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Performance of Teff Grass Cultivars for Biomass Yield and Nutritive Value Under Fall Planting Conditions

Abstract

Teff grass (*Eragrostis tef* [Zuccagni] Trotter) is a warm-season annual grass not typically produced in Mississippi. The objective of the study was to determine the biomass production and nutritive value of seven cultivars planted in the fall of 2021. The experimental design was a randomized complete block replicated four times. The cultivars included ‘Bonus’, ‘Charger’, ‘Corvallis’, ‘Dessie’, ‘Moxie’, ‘Oasis’, and ‘Tiffany’. Teff grass was established in a prepared seedbed at a rate of 10 lbs PLS (pure live seed) ac^{-1}. Nitrogen was applied at 100 lbs N ac^{-1} using urea ammonium sulfate (33-0-0-18S) in split applications. Percentage of green canopy cover (GCC), Leaf Area Index (LAI), and Normalized Difference Vegetation Index (NDVI) measurements were taken before each harvest. Plots were harvested on Oct 14 and Nov 8 and forage sub-samples were collected for dry matter determination and nutritive analysis. Samples were analyzed for CP, ADF, NDF, IVTDMD, WSC, and starch using a Foss DS2500 NIR instrument and using the 2021 grass hay equation developed by the NIRS Forage and Feed Testing Consortium. Cultivars ‘Corvallis’, ‘Bonus’, ‘Tiffany’, and ‘Charger’ yielded 16 to 23% more compared to the other cultivars. There was a 40% yield

decrease between the first and second harvests ($P = 0.0021$). LAI decreased by 41% between the first and second harvests. NDVI ($P < 0.0001$) decreased by 10% between harvests. There was a harvest by cultivar interaction for GCC ($P = 0.0260$). Nutritive values were influenced by harvest with CP ($P < 0.0001$) increased by 5% and starch ($P<0.0001$) decreased by 70%.

Abbreviations: PLS = pure live seed; N = nitrogen; LAI, leaf area index; GCC = green canopy cover; NDVI = normalized difference vegetative index; 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: teff grass, biomass yield, nutritive value

Introduction

Teff grass (*Eragrostis tef* [Zuccagni] Trotter) is an annual C_4 plant traditionally grown in Ethiopia as a warm-season cereal grain. Due to the canopy architecture of teff (thinned stems, fine leaves, and a shallow root system), it is mainly recommended as a hay crop. Teff can produce between 11 and 42 tillers, depending on the cultivar (Bedane et al., 2015). Teff can tolerate a wide range of soil types and soil conditions such as poor drainage to severe drought.

Due to a shallow root system, windy conditions, and sometimes excess N application, lodging issues have been reported near harvest time (Roseberg, 2018). In the US, most of the biomass production data for teff as a potential forage crop has been collected in the Pacific Northwest with reported yields ranging from 5.0 to 7.0 tons of dry matter per acre under irrigated conditions (Miller, 2011; Roseberg et al., 2005; Saylor, 2017). Studies conducted in the southern USA (Lemus et al., 2016) have indicated low threshold yields ranging from 1,400 to 2,100 pounds of dry matter per acre. Although average teff fields of 3,100 lbs DM ac^{-1} has been reported in Mississippi, most of the biomass production had a considerable barnyard grass infestation (Parish et al., 2011).

Teff grass requires 36 to 45 days for panicle emergence and reaches physiological maturity between 80 and 100 days after planting (Assefa et al., 2001). Subsequent cuttings are usually harvested on a 28-day cutting schedule. In the southern USA, teff is managed as an annual crop with two possible cuttings where 70% of the yield potential is accomplished in the first harvest due to growing conditions and rain limitations between late July and early September. Under certain circumstances, teff biomass and nutritive value could be maintained with nitrogen (N) applications of 50 lb ac^{-1} (Hancock and Durham, 2009; Lauriault et al., 2013; Roseberg et al., 2018). Teff grass has been reported to have higher protein and nutritive value than other warm-season annual grasses (Hunter et al., 2007; Twidwell et al., 2002). The nutritive value of teff ranges from 12 to 17% CP, 32 to 42% ADF, 53 to 70% NDF, and RFV of 80 to 120 (Miller, 2009). Vinyard et al. (2018) indicated a decline in CP with maturity. They indicated that CP was 18.7, 14.7, and 11.9% at the boot, early-heading, and late-heading stages, respectively.

Despite planting date, growth stage, fertilization, and cutting management, Lemus et al. (2016) and Hancock and Durham (2009) have indicated low forage teff grass productivity in the southern USA. One of the advantages in the southern USA is the extended grazing season until early November with average temperatures ranging from 84/63 °F (day/night) in September and 72/52 °F in October. However, no research-based information is available on teff cultivars' performance under fall planting conditions. The objective of this study was to evaluate teff grass cultivar production and nutritive value under fall planting conditions.

Methods

An exploratory study was conducted at the Henry H. Leveck Animal Research Farm at Mississippi State University in a Marietta fine sandy loam (Fine-loamy, siliceous, active, thermic Fluvaquenti Eutrudepts) during the fall of 2021. The experimental design was a randomized complete block replicated four times. Seven teff grass cultivars 'Bonus' (BGT), 'Charger' (RTG), 'Corvallis' (CTG), 'Dessie' (DTG), 'Moxie' (MTG), 'Oasis'

(OGT), and ‘Tiffany’ (TTG) were established on September 10, 2021, using an ALMACO plot drill (ALMACO, Nevada, IA) at the recommended seeding rate of 10 lb PLS ac^{-1}. The standard recommended date is due to the small seed size with approximately 1.2 M seeds per pound. Plots were 6 ft x 10 ft and fertilized with 100 lb N ac^{-1} in split applications using urea ammonium sulfate (33-0-0-18S) when plants reached a height of two inches after emergence and 50 lb N ac^{-1} applied after the first harvest.

The study was harvested to a 3-inch stubble with a self-propel Cub Cadet mower equipped with a bagging system on October 14 and November 8 when 50% of the plots reached 12 to 15 inches tall (vegetative to early boot stage). Forage subsamples were ground to pass through a 1-mm screen using a Wiley mill (Thomas Scientific, Swedesboro, NJ) for nutritive analysis. Samples were analyzed for crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), *in vitro* dry matter digestibility at 48h (IVTDMD), water-soluble carbohydrates (WSC), and starch using a Foss DS2500 Near Infra-red Reflectance Spectroscopy (NIRS) instrument (Foss North America, Eden Prairie, MN). The analysis was conducted using the 2021 grass hay equation developed by the NIRS Forage and Feed Testing Consortium (Berea, KY).

Before each harvest, percentages of green canopy cover (GCC) were obtained by taking two images at 3-ft above the canopy in the center of each plot and analyzed using the Canopeo® app (Oklahoma State University, OK) installed in MatLab (The MathWorks, Inc., MA). Leaf Area Index (LAI) was measured using a line quantum sensor (LI-2000; Li-Cor, Lincoln, NE). Normalized Difference Vegetation Index (NDVI) was taken using a hand-held GreenSeeker® crop sensing system (Trimble, Sunnyvale, CA).

Data were analyzed using harvest frequency as a repeated measure for each of the dependent variables. Data were further analyzed in the PROC GLIMMIX of SAS and the least significant difference was used to determine treatment differences at $\alpha = 0.05$.

Results and Discussion

Weather

There was excess precipitation (37 in) during the first half of 2021 in Starkville, MS but during the establishment and growth of teff from September to November, there was a precipitation deficit of four inches when compared to the long-term normal. Mean temperature and growing degree days (GDD) were only above normal in October before the first harvest. Despite cooler temperatures in September, teff grass was harvested at the boot stage 35 days after planting.

Table 1. Weather conditions during the preliminary evaluation of teff grass cultivars in 2021 at Starkville, MS along with the 30-yr normal for each parameter.

	Month				
Weather Variable	***Aug***	***Sep***	***Oct***	***Nov***	***Dec***
Precipitation (in)	11.6	4.4	2.7	1.2	3.8
30-yr Normal (in)	4.5	4.0	3.9	4.4	5.3
Deviation (in)	7.1	0.4	-1.2	-3.2	-1.5
Max Temp (°F)	90.6	85.2	78.5	65.8	67.7
Min Temp (°F)	71.6	64.4	56.6	38.2	45.5
Mean Temp (°F)	81.1	74.8	67.6	52.0	56.6
30-yr Normal (°F)	80.9	75.1	64.1	52.6	46.6
Deviation (°F)	0.2	-0.3	3.5	-0.6	10.0
GDD_{50}*	973	751	553	110	270
30-yr Normal	961	765	455	154	82
Deviation	12	-14	98	-44	188

*Growing degree days (GDD) base 50.

Physiological measures

Green canopy cover (GCC), LAI, and NDVI were affected by the harvest date. There was a 10, 41, and 10% decrease in GCC, LAI, and NDVI between the first and second harvests, respectively. Across harvest dates, ‘Oasis’ had significantly lower GCC compared to ‘Charger’ and ‘Corvallis’ (Fig. 1) but still within acceptable levels (>80%) that will have a diminished impact on biomass production. On the other hand, ‘Tiffany’ had greater GCC and was significantly different when compared to ‘Bonus’ and ‘Charger’. There were significant differences in LAI among cultivars with ‘Charger’ and ‘Oasis’ exhibiting the greatest (2.8) and lowest (2.4) LAI, respectively. No differences in NDVI were observed among cultivars and this should be expected since N fertilization was the same for all the cultivars after germination and the first cut. Overall, cultivars had similar physiological responses under fall Mississippi conditions

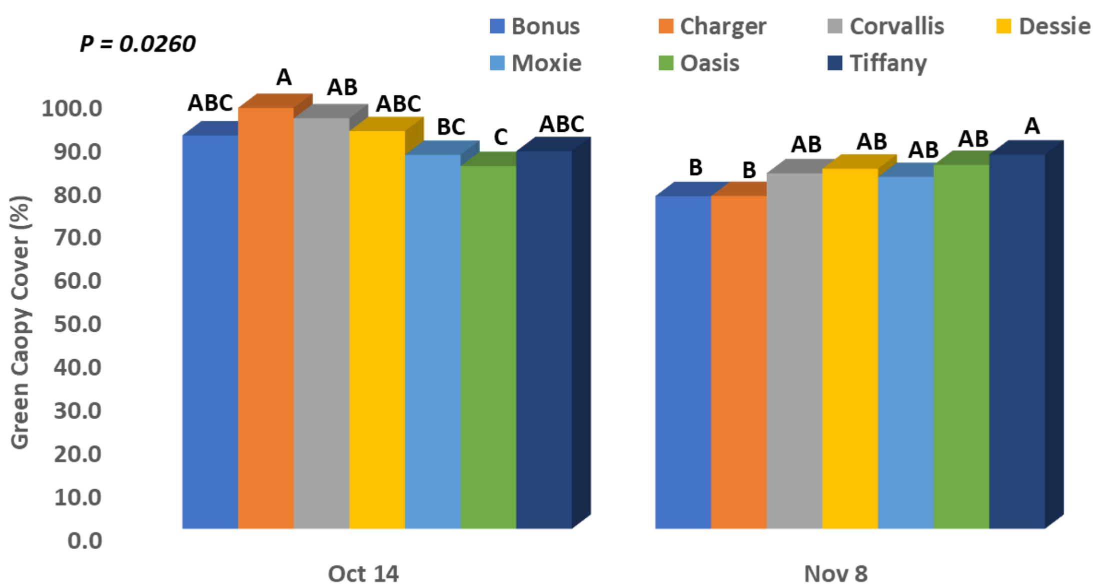

Figure 1. Influence of harvest date on green canopy cover (GCC) of different teff grass cultivars at Starkville, MS in fall 2021. Letters are for comparison of significant mean differences of cultivars within harvest dates at α = 0.05 probability level.

Biomass production

The mean biomass production across cultivars was 1,378 lb DM ac^{-1} with 70% of biomass production occurring during the first harvest (October 13). There were no significant differences in seasonal or harvest biomass production among cultivars (Fig. 2). The cultivars 'Dessie', 'Moxie', and 'Oasis' were the lower-yielding cultivars in the study. Yield comparisons to 'Moxie' (1225 lb DM ac^{-1}) indicated yield increases from 4 ('Oasis') to 23% ('Corvallis'). Despite cooler temperatures during the growing period, yields are very comparable to yields previously reported in the region (Hancock and Durham, 2009; Lemus et al., 2016). Due to the short growth duration in the fall, the best recommendation will be planting in mid-May to early June with a window of opportunity for a double-cropping annual hay system in the southern USA.

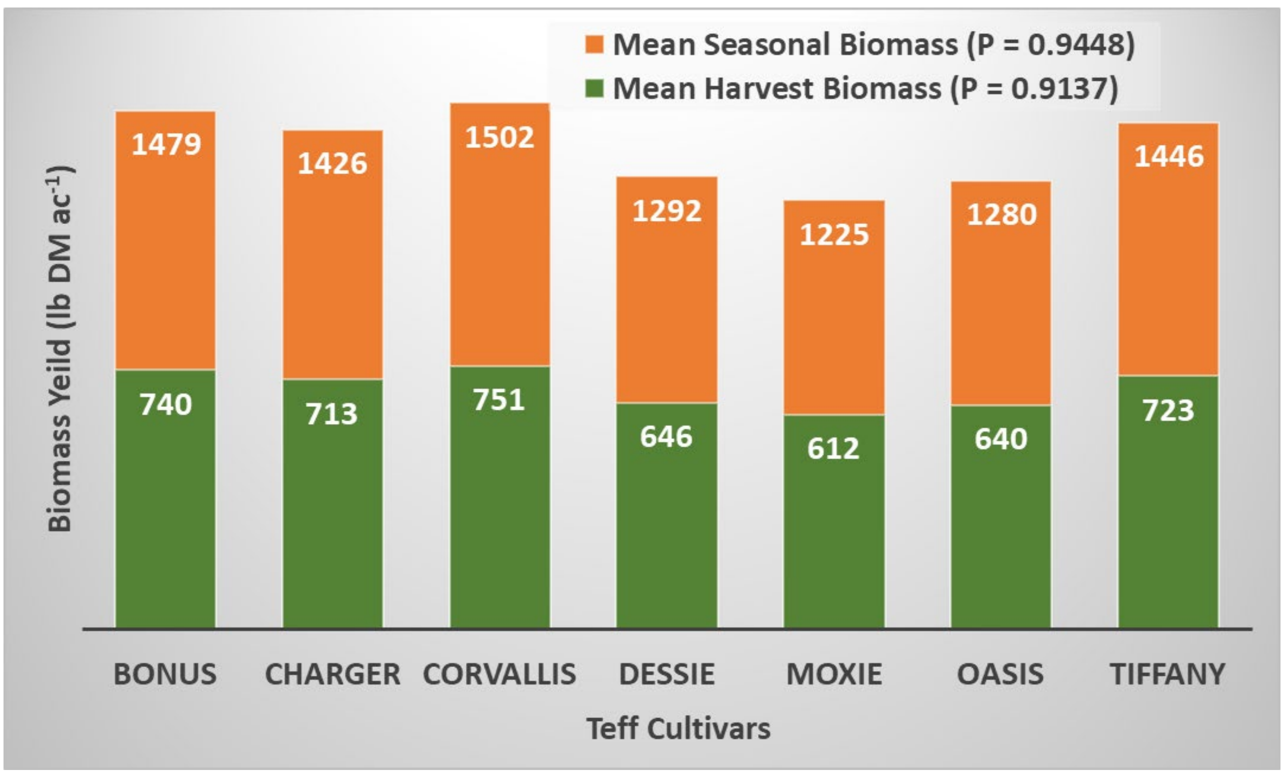

Figure 2. Mean seasonal and harvest biomass yield of seven teff grass cultivars at Starkville, MS during the fall of 2021.

Nutritive value

There were no significant differences in nutritive values among cultivars. Fiber levels (ADF and NDF) are consistent with those reported in the literature within the growth stage reported in this study. The levels for ADF range from 32 to 40% while the NDF range from 52 to 70%, respectively, depending on the stage of maturity (Miller, 2011). However, the sampling date did impact CP and starch concentrations (Table 2). The November harvest had a greater CP concentration but a lower starch concentration. Previous studies have indicated CP levels ranging from 12 to 18% in teff production (Miller, 2011). Our data indicated CP concentrations of 28 (harvest 1) and 26.6% (harvest 2), respectively. These values are too high which raises concerns about nitrate accumulation. The high CP concentrations in the fall could be attributed to a very wet fall with cooler temperatures that could have impacted growth and the utilization of the applied nitrogen. While teff has no known toxicity issues, samples analyzed for nitrates (NO_3-N) indicated levels of 1,343 ppm (harvest 1) and 464 ppm (harvest 2). This means that nitrate levels of 1,000 ppm or less are considered safe under all conditions. On the other hand, nitrate levels of about 1,000 ppm will create a limitation on feeding forage as part of the total ration depending on the type of livestock and growth stage. No differences in NO_3-N were observed among cultivars. This is an indication that reduced nitrogen fertility might be important in the fall with reduced plant growth.

Table 2. Influence of harvest date on the nutritive value of teff grass at Starkville, MS in the fall of 2021. Letters are for the comparison of mean differences within a nutritive value parameter between harvest dates at the $\alpha = 0.05$ probability level.

	Nutritive Value Parameters					
Harvest Date	**CP**	**ADF**	**NDF**	**IVTDMD**	**WSC**	**Starch**
	---------------------------------- % DM ----------------------------------					
13-Oct	26.6 B	24.2	50.7	87.1	7.0	2.3 A
8-Nov	28.0 A	24.7	50.9	86.7	7.0	0.7 B

Conclusions

Teff performed below mean production as a fall forage in Mississippi compared to previously reported summer biomass production. The cultivars tended to mature early, and as a result forage quality and yield suffered. Based on previous research that addresses nitrogen fertility and cutting management in the southern USA, teff might have limited utilization as an annual forage crop compared to traditional warm-season annual crops (crabgrass, pearl millet, forage sorghum, etc.) due to its yield potential. While teff has no known toxicity issues, like many other warm-season annual types of grass, it may accumulate nitrates (NO_3) if conditions are conducive to doing so such as cooler temperatures in the fall that dimmish growth. Because nitrates persist in the hay, nutritive value and toxicity testing will continue to play a major role in determining how to manage and utilize teff in a feeding system. Further assessment of genotype variability, performance, and nutritive value across planting dates in specific environments across the southern USA is key for future teff grass utilization and exploring the full potential of teff for forage production in the region.

Conflict of Interest

The authors declare that there is no conflict of interest.

Acknowledgement

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