Shade Tolerance of Grass and Legume Germplasm for Use in the Southern Forest Range

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Abstract

A series of experiments was conducted during 1978, 1979, and 1980 to screen selected cultivars of grasses and legumes for their adaptation and performance under a multiple harvest system in a shaded environment. Acceptable stands of all species except *Uniola sessiliflora* Michx. were obtained under each shade treatment. The most shade tolerant species were 'Nangeela' subclover (*Trifolium subterraneum* L.), ryegrass (*Lolium multiflorum* Lam.), Persian clover (*Trifolium resupinatum* L.) and crimson clover (*Trifolium incarnatum* L.). Shade reduced the height of species with an upright growth habit while decumbent type species (subclover) showed less reduction. Nitrogen content was not affected by shade while potassium and phosphorus levels increased for all species under 50% shade. In separate field experiments the yield, stand density, and persistence of sericea lespedeza [*Lepedeza cuneata* (Dumont) G. Don] decreased with increasing shade although crude protein content was not affected. Cultivars of 4 species, ('Mt. Barker' subclover, 'Tibbee' crimson clover, 'Kentucky 31' tall fescue (*Festuca arundinacea* Schreb.), and 'Gulf' ryegrass), had acceptable stands and yields under 50% shade in a multiple harvest regime. These results demonstrate that several forage species are sufficiently shade tolerant to warrant consideration for use in forested environments.

It has been demonstrated that potential forage biomass production is higher in the South than in any other range area of comparable size in the United States (Grelen 1978). However, native range production is declining rapidly due to accelerated pine regeneration and the establishment of fast-growing slash (*Pinus elliottii* Engelm.) and loblolly pine (*P. taeda* L.), which results in drastically reduced herbage production within a few years. Grelen stated that operational scale multiple-use research is badly needed to evaluate compatibility of tree production, wildlife, livestock, and other resources.

One promising possibility for improving the southern forest range is the introduction of shade tolerant forages. Such germplasm could provide better quality forage over an extended period for both wildlife and livestock, could serve as a groundcover to reduce erosion during the winter, and could contribute to soil organic matter levels and add nitrogen in the case of legumes.

This study reports an evaluation of the effects of shade on morphological and physiological characteristics of selected forage species.

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Methods

Experiment 1A

Twenty species and/or cultivars of cool-season grasses and legumes were planted on a prepared seedbed on October 20, 1978, at Mississippi State, Miss. (Table 1). All species were planted in

Table 1. Species and varieties of grass and legume germplasm subjected to shade management at Mississippi State University, 1978.

Species	Variety	Common name
<i>Trifolium subterraneum</i> L.	Nangeela	Sub Clover
	Woogenellup	
	Daliak	
	Geraldton	
	Miss. Ecotype	
	Tallarook	
	Mt. Barker	
<i>Trifolium vesiculosum</i> Savii.	Dwalganup	Arrowleaf Clover
	Amclo	
	Yuchi	
	Meechee	
<i>Trifolium nigrescens</i> L.	— ¹	Ball Clover
<i>Trifolium resupinatum</i> L.	—	Persian Clover
<i>Trifolium alexandrinum</i> L.	—	Bersem Clover
<i>Trifolium incarnatum</i> L.	Chief, Tibbee	Crimson Clover
<i>Festuca arundinacea</i> Schreb.	Kentucky 31	Tall Fescue
<i>Lolium multiflorum</i> Lam.	Marshall	Ryegrass
<i>Uniola sessiliflora</i> Michx.	—	Uniola (Broadleaf)
<i>Vicia villosa</i> Roth.	—	Hairy Vetch

¹Where no cultivar is designated the seed was purchased as a common brand (non-variatal).

single row plots 30 cm wide × 2 m long. Immediately after planting, artificial shade chambers were placed over the planted areas. Shade chambers were constructed from lumite vinyl shade cloth designed to provide 50 and 25% of natural illumination. The shade cloth was mounted on 2 × 5 meter metal frames with legs to maintain them 30 cm above the soil surface. Soil pH was 6.7 and fertility was maintained at adequate levels for all species.

The experimental design was a split-plot with level of shading as whole plots and species and/or cultivars as subplots. There were 4 replications. Data were collected on each of the species after seedling emergence for stand quality parameters.

All plots were harvested May 14, 1979. Parameters measured were dry matter yield, percent dry matter, height, root and nodule weights, and mineral composition for nitrogen, potassium, phosphorus, sulfur, magnesium, calcium, iron, aluminum, manganese, and boron. Dry matter yields were determined by harvesting the entire plot with a hand sickle to a stubble height of 2.54 cm. The forage was weighed and dried in a forced draft oven at 60°C for 36

Table 2. Seedling counts, relative yield, plant height, and percent dry matter of 20 species grown under three levels of shade in 1979.

Species	Level of Shade (%)										
	0	50	75	50	75	0	50	75	0	50	75
	Seedlings per 30.5 cm of row			% of yield in full sun		Plant height cm			Dry matter %		
Nangella Subclover	46	49	47	92	49	12	13	9	28	23	25
Woogenellup Subclover	30	33	30	59	26	14	15	11	29	25	26
Miss. Ecotype Subclover	34	34	35	55	32	9	12	10	24	21	26
Tallarook Subclover	37	40	42	48	26	14	14	10	25	22	25
Mt. Barker Subclover	41	44	34	37	24	15	15	9	26	22	24
Dwalganup Subclover	23	32	25	65	24	12	11	9	29	24	29
Amclo Arrowleaf Clover	11	9	13	34	27	59	30	23	24	18	21
Yuchi Arrowleaf Clover	4	8	6	57	49	51	32	30	22	18	18
Meechee Arrowleaf Clover	2	4	10	39	23	47	29	22	21	16	17
Persian Clover	15	16	15	58	36	25	17	12	25	18	20
Berseem Clover	8	23	12	88	56	39	31	19	24	17	17
Chief Crimson Clover	87	38	35	57	31	43	26	22	34	26	24
Tibbee Crimson Clover	28	40	31	62	34	44	25	18	47	23	29
Ky 31 Tall Fescue	18	16	18	39	29	13	24	21	35	29	30
Marshall Ryegrass	60	54	60	51	28	72	38	31	23	23	
Uniola	0	0	0	—	—	3	6	4 ²	—	—	—
Hairy Vetch	21	18	18	33	22	38	21	15	17	17	18
LSD _A (.05) ²	1	1	1	5	5	2	4	4			
LSD _B (.05)	1	1	0	2	3	2	2	2			
CV _A (%)	6	13	16	12	13	12	15	17			
CV _B (%)	5	6	10	19	11	11	17	18			

¹Planted on 10/20/78 and counted on 1/20/79.

²"A" refers to differences among cultivars within a shade level while "B" refers to differences across shade levels within a cultivar.

hours. The dried forage was ground in a Wiley mill fitted with a 1-mm screen. Samples were analyzed for mineral composition by the use of spectrophotometry (Carlisle 1978).

Experiment 1B

A 1-year-old stand of 'Serale' sericea lespedeza (*Lepedeza cuneata* (Dumont) G. Don.) located in Lauderdale County, Miss., was subjected to 3 levels of shade and harvested twice in 1979 and twice in 1980.

The experimental design was a randomized complete block with 3 replications and soil pH and fertility were maintained at adequate levels. Plot size was 3.81 × 4.21 m. Parameters measured were dry matter yield, stems per crown, estimated forage quality, and total available carbohydrates. Dry matter yields were determined by harvesting the plots with a sickle mower to a height of 2.54 cm. The forage was weighed and dried in a forced draft oven for 36 hours at 60°C. The dried forage was ground in a Wiley mill fitted with a 1-mm screen and chemical analyses were run on the ground samples. Crude protein was determined from the Kjeldahl procedure

Table 3. Average nitrogen, potassium, and phosphorus content of grass and legume species and cultivars grown under three levels of shade in 1979.

Variety	Level of shade (%)								
	0	50	75	0	50	75	0	50	75
	Total nitrogen (%)			Potassium (%)			Phosphorus (%)		
Nangeela S.C. ¹	2.0	2.3	2.3	1.2	1.5	2.0	.18	.22	.20
Wooenellup S.C.	1.8	1.9	2.2	0.9	1.2	1.6	.14	.22	.20
Miss. Ecotype S.C.	2.0	2.4	2.4	1.2	1.5	1.7	.17	.26	.22
Tallarook S.C.	2.0	2.4	2.4	1.2	1.6	1.6	.16	.29	.20
Mt. Barker S.C.	1.7	2.3	2.6	1.3	1.4	1.6	.13	.24	.24
Dwalganup S.C.	1.4	2.2	2.0	0.9	1.5	1.5	.12	.25	.23
Amclo Ar. C.	1.9	2.3	2.3	1.2	1.9	2.2	.16	.27	.27
Yuchi Ar. C.	1.8	2.0	2.4	1.3	2.0	2.1	.14	.23	.24
Meeche Ar. C.	2.1	2.7	2.3	1.5	2.4	2.0	.16	.30	.24
Persian Clover	2.1	2.2	2.0	1.3	1.5	1.6	.19	.23	.21
Berseem Clover	1.7	2.3	2.3	1.1	2.0	1.8	.12	.23	.27
Chief C.C.	2.0	2.0	2.0	1.1	1.5	1.7	.15	.21	.18
Tibbee C.C.	1.4	1.7	1.8	1.0	1.5	2.0	.15	.19	.20
K 31 Tall Fescue	1.2	1.4	1.0	2.1	2.5	1.8	.19	.28	.22
Marshall Ryegrass	0.8	1.1	1.1	1.6	2.1	2.7	.16	.25	.27
Hairy Vetch	3.4	3.0	2.8	2.3	2.9	2.9	.34	.36	.36
LSD _A (0.5) ²	1.8	2.0	2.1	2.3	4.0	5.2	1.9	2.3	3.6
LSD _B (0.5)	1.2	1.3	1.4	3.7	4.1	5.8	1.8	2.2	3.8
CV _A (%)	9.1	9.4	10.7	8.6	9.3	12.7	7.4	9.1	10.3
CV _B (%)	9.1	9.9	11.4	9.2	10.9	14.6	8.5	10.3	12.0

¹S.C. = Subterranean Clover, Ar.C. = Arrowleaf Clover, C.C. = Crimson Clover.

²"A" refers to differences among cultivars within a shade level while "B" refers to differences across shade levels within a cultivar.

for total nitrogen, digestibility according to procedures of Van Soest (USDA Agr. Handbook 379) and total available carbohydrates after Weinmann (1947).

Experiment 2

Based on the results obtained in Experiment 1A, 4 species ('Mt. Barker' subterranean clover, 'Tibbee' crimson clover, 'Kentucky 31' tall fescue, and 'Gulf' ryegrass) were grown under 3 levels of shade and a multiple harvest schedule in 1979-80. Experimental design was a split plot with 4 replications as in Experiment 1A and soil pH and fertility were adequate for all species. Plots were planted on a prepared seedbed on September 20, 1979, at Mississippi State, Miss. Forage was harvested February 20, April 16, and May 18, 1980. The specific cultivars were chosen because of the availability of seed from commercial sources.

Results

Experiment 1A:

Acceptable stands of all species except *Uniola* were obtained (Table 2). In general, level of shade had little effect on the number of seedlings that germinated. Exceptions were 'Yuchi' and 'Meechee' arrowleaf clover and berseem clover, which had more seedlings present as level of shade increased. In contrast, numbers of seedlings of 'Geraldton' subclover decreased as shade increased. Ball clover did not germinate adequately under any treatment.

Moderate to heavy cold damage was recorded on some seedlings due to the widely fluctuating environmental conditions that were prevalent in Mississippi during the course of the observations. There was a trend for some species such as subterranean clover and hairy vetch to have less apparent cold damage as level of shade increased (data not shown).

Dry matter yields varied considerably among species and shade levels (Table 2). In general, yields across shade levels were highest for ryegrass followed by the subterranean and crimson clovers. Most yields decreased by 40% or more under 50% shade and by 75% or more under 75% shade. Exceptions were "Nangeela" subclover and Persian clover, where production was decreased 8 and 12%, respectively, by 50% shade.

In contrast, root yields and the percent of root weight represented by nodules were not affected by shade (data not shown). Root weights ranged from 1.9 to 2.4 gm dry matter per plant and nodules made up 12 to 15% of the root weight.

There were wide variations in height among species, and shade generally reduced the height of the upright type of species (Table 2). Decumbent type species such as the subclovers showed less variation in height among the levels of shade. There was a trend for percent dry matter to be lower in all species as level of shade increased. Plant maturity was delayed 5 to 10 days by shade.

Total nitrogen content was not affected by shade, but values obtained for the legumes were higher than for the grasses (Table 3). In contrast, potassium content of the grasses was generally higher

than for the legumes, and there was a trend for potassium levels of all species to increase as level of shade increased. Phosphorus content increased in all species grown under 50% shade, but values did not change as shade was increased to 75%. There were no trends related to species or shade for sulfur, magnesium, calcium, manganese, or boron content. No definite trends were observed in iron and aluminum content.

Experiment 1B

Dry matter yield of sericea lespedeza (Table 4) decreased significantly as the level of shade was increased, and the response was magnified as the growing season progressed. Yields under 75% shade were only 50% of those in full sun by the second harvest for both years. Plants grown under shade were also significantly shorter at the second harvest. However, plants growing in 50% shade persisted and produced satisfactory yields through both years of the experiment.

Numbers of stems per crown was decreased significantly in the second growth (regrowth) forage by shade (Table 4). Percent leaves was also decreased in the first harvest as level of shade increased, but not in the regrowth.

Neither crude protein content nor digestibility was affected by shade for either harvest. Crude protein content of sericea (16%) was high enough throughout the season to meet the requirements of ruminant animals.

Average total available carbohydrates (TAC) in the root systems of sericea averaged 31, 27, and 10% for 0, 50, and 75% shade, respectively, suggesting that shade should not exceed 50% for good stand persistence.

Experiment 2

Under a multiple harvest regime, dry matter yields decreased for each species as level of shade increased (Table 5). However, performance of the 4 species was satisfactory under 50% shade, acceptable yields were produced, and all of the species yielded sufficient seed to re-establish themselves the next growing season. Establishment of a good stand the first year and regulation of late spring grazing to permit seed production are critical to continued persistence.

Discussion

Within the southeastern United States, there have been a number of sporadic reports on the use of traditionally agronomic forages in forestry situations. None have started with an evaluation of shade tolerance and most have emphasized the potential benefits of increased tree production through associations with legumes.

The present investigation emphasized legumes and cool season forages because it is during the winter months that adequate browse is least available in southern pine forests. Subclover has been used extensively in forest environments in Australia because of its shade tolerance, persistence under unfavorable conditions, and forage quality (Anderson and Batini 1979). Other research

Table 4. Dry matter yields, height, stems per crown, and percent leaves for *Sericea lespedeza* grown under three levels of shade. Lauderdale, Co., MS, 1979-1980.

% Shade	Dry matter yield						1979					
	1979			1980			Height-cm		Stem/crown		% Leaves	
	6/4	8/3	Total	6/6	8/7	Total	6/4	8/3	6/4	8/3	6/4	8/3
0	4900	3350	8250	4820	2670	7490	75	65	10.4	11.7	63.4	63.0
50	4160	2546	6706	3220	1926	5146	78	53	10.2	8.6	56.6	61.0
75	3830	1740	5570	1410	620	2030	76	52	8.9	9.1	59.5	61.3
LSD (.05)	760	472	1100	818	592	1215	1.6	0.9	n.s.	1.0	2.5	n.s.
CV (%)	9.2	10.5	9.8	9.7	1.6	8.4	9.5	4.0	15.4	6.9	10.6	5.7

Table 5. Dry matter yield of ryegrass, tall fescue, subterranean clover, and crimson clover under three levels of shade at Mississippi State, MS, 1979-80.

	D.M. Yield-Lbs./A.			
	2/80	4/80	5/80	Total
'Gulf' Ryegrass				
0	786	5974	1385	8145 a ¹
50	620	4500	1158	6278 b
75	600	2076	1079	3755 c
'Kentucky 31' Tall Fescue				
0	742	3190	1299	5231 a
50	720	2415	765	3900 b
75	676	2292	627	3595 b
'Mt. Barker' Subclover				
0	620	3011	1158	4789 a
50	606	1875	1475	3956 b
75	537	1664	697	2898 c
'Tibbee' Crimson Clover				
0	715	3174	983	4872 a
50	622	1695	1100	3417 b
75	543	1523	521	2587 c
LSD (.05)	N.S.	1173	649	896
CV (%)	15.3	11.3	13.6	11.1

¹Letters indicate significant differences at the 5% level according to Duncan's Multiple-Range Test.

results confirm that some cultivars of subclover would be excellent choices for use in forested settings in the South (Haines et al., White, and Sawyer 1978) as well as 'Chief' and 'Tibbee' crimson clover, 'Marshall' ryegrass and 'Kentucky 31' tall fescue. Further research should examine the productivity and persistence of such shade tolerant forages under more naturalized forested settings.

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