 | 2.7 | - | - | - |
| | **SS** | 65.2 | 51.9 | 2.4 | - | - | - |
| | **$LSD_{0.05}$** | 2.3 | 2.0 | - | - | - | - |

The least significant difference (LSD) values are for comparison of mean differences among treatments within the sampling date across species at α=0.05.

## Discussion

While prior experiments have focused on planting AWSG as monocultures following annual cool-season grasses such as annual ryegrass, to date there are no other studies that address the use of warm-season annual grasses as companion crops. This study took a novel approach to use them as companion crops for the establishment of PWSG. The biomass production of these AWSGs indicated that they might serve as companion crops to provide supplemental forage for livestock during the transitional establishment period for PWSG in the southern USA. The three species of summer-annual grasses are characterized by rapid growth in late spring and summer. These species also showed an enhanced nutritive value. The data indicated that producers could benefit from forage production of FS, PM, and SS at the 10 to 15-lb PLS $ac^{-1}$ seeding rates with negligible BH and BG yield losses. If producers do not need to compensate for lost forage production during the BH or BG establishment year, then not planting AWSG will likely result in forage production losses.

Although the use of AWSG as companion crops can provide a wide array of benefits to livestock producers including forage stability under changing climatic conditions as the grass species could act as a buffer to each other. The choice of herbicides that could be applied to forage grasses during seedling establishment is very limited. This type of approach to intercropping could also help producers decrease the need for direct weed control measures as the increased demand for nutrients, sunlight, and moisture could create an unfavorable environment for some weed species. There is a need to further study planting dates, plant density changes, weed species population, allelopathic effects, timing of nitrogen applications, and grazing management strategies that could aid in improving establishment practices of bahiagrass and bermudagrass while using AWSG as companion crops. This approach will provide producers with valuable information about the utilization options of AWSG.

## Conclusions

Using a warm-season annual grass as a companion crop may fill gaps in seasonal forage availability during the establishment of warm-season perennial grasses and the feed needs for beef cattle producers in the Southeastern United States. The utilization of these AWSGs as companion crops with a seeding rate of 10 to 15 lb $ac^{-1}$ should be sufficient to provide adequate biomass. In the summer, the integration of forage sorghum, pearl millet, or sorghum x sundan grass could be an option to increase forage production and establish moderate-to-highly productive seeded varieties of bermudagrass or bahiagrass stands in subsequent years. The lack of significant differences in biomass production a year post-establishment between the PWPG monoculture and those inter-seeded with AWSGs suggests that there are benefits of establishing BH and BG with companion crops. Further research will be needed to establish more economic impact and determine the use of these companion crops during the establishment of other seeded varieties or hybrid bermudagrass. There is a need to explore more practices that could help reduce weed competition under producer's settings and quantify the economic benefits since the establishment of warm-season annual grasses could be expensive. Such expenses include seed, fertilizer, herbicide, and field operations (disking, cultivation to prepare seedbed, and planting).

## Conflict of Interest

The authors declare that there is no conflict of interest.


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