QUALITY AND YIELD OF SEVEN FORAGES GROWN UNDER PARTIAL SHADING OF A SIMULATED SILVOPASTORAL SYSTEM IN EAST TEXAS

J. Hill, K. Farrish, B. Oswald, L. Young, and A. Shadow[1]

Abstract—The goal of this project is to evaluate the growth and nutritional characteristics of seven forages, including various warm season native grasses, grown under simulated partial shading (50 percent typical of a loblolly pine silvopastoral system in east Texas. The results are from year two of a three year study. In order to meet the overall objective, individual, slatted shade structures were constructed that simulate the quantity, quality, and overall light regime found beneath loblolly pine stands arranged for silvopasture. The forages selected for the study include 'Tifton 9' bahiagrass (*Paspalum notatum*), 'Tifton 85' bermudagrass (*Cynodon dactylon*), 'Alamo' switchgrass (*Panicum virgatum),* 'Kaw' Big Bluestem (*Andropogon gerardii*), 'Americus' Indiangrass (*Sorghastrum nutans*), 'Harrison' Florida Paspalum (*Paspalum floridanum*), and Nacogdoches Eastern gamagrass (*Tripsacum dactyloides*). The experimental design is a two-way factorial design with forage type randomly assigned to plots, and shade treatment (0 percent, 50 percent) randomly assigned within forage type. Forage produced beneath the slats is managed to simulate intensive grazing, with recognition of minimum and optimal grazing heights based on forage type. Data is presented on dry matter yield, as well as several nutritional parameters including *in vitro* true digestibility (IVTD), crude protein (CP), neutral detergent fiber (NDF), and acid detergent fiber (ADF). Results show that significant differences existed in all parameters ($p < 0.0001$) due to forage type. Significant differences existed due to shade treatment for all parameters except for ADF ($p = 0.1324$). Results showed that shade improved forage quality overall. It reduced NDF ($p = 0.0399$), increased CP ($p = 0.0007$), and increased digestibility IVTD ($p < 0.0001$). The study is currently in year two of three. Results are preliminary.

INTRODUCTION

The number of people dependent on the world's resources has greatly increased (Brown and others 2011). With this increase in human population, there is an increased need for land, food, fiber, and energy that places strain on the world's resources. Production practices must be implemented that will utilize scarce resources in the most efficient way possible while insuring the long term productivity of the land. Agroforestry provides an alternative to traditional agricultural practices and has been shown to reduce nutrient runoff (Verchot and others 2007; Bambo, and others 2009a), increase production (Belsky, 1994; Jose, 2009), and provide more sustainable options for the production of food and fiber (Verchot, and others 2007; Jose, 2009, Aiyeloja and others 2011). Agroforestry combines trees, crops, and possibly grazing animals in a single land base, and provides long-term financial stability for producers while reducing the environmental impact seen in traditional agricultural systems (Jose, 2009). Agroforestry provides an opportunity for a producer to diversify production, allowing the producer to meet their current income needs while investing in a future harvest that will provide long-term economic stability (AFTA, 2000; Bambo and others 2009b; Jose, 2009).

One type of agroforestry, silvopasture, is an intensively managed system that combines trees with pasture and grazing. This system has been shown to increase nutritional quality of warm and cool season grass species (Burner and Brauer, 2003; Buergler and others 2005) as well as increase animal health by providing shelter from heat and cold (Buergler and others 2006; Karki and Goodman, 2010). This system provides an annual income to the producer in the form of cattle, while providing high quality sawtimber for harvest in the future (Grado, 2001). In addition, management of the tree crop to improve stem quality is easily accomplished due to the spacing of trees, while the forage yields of some species under partial shade (up to 50 percent remain similar to that of traditional fields in full sun (AFTA, 2000).

East Texas is unique in that it has high productive potential for a silvopasture production system. Warm season forages provide long grazing periods that last from approximately April through September,

[1]Arthur Temple College of Forestry and Agriculture, Stephen F. Austin State University; USDA NRCS East Texas Plant Materials Center, Nacogdoches, Texas, 75965 respectively

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and sometimes extending into October. Rainfall is relatively high, which would potentially offset some of the moisture competition among the intercropped trees and forages. Also, species common to the area such as loblolly pine (*Pinus taeda*) have shallow lateral roots that allow stratification with the deeper roots of many warm season grasses. Cattle production can be sustained without supplemental feeding almost year round with the use of cool season forages, and there are many legumes available that can extend the grazing period and add nitrogen to the system through symbiosis and N_2 fixation. This also serves to provide additional protein to cattle and can enhance overall gains.

Other environmental factors exist that make this area especially favorable for silvopasture. These include sensitive watersheds that could benefit from the ecosystem services provided by this system of production. Also, marginal overall land productivity inherent to the region may be improved with a multiple production strategy.

There is a lack of site specific research that has been completed on forage quality in a silvopastoral operation in this region. Without data on the potential yields and quality from specific forages, it is unlikely that producers will be willing to move into this system of production. This project seeks to fill information gaps by determining the yield and quality of specific forages grown under the partially shaded environment of a simulated loblolly pine silvopasture system.

METHODS

Sites

Plots were located at the NRCS East Texas Plant Material Center in Nacogdoches Texas. Plots were installed on the Woden soil series (coarse-loamy, siliceous, semiactive, thermic Typic Paleudalfs) characterized by very deep, moderately-well drained, slightly acidic soils formed from alluvial sediments, and recently cleared of loblolly pine forest. Roundup ready soybeans were maintained as a cover crop on the site prior to the establishment of the grasses for this study.

Procedures

To meet the overall goal of this project, slatted lath shade structures were constructed that simulated the quantity, quality, and overall behavior of the light found under a loblolly pine canopy in a silvopasture setting. Shade slats were used for this study instead of cloth in order to most closely mimic light regimes under a loblolly pine silvopastoral canopy, while still allowing for controlled treatments. The size of the slat structures were sufficiently small to cover a single 1.22 m^2 plot, and to allow for overall easy mobility of the structures during forage management. Individual plants were started in trays in a greenhouse in order to bypass the establishment periods of two to three years common to native grasses. Plugs were hardened off for a week in a shade house before field transplanting. Forage was planted in four rows of twelve plugs, three per linear foot. The total number of plugs in each plot is 48. The middle two square feet are considered the sample zone and forage is clipped at the appropriate height and bagged for analyses. The remaining one foot perimeter zone is a buffer zone that reduces edge effects. This portion of the plot is clipped at the same time as the sample portion but is discarded out of the plot area. Specifically, wooden laths were used to produce shade on a frame of Charlotte PVC pipe 1inch x 20 feet schedule 40 PVC plain end pipe (Lowes: Item #: 23975 | Model #: PVC 04010B 0800). The PVC pipe was cut into 1.22 m (4 foot) sections and attached into a cubical shape using LASCO 1inch Schedule 40 Side Outlet Elbows (Lowes: Item #: 315499 | Model #: 413010RMC). The top portion of the frame was adjustable, achieved by drilling holes in the top of the upper four elbows to create an opening through which the side legs could slide, so that the top could be maintained at an approximate height of 0.3 m (0.98foot) above the forage canopy (Varella and others 2011). The slats not only achieved the same light quantity found in this system (50 percent, but also allowed for recreation of the intermittent light characteristic of sub-canopy environments. The overall light behavior contributes to changes in the morphology of understory vegetation beyond differences in light quantity (Varella and others 2011). Light quality and quantity found beneath the slats were manually measured and compared to light under loblolly pine canopy cover using a FieldSpec® HandHeld Spectroradiometer (model FS HH 325-1075) by ASD, Inc (2555 55th Street, Suite 100 Boulder, CO 80301) with Full Sky Irradiance Reverse Cosine Receptor (RCR) attached. The total shading of 50 percent selected for this study is slightly above the known upper limits of acceptable shading for warm season grasses of approximately 45 percent (Lin and others 2001).

Plots were established using a 7x2, factorial design (seven forages and two shade levels, 0 and 50 percent and data were analyzed with a Model I ANOVA using SAS 9.3 for Windows (SAS Institute, Inc.). The factors were fixed and included seven forages and two light treatments (full sun, 50 percent full sun). All factors were completely randomly assigned to treatment plots. The forages selected for the study include 'Tifton 9' bahiagrass (*Paspalum notatum*), 'Tifton 85' bermudagrass (*Cynodon dactylon*), 'Alamo' switchgrass (*Panicum virgatum),* 'Kaw' Big Bluestem (*Andropogon gerardii*), 'Americus' Indiangrass (*Sorghastrum nutans*), 'Harrison' Florida Paspalum (*Paspalum floridanum*), and Nacogdoches Eastern gamagrass (*Tripsacum dactyloides*).

Shade slats were constructed during the winter 2013 and erected during spring emergence. Fifteen collections were conducted in year one, and 24 collections were completed in year two. Each plot was not cut at each collection, because plots were managed individually. Plots were harvested when heights reached 55-60 cm down to a minimum height of 20 cm for natives, and 10 cm for introduced grasses, to simulate intensive grazing. During the peak growing season plots typically reached height and were harvested every one and a half to two weeks. A total of 539 samples were collected during the 2013 growing season, and at least 800 samples were harvested in season two. Preliminary results for year one were presented at the ASSA, CSSA, and SSSA 2013 annual meetings in Tampa, Florida November 3-6 (Hill, J.E., K.W. Farrish, B. Oswald, J.L. Young and A. Shadow. 2013. Quality and yield of seven forages grown under partial shading of simulated silvopastoral production system in east Texas. Poster presentation.); preliminary results for year two were presented at the ASSA, CSSA, SSSA 2014 annual meetings in Long Beach, California November 2-5 (Hill, J.E., K.W. Farrish, J.L. Young, B. Oswald, and A. Shadow. 2014. Quality and yield of seven forages grown under partial shading of a simulated silvopasture system in east Texas. Oral presentation)

Plant heights were recorded, and then samples were harvested and ground to 1 mm. Samples were analyzed for dry matter yield (DMY), crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), and *in vitro* true digestibility (IVTD) (NIRS only). Chemical analyses were conducted at Stephen F. Austin State University Soil, Plant, and Water Analysis Laboratory in Nacogdoches, Texas and included the following: *in vitro* true digestibility (IVTD) via near infrared reflectance spectroscopy (NIRS), CP (NIRS), and neutral detergent fiber (NDF) and acid detergent fiber (ADF) content using Van Soest's detergent method. Soil samples were collected from the research plots and mineral content analyzed in order to determine and define nutritional status of the soil, and for the purpose of fertilizer application. Other measurements included soil temperature and moisture content.

RESULTS AND DISCUSSION

For the establishment year (2013), data suggested little or no shade effect on any of the above constituents or properties ($p = 0.1305\text{-}0.989$) except for height ($p < 0.0001$). Shaded plants were taller (mean = 5cm) except for gamagrass (*Tripsacum dactyloides*) and switchgrass (*Panicum virgatum*), where there were no significant differences ($p = 0.5687$ and 0.0593 respectively).

There were no significant differences in yield based on shade treatment ($p = 0.9463$) in year one. However, there was a trend for shaded plants to exhibit lower yields except for Tifton 9 and big bluestem, which were unaffected. There were differences in yield due to forage type ($p<0.0001$); Tifton 9 bahiagrass and Florida Paspalum showed the highest yields regardless of shade treatment. Table 1 shows yields for growing season two.

Overall, year two was much more productive than the establishment year. This is not surprising because native grasses are known to frequently require lengthy establishment periods of up to two or three years. Results show that significant differences existed in all parameters ($p < 0.0001$) due to forage type. Significant differences existed due to shade treatment for all parameters except for ADF ($p = 0.1324$). Results showed that shade improved forage quality overall (table 2). It reduced NDF ($p = 0.0399$), increased CP ($p = 0.0007$), and increased digestibility IVTD ($p < 0.0001$). As a result, TDN which is calculated from NDF, ADF, and CP was also significantly increased under shade ($p = 0.0241$).

Table 1—Comparison of yields in Mg ha^{-1} for sunny versus 50% shaded plots. Each of the forage types in the study are compared side by side and results include only growing season two

	Sunny	Shaded
	(Mg ha^{-1})	
Kaw' big bluestem	7.30	4.70
Nacogdoches' eastern gamagrass	10.10	8.70
Americus' indiangrass	9.80	7.20
Harrison' Florida paspalum	7.60	5.30
Alamo' switchgrass	8.20	5.20
Tifton 85 bermudagrass	5.30	3.30
Tifton 9 bahiagrass	14.50	11.00

Table 2—Results of shade treatment for growing season 2014 showing improved overall quality of forage. All parameters were analyzed at α = 0.005 and all were significant except for ADF

Parameter	Sunny	Shade	P- value
Dry matter yield (Mg ha^{-1})	9.1	6.5	0.0021
Crude protein (g kg^{-1})	14.39	15.65	0.0007
Neutral detergent fiber (g kg^{-1})	65.74	64.76	0.0399
Acid detergent fiber (g kg^{-1})	35.16	35.57	(0.1324)
In vitro true digestibility (g kg^{-1})	65.65	67.31	< 0.0001
Soil moisture (kg HOH kg^{-1} soil)	0.0388	0.0497	0.0222
Soil temperature (C°)	34.6	32.7	0.0084

Tukey and SNK means separations tests were performed on all parameters that showed significant differences. The results of each of these analyses consistently show that switchgrass, Florida paspalum, and Eastern gamagrass are the "best" forages in year two. Furthermore, yields were only slightly reduced in Florida paspalum and Eastern gamagrass by shade, and reduced by approximately half for switchgrass. However, switchgrass has shown high yields in both sun and shade, as well as persistence under intensive defoliation. Eastern gamagrass appears to exhibit some shade tolerance, but persistence is questionable based on visual observation of plots and is likely due to excessive defoliation or to close planting. Florida paspalum also has exhibited some decline, and year three will be a good indicator of the level of decline that can be expected.

Other analyses described in the objectives that have been completed include analyses of soil temperature and moisture differences between shaded and non-shaded plots. No differences in soil moisture were detected in year one, but significant increases in moisture under shade were detected in all plots in year two. Optimal soil temperature (31°C) for root growth was exceeded throughout the study, but shade treatment significantly reduced ($p < 0.0001$) plot temperatures by about 2 C° on plots with forage growth. Temperature reduction was over 4 C° ($p= 0.0058$) for bare mineral plots.

The forages that performed well, but appear to be declining include 'Nacogdoches' Eastern gamagrass (*Tripsacum dactyloides*) and 'Harrison' Florida paspalum (*Paspalum floridanum*). This is possibly due to close planting instead of defoliation or shade because native grasses are typically planted one plant per square foot in pastures whereas there are three plants per linear foot in the current study.

The forages that have performed well *and* have persisted well at end of season 2 include 'Alamo' switchgrass (*Panicum virgatum*) and Tifton 9 bahiagrass (*Paspalum notatum*). It is important to note that big bluestem appears to be improving over time, a trend that was not apparent until the end of season two. Year three results will be included in future papers.

Several warm season grasses, including native grasses, may be productive inputs to a silvopasture system; however, certain recommendations such as grazing intensity (grazing height and frequency) need to be evaluated more closely. The application of shade has positively affected the forage quality in this study through the end of season two. Dry matter yields were lower but the overall possible beef cattle gains per individual animal were higher when estimated using Foragval (TAMU), a software calculator used to estimate beef cattle gains based on forage quality parameters.

In conclusion, intake, digestibility, and metabolism determine quality of forage, and all three of these factors were improved under shade at the end of season two of three. Micro-environments under partial shade were cooler and moister which improves nutrient cycling, plant growth, beef cattle gains, and soil quality. Based on the preliminary results of this study, it is recommended that further research be completed on switchgrass, gamagrass, and big bluestem. Although the bahiagrass is the most productive in this study, it is avoided by many producers because it tends to out-compete adjacent, higher quality fields. Bahiagrass is known to quickly lose quality with maturity, and to produce seed heads early before harvestable yields have been achieved. This makes it difficult for producers who can either harvest early and get high quality and low yields, or harvest later and get higher yields of low quality forage. Further studies on the top native grass performers from this group should be conducted that include a grazing trial and various defoliation levels. It is recommended that further studies focus on Eastern gamagrass and Florida paspalum, but with lighter grazing intensities. Also, it appears big bluestem is increasing in yields and quality, and seems to be relatively unaffected by shade. No data is available at this time but will be presented after the current and third growing season.

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