Quality and Quantity Evaluations of Shade Grown Forages

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ABSTRACT

Seven legumes were grown during the summer-fall of 2000, at the Horticulture and Agroforestry Research Center (39° 01' N, 92° 46' W) near New Franklin, MO. The forages were grown in 7.5L white pots placed on light-colored gravel either under full sunlight, 45% sunlight, or 20% sunlight created by a shade cloth over a rectangular frame. Drip irrigation was applied once a day. Forages were grown in a well-drained potting medium with a complete slow-release fertilizer. Forages were sown and germinated in the greenhouse between May 18 and June 14 and put outside into the shade study on June 21 to June 30. Forages were harvested in August and October. All forages were analyzed for their content of N (nitrogen), NDF (neutral detergent fiber), ADF (acid detergent fiber), and NDFIS (neutral detergent fiber in situ digestibility). Three of the legume species had greater ($P>0.05$) forage production at 45% than in full sunlight. As the percentage sunlight was decreased, most forage species studied had greater ($P>0.05$) concentrations of nitrogen and fiber. Fiber digestibility was higher ($P>0.05$) or unchanged ($P>0.05$) for most forage species as sunlight intensity was decreased. Several legume species have the potential to be used in a silvopastoral practice to improve forage productivity and quality as compared to an open pasture environment.

Keywords: fiber digestibility, light, forage quality

Introduction

Agroforestry is a collective name given to a land-use system that incorporates woody perennials, herbaceous plants, and/or livestock together. Both ecological and economic benefits are obtained from this kind of system. Agroforestry systems are both stable and sustainable. While agroforestry has been practiced for thousands of years, only recently has it been accepted as science. The use of trees in an agroforestry system may result in more efficient use of sunlight, moisture, and plant nutrients. A well-designed system should satisfy three basic criteria: productivity, sustainability, and adaptability.

Silvopasture is an agroforestry practice used to intensively manage the production of livestock, forages, and trees in a structured practice of planned interactions. These interactions are managed for simultaneous production of wood products, high quality forage, and livestock on an environmentally sustainable basis. Silvopasture can be used to maximize the growth potential from an acre of land by more fully utilizing the horizontal and vertical growing space.

Photosynthesis is a primary mechanism for increasing useable energy in biological systems. With forage plants, we have a manageable process for capturing solar energy and converting it into useful products, mainly through ruminants which are dependent on forages to meet their nutrient needs (Nelson, 1988). Research performed by Garrett and Kurtz, (1983) and Lin, (1999) demonstrated an improvement in yield of some forages when grown in shade as compared to full sunlight. Plants respond differently both physiologically and morphologically to shade and vary considerably in regard to their shade tolerance (Bjorkman, 1966; Boardman, 1977). Grasses in general respond to shade by increasing their leaf-area and shoot-to-root ratio to increase light interception (Cooper and Tainton, 1968; Allard et al., 1991; Kephart et al., 1992). Lin (1999) reported that leaves of grasses grown at 50% shade had a leaf blade area that was 13% to 126% larger than leaves grown in full sun. As the shade level increased to 80%, the leaf blade area of most grasses was 19% to 220% greater than for plants grown under full sun. The effect of shade stress on forage quality also varies. Kephart and Buxton (1993) illustrated that reduction of ambient sunlight to 37 and 70% of full intensity resulted in increased nitrogen concentration, decreased neutral detergent fiber, enhanced degradability by in vitro dry matter digestibility while cell-wall composition remained constant. By knowing how forage quality changes in response to different shade intensities, we can more effectively use and manage forage species in an agroforestry practice. This experiment was used to examine the effects of shade on various legume species to determine biomass production and nutritional quality.

Materials and Methods

Seven legume species were used in this shade study (Table 1). Forage species were grown from April to October, 2000. The forages were germinated during the first week in May, 2000, in a greenhouse at the University of Missouri Horticulture and Agroforestry Research Center, New Franklin, Missouri (longitude 92° 46' W; latitude 39° 01' N). The seed were sown in germination flats filled with Scott's Metro Mix 380 as a soil medium, with one forage species per flat. A water soluble fertilizer (Peter's 20-20-20) was added, using a hose siphon at 1.72 grams per 15.1 L of water. Seedlings were transplanted to 7.6 cm pots in a greenhouse between May 10 and May 26. On June 21 to June 30, three plants each were transplanted outside into 7.5 L white pots and placed on white gravel. A growth medium (containing a horticulture mix of composted pine bark, medium grade vermiculite, Canadian sphagnum peat moss, horticulture perlite, starter nutrient charge and wetting agent) was used. Water was supplied once per day by a trickle irrigation system controlled by an electronic timer. Forages were harvested on August 7 (cutting 1) and October 17 (cutting 2).

The treatments consisted of three levels of sunlight: 100%, 45% and 20% full sunlight. Differing levels of sunlight were created by placing polypropylene fabric over rectangular frames (5-m wide x 15-m long x 2.5-m high). Three each of the sunlight treatments were randomly assigned to nine frames. Six pots of each plant species were placed in each frame. The pots were placed 50 cm apart between each row. Forages from the six pots were combined for one composite sample before dry weight determination.

Forages were harvested by clipping all material 5 cm above ground level. Clipped material was then dried at 45°C in a forced air oven for a minimum of 72 hours. Dried forage samples were ground in a Wiley mill through a 2-mm screen. Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined (Goering and Van Soest, 1970) by weighing out a 0.5 to 1.0 g sample into a 600 mL Berzelius beaker. One hundred mL of NDF or ADF solution was added and refluxed for one hour. After refluxing, the samples were filtered, dried overnight in a 105°C oven and reweighed. Nitrogen (N) was determined by weighing out a 0.05 to 0.1 g sample into a foil pouch and then analyzed using a LECO Model FP-248 Nitrogen Determinator. Neutral detergent fiber in situ digestibility (NDFIS) was determined by weighing out 5.0 g of sample into Dacron mesh bags. The bags were incubated in the rumen of forage-fed cows for 48 hours. The bags were removed, rinsed and dried overnight at 55°C and reweighed. The NDF procedure was then conducted on the dried residue to determine digestibility.

The experiment was conducted as a randomized complete block design where shade was used as the main plots and forage species as subplots. Analysis of variance was performed using the general linear model of the Statistical Analysis System. The least significant difference (LSD) program was conducted using a split plot LSD testing for significant differences at the ($P<0.05$) level.

Table 1. Forage legumes used in 2000 shade study.

Species	Scientific Name
Creeping Alfalfa	*Medicago sativa L.*
Alfalfa	*Medicago sativa L.*
Birdsfoot trefoil 'Norcen'	*Lotus corniculatus L.*
Rhizomatous (R) Birdsfoot trefoil	*Lotus corniculatus L.*
Alsike clover	*Trifolium hybridum L.*
Korean lespedeza	*Kummerowia stipulacea [Maxim.]*
Crimson clover	*Trifolium incarnatum L.*

Results

Forage Dry Weight Production

Forage dry weight production was determined as an average weight per pot in grams (g) (Table 2). Only one legume species (Korean lespedeza) showed significant decreases ($P<0.05$) in production between 100% and 45% sunlight. Three legume species (Crimson clover, Birdsfoot trefoil, and rhizomatous Birdsfoot trefoil) yielded significant increases ($P<0.05$) in production when grown in 45% sunlight as compared to full sun. All species produced significantly less ($P<0.05$) biomass when grown at 20% light compared to 45% or full sunlight.

Table 2. DM (g) produced by legume species grown in 2000 shade study.

Forage Species	Cutting 1 % sunlight			Cutting 2 % sunlight		
	100	45	20	100	45	20
Creeping alfalfa	9.7^{a}	11.5^{a}	3.4^{b}	11.7^{a}	14.8^{a}	4.3^{b}
Alfalfa	10.3^{a}	12.6^{a}	3.1^{b}	14.5^{a}	16.7^{a}	4.7^{b}
Birdsfoot trefoil 'Norcen'	7.8^{a}	7.4^{a}	3.7^{b}	11.7^{b}	23.9^{a}	7.2^{c}
(R) Birdsfoot trefoil	8.7^{a}	6.0^{a}	2.7^{b}	8.3^{b}	13.1^{a}	5.3^{c}
Alsike clover	14.7^{a}	16.0^{a}	3.3^{b}	16.9^{a}	18.8^{a}	5.0^{b}
Korean lespedeza	24.3^{a}	21.0^{a}	7.1^{b}	25.3^{a}	7.8^{b}	2.7^{c}
Crimson clover	5.0^{b}	8.6^{a}	2.0^{c}	6.5^{b}	14.2^{a}	1.1^{c}

^{a,b,c} Means within a row and cutting with unlike superscripts are significantly different (P<0.05). Comparisons were made within cuttings and not between cuttings.

Nitrogen (N)

Most of the legumes studied had increased nitrogen concentration when grown under shaded conditions as compared to full sun (Table 3). Three species (Creeping alfalfa, Birdsfoot trefoil, (R) Birdsfoot trefoil) produced significantly higher (P<0.05) levels of N at 45% sun as compared to full sun.

Table 3. N (%) of legume species grown in 2000 shade study.

Forage Species	Cutting 1 % sunlight			Cutting 2 % sunlight		
	100	45	20	100	45	20
Creeping alfalfa	3.06^{b}	3.67^{a}	$3.33^{a,b}$	2.36^{a}	2.72^{a}	–
Alfalfa	3.31^{a}	3.45^{a}	3.75^{a}	–	–	3.39^{a}
Birdsfoot trefoil 'Norcen'	1.61^{b}	$2.25^{a,b}$	3.04^{a}	3.43^{a}	3.55^{a}	3.04^{a}
(R) Birdsfoot trefoil	1.87^{b}	$2.25^{a,b}$	2.98^{a}	3.35^{a}	3.35^{a}	3.13^{a}
Alsike clover	3.42^{a}	3.38^{a}	3.46^{a}	–	–	–
Korean lespedeza	2.23^{a}	2.61^{a}	3.03^{a}	3.40^{a}	3.61^{a}	2.78^{a}
Crimson clover	2.66^{a}	3.41^{a}	3.31^{a}	–	–	–

^{a,b,c} Means within a row and cutting with unlike superscripts are significantly different (P<0.05). Comparisons were made within cuttings and not between cuttings

Neutral Detergent Fiber (NDF)

Only two species (alfalfa and crimson clover) showed a significant increase (P<0.05) in NDF content when grown under 100% light as compared to 45% light for cutting 1 (Table 4). For cutting 2 only Birdsfoot trefoil 'Norcen' and crimson clover showed an increase in NDF.

Table 4. NDF (%) of legume species grown in 2000 shade study.

Forage Species	Cutting 1 % sunlight			Cutting 2 % sunlight		
	100	45	20	100	45	20
Creeping alfalfa	29.6[a]	35.2[a]	35.0[a]	50.3[a]	47.6[a]	41.6[b]
Alfalfa	28.0[b]	36.9[a]	38.0[a]	30.7[a]	32.5[a]	30.7[a]
Birdsfoot trefoil 'Norcen'	32.7[b]	39.6[a,b]	43.3[a]	25.3[b]	37.0[a]	36.2[a]
(R) Birdsfoot trefoil	36.0[a]	39.2[a]	38.3[a]	29.7[a]	31.3[a]	34.9[a]
Alsike clover	27.0[a]	32.2[a]	31.2[a]	—	—	—
Korean lespedeza	38.1[b]	41.0[b]	47.9[a]	48.3[a]	48.7[a]	48.8[a]
Crimson clover	31.8[b]	43.7[a]	40.3[a]	43.0[b]	48.5[a]	50.2[a]

[a,b,c] Means within a row and cutting with unlike superscripts are significantly different ($P<0.05$). Comparisons were made within cuttings and not between cuttings

Acid Detergent Fiber (ADF)

ADF followed the same pattern as NDF except for Alsike clover which had a significant increase ($P<0.05$) in ADF when grown at 100% light as compared to 45% light (Table 5).

Table 5. ADF (%) of legume species grown in 2000 shade study.

Forage Species	Cutting 1 % sunlight			Cutting 2 % sunlight		
	100	45	20	100	45	20
Creeping alfalfa	22.0[a]	24.0[a]	25.7[a]	36.1[a]	36.6[a]	31.2[b]
Alfalfa	20.7[b]	26.9[a]	28.7[a]	21.1[a]	23.2[a]	24.0[a]
Birdsfoot trefoil 'Norcen'	24.8[b]	27.0[a,b]	33.0[a]	17.3[b]	25.4[a]	25.4[a]
(R) Birdsfoot trefoil	27.4[a]	30.7[a]	30.4[a]	20.8[b]	22.2[a,b]	24.6[a]
Alsike clover	19.8[b]	23.4[a]	24.3[a]	—	—	—
Korean lespedeza	29.0[b]	30.6[b]	42.7[a]	35.1[a]	36.9[a]	37.8[a]
Crimson clover	19.4[b]	25.8[a]	27.4[a]	29.9[b]	34.9[a]	35.5[a]

[a,b,c] Means within a row and cutting with unlike superscripts are significantly different ($P<0.05$). Comparisons were made within cuttings and not between cuttings

Neutral detergent fiber digestibility (NDFIS)

For cutting 1 only alsike clover had a significant increase ($P<0.05$) in NDFIS when grown under 45% light as compared to full sun. Alfalfa for cutting 1 showed a decrease ($P<0.0.5$) in NDFIS from 45% to full sun. For cutting 2 only Birdsfoot trefoil 'Norcen' showed a significant change ($P<0.05$) in NDFIS from 45% to full sun.

Table 6. NDFIS (%) of legume species grown in 2000 shade study.

Forage Species	Cutting 1 % sunlight			Cutting 2 % sunlight		
	100	45	20	100	45	20
Creeping alfalfa	80.8[a]	73.3[a,b]	60.8[b]	53.3[b]	56.6[b]	65.1[a]
Alfalfa	60.8[b]	82.7[a]	76.1[a,b]	78.7[a]	80.4[a]	79.7[a]
Birdsfoot trefoil 'Norcen'	76.4[a]	75.3[a]	70.7[a]	85.1[a]	70.0[b]	72.5[b]
(R) Birdsfoot trefoil	72.5[a]	69.3[a]	73.4[a]	77.8[a]	78.1[a]	75.8[a]
Alsike clover	90.6[a]	77.8[b]	78.0[b]			
Korean lespedeza	62.7[a]	66.4[a]	61.5[a]	58.7[a]	56.7[a]	
Crimson clover	80.0[a]	74.1[a]	73.9[a]	56.8[a]	50.7[a]	56.1[a]

[a,b,c] Means within a row and cutting with unlike superscripts are significantly different (P<0.05). Comparisons were made within cuttings and not between cuttings

Discussion

Due to the significant (P<0.05) decrease in dry matter production at the 20% light level, comparisons for NDF, ADF and NDFIS were only made between the 100% and 45% light levels. The 45% light level is the light intensity that will closely resemble the available light potential of a silvopasture system.

Forage nitrogen content generally increased while changes in NDF, ADF and NDFIS digestibility were less predictable under shade. Halim et. al. (1989) reported that stressful conditions such as drought and shade likely reduces availability of photosynthesis for secondary cell-wall development, and stress may increase the percentage of digestible intracellular constituents, by reducing cell wall (fiber) content as suggested by Kephart and Buxton (1993). However, this study showed that digestibility over all remained constant with a few legumes having a slight increase or decrease in digestibility as the light level changed. The nitrogen concentration increased overall as the light levels decreased which coincides with previous research by Kephart and Buxton (1993). The overall percent NDF and ADF remained constant as the light levels were changed. Based upon the findings from this study, certain legume species appear to have the potential to be very beneficial in a silvopasture system by providing high quality forage while serving as a source for nitrogen fixation.

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