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VARIABILITY FOR BIOMASS PRODUCTION AND PLANT COMPOSITION IN SERICEA LESPEDEZA

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Abstract—Sericea lespedeza [*Lespedeza cuneata* (Dumont de Courset) G. Don.] is a deep-rooted legume that is well adapted to the acid, eroded soils found throughout the southeastern region of the U.S.A. A field experiment aimed at measuring biomass yield and biomass composition of 81 genotypes of sericea lespedeza harvested once every season was conducted. Results indicated substantial differences for biomass yield among sericea lespedeza genotypes. However, dry matter percentage was the same. Genotype R194-79-290-9 had the highest mean biomass yield (9.0 Mg ha^{-1}) and, consistently, ranked among the top four during the four years that this study was conducted. Other genotypes that also exhibited a good performance over the four years were the cultivar Serala (7.8 Mg ha^{-1}) and the breeding line 75-2-3 (7.8 Mg ha^{-1}). Differences in yield stability over time among genotypes were observed, hence, long term performance would need to be considered in a breeding program. These results suggested that sericea lespedeza genotypes with a consistently high biomass yield can be selected. No significant differences were found among genotypes for crude protein concentration. Crude protein concentrations were about 25% lower than those previously reported. Significant differences among genotypes for neutral detergent fiber, hemicellulose, and holocellulose concentration were observed. However, no significant differences for acid detergent fiber, lignin, cellulose concentration, and holocellulose yield were measured. In summary, there is variability and potential to select for biomass yield and quality traits that are considered important for biofuel production. Copyright © 1996 Elsevier Science Ltd.

Keywords—Herbaceous energy crop; *Lespedeza cuneata* (Dumont de Courset) G. Don.; nitrogen concentration; neutral detergent fiber; acid detergent fiber; lignin; cellulose; hemicellulose; holocellulose.

1. INTRODUCTION

Sericea lespedeza is a deep-rooted legume that is well adapted to the acid, eroded soils found throughout the southeastern region of the U.S.A.[1] The soils of this region are also low in organic matter. Sericea lespedeza is capable of improving soil by rapidly increasing its organic matter and nitrogen concentration. In good stands, sericea lespedeza sheds the lower leaves during the growing season to form a protective mat on the soil surface. This leaf litter decomposes to form a valuable source of organic matter. A field with a four year stand of sericea lespedeza grown for soil conservation or biomass production may have over 7 Mg ha^{-1} of residues on the soil surface.[2]

Once established, sericea lespedeza production costs are relatively small compared to other species. While most herbaceous plants require nitrogen fertilization, sericea lespedeza produces its own through dinitrogen fixation. Compared to most other crops, sericea lespedeza has relatively few disease and insect problems.[3]

Sericea lespedeza has been used as a forage crop for grazing or hay, or for soil conservation. It is commonly used for plantings on strip mine spoils, roadbanks, and other disturbed or eroding areas. Recent reports[4] indicate that sericea lespedeza could be grown for the production of ligno-cellulosic biomass. Biomass production of sericea lespedeza has been studied in only a few cultivars. In those tests, sericea lespedeza was harvested as a hay crop. Ansley[5] reported that maximum biomass yield of this crop is obtained when it is cut only once during the growing season. Sericea lespedeza has the advantage over other herbaceous species that uncut biomass can remain in the field during a good part of the winter, i.e. it does not require storage facilities.

Conversion of plant biomass to biofuels depends on the conversion process as well as on the composition of the feedstock. Composition of sericea lespedeza biomass has been reported for plants that have been managed for forage

Table 1. Biomass dry matter yield of the 16 highest yielding sericea lespedeza genotypes in the year of establishment (1986) and subsequent years

Genotype	1986	1988	1989	1990	Mean yield	
					Four year[a]	Three year[b]
			Mg ha^{-1}			
R194-79-290-9	1.8	16.5	11.6	7.0	9.0	12.2
73-34-7	1.6	13.2	9.9	7.1	7.9	10.0
Low-tan Synth.	1.1	16.6	9.1	7.0	7.9	10.9
75-2-3	1.3	14.9	10.0	7.2	7.8	10.7
73-167-12	1.7	16.5	9.0	6.2	7.8	10.5
Serala	0.8	14.9	9.9	7.8	7.8	10.9
73-162-16	1.0	17.9	7.1	7.2	7.8	10.7
75-2-10	1.1	12.0	12.2	7.6	7.7	10.6
79-290-9	1.3	14.9	8.4	7.4	7.5	10.3
AU L6	1.4	13.2	8.8	8.6	7.5	10.2
73-163-5	1.3	14.1	10.4	6.2	7.5	10.2
AU Lotan	1.2	14.9	9.1	5.6	7.2	9.9
AU L11	1.5	13.1	8.2	7.8	7.2	9.7
R186-79-289-7	1.4	15.0	7.9	6.2	7.1	9.7
73-162-17	1.6	16.7	6.6	4.7	7.0	9.4
AU L2	0.9	13.4	7.6	7.9	7.0	9.6
MSD (0.05)[c]	ns	3.0	4.3	4.8	1.2	1.7

[a] 1986 (establishment), and 1988 to 1990.

[b] 1988 to 1990.

[c] Minimum significant difference at a probability of 0.05 according to Waller–Duncan *k*-ratio test.

production.[4] A study of the composition of sericea lespedeza biomass cut only once late in the season was needed to provide more realistic information from the standpoint of renewable fuel production. For example, nitrogen concentration is known to decline as the plant tissue matures. Conversely, ligno-cellulosic compounds increase as the plant matures.[6] Furthermore, plant composition can have a strong genetic component in that composition may vary with genotype.

The objectives of this research were to determine the variability for single-harvest biomass production and plant composition among 81 genotypes of sericea lespedeza.

2. MATERIALS AND METHODS

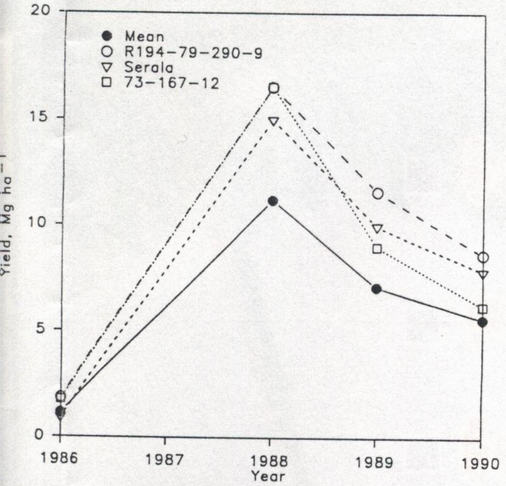
A collection of 81 entries of sericea lespedeza were planted in a randomized complete block design with three replications at Tallassee, Alabama, in May 1986. This experiment was located on a Bassfield loamy fine sand (coarse-loamy, siliceous, thermic, Typic Hapludults) soil under dryland conditions. The plots were single rows 7.6 m long, planted 0.91 m apart. In the year of establishment and subsequent years, plants were cut only once at the end of the growing season (October) leaving a 5 cm stubble. Because seedling height was found closely correlated to seedling dry weight in another study with sericea lespedeza,[7] plant height was measured in three places in each plot before cutting in 1986 and 1990. Total biomass yield and percentage of dry matter were measured in 1986, 1988, 1989, and 1990 (1987 data was lost). In 1990, biomass samples were dried at 60 °C for 48 h, ground to pass a 1 mm screen, and analyzed for nitrogen concentration with a LECO combustion analyzer, neutral detergent fiber (NDF), acid detergent fiber (ADF), and permanganate lignin using the methods described by Goering and Van Soest.[8] Hemicellulose concentration was estimated by the difference between NDF and ADF. Holocellulose concentration was estimated by adding cellulose and hemicellulose. Data were subjected to analysis of variance. Simple correlations among quality parameters were also obtained.

3. RESULTS AND DISCUSSION

Analysis of variance on the combined data for biomass yield for four years (1986, 1988, 1989,

Table 2. Mean, standard deviation, minimum, and maximum biomass yield (Mg ha^{-1}) obtained from 81 sericea lespedeza genotypes in four years

Year	Mean	Standard deviation	Minimum	Maximum
1986	1.140	0.31	0.519	1.896
1988	11.183	2.63	5.437	17.949
1989	7.137	1.66	2.629	12.262
1990	5.602	1.34	2.891	8.664



g. 1. Mean biomass yield of 81 genotypes and yield of three selected genotypes.

and 1990) indicated a significant genotype–year interaction. Biomass yield of the best (top 20%) genotypes for years 1986, 1988, 1989, 1990, and their mean yield are presented in Table 1. Yields during the year of establishment (1986) were typically low compared to yields of mature plants. Genotype R194-79-290-9 had the highest mean yield and, consistently ranked among the top four throughout the years in which this experiment was conducted. Other genotypes that also performed well over the four years are the cultivar Serala and the breeding line 75-2-3. Although these results give precise information on genotype performance at Tallassee, their extrapolation value for Alabama or the southeast region cannot be determined because this study was conducted in only one location

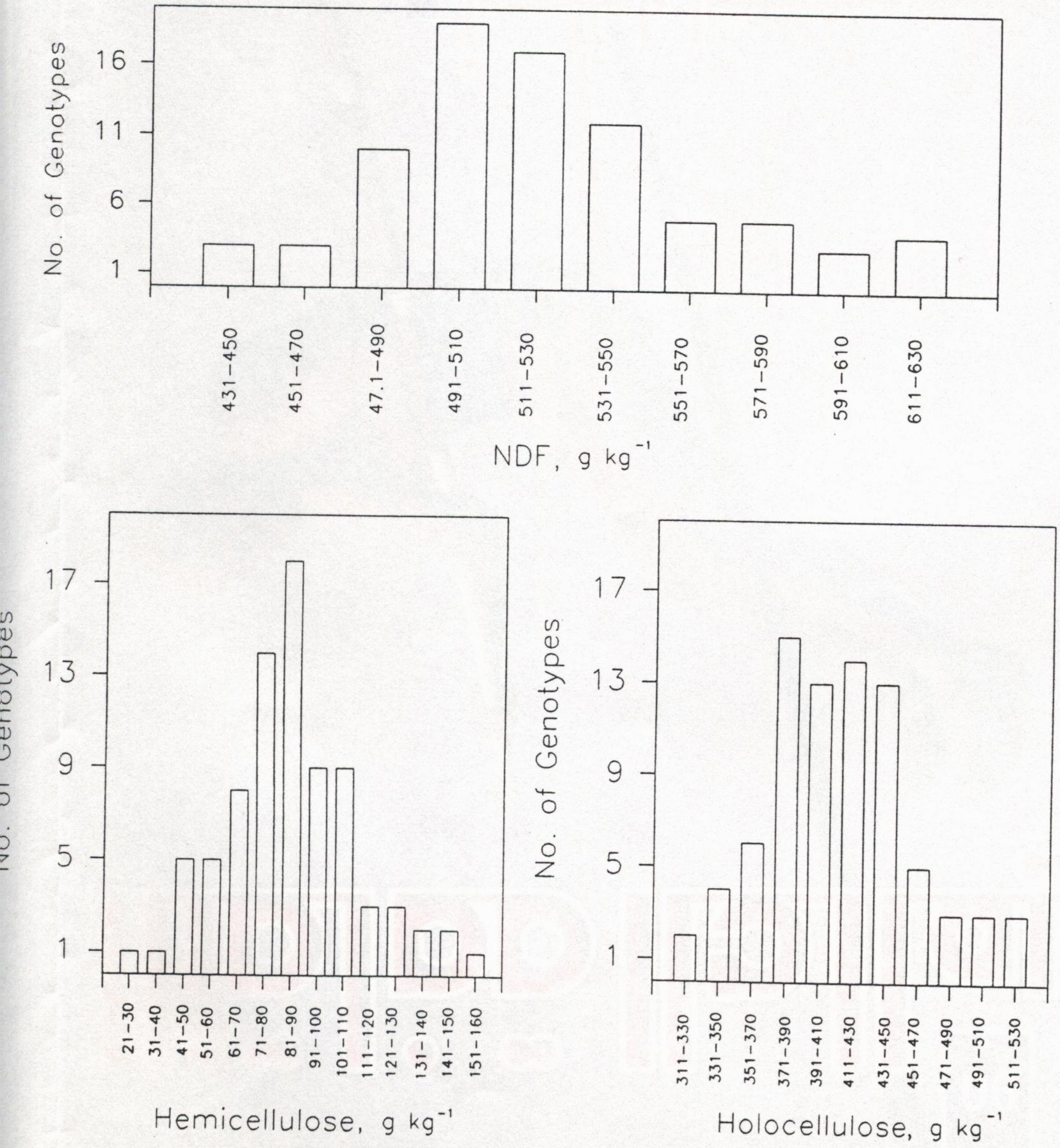


Fig. 2. Distribution of sericea lespedeza genotypes for NDF, hemicellulose, and holocellulose.

Table 3. Neutral detergent fiber (NDF), hemicellulose, and holocellulose concentration of the 16 highest yielding sericea lespedeza genotypes

Genotype	NDF	Hemicellulose	Holocellulose
		g kg^{-1}	
R194-79-290-9	507	100	407
73-34-7	507	83	373
Low-tan Synth.	507	80	363
75-2-3	537	103	430
73-167-12	483	87	370
Serala	443	50	347
73-162-16	517	107	437
75-2-10	453	60	437
79-290-9	493	60	353
AU L6	493	67	380
73-163-5	480	93	373
AU Lotan	503	70	403
AU L11	500	37	397
R186-79-289-7	540	127	380
73-162-17	470	73	450
AU L2	480	50	346
MSD (0.05)[a]	121	95	168

[a]Minimum significant difference according to Waller–Duncan *k*-ratio test.

and results may be specific to soil type and weather. However, a general conclusion is possible: genotypes of sericea lespedeza with a consistently high biomass yield can be selected.

Mean biomass yield of the 81 sericea lespedeza genotypes showed a steady decline from 1988 to 1990 (Table 2). This change in dry matter yield over time is similar to the quadratic yield pattern described for a mixture of alfalfa–smooth bromegrass (*Medicago sativa* L., *Bromus inermis* Leyss.).[9] However, a closer look at some yield statistics showed that higher yields declined whereas the lower yields remained constant in 1989 and 1990. Factors that were most likely to have influenced the observed yield decline were a reduction in plant stand and in plant height that were observed over the years. Also rainfall in the summer of 1990 was low (217 mm from May to August, whereas the 30-year normal is 442 mm). Although biomass yield of all genotypes declined over time, differences among genotypes in the pattern of yield reduction were observed. For instance, genotypes R194-79-290-9 and Serala had a yield reduction that paralleled the change in mean yield of the 81 genotypes, whereas yield reduction in 73-167-12 was more abrupt (Fig. 1). Therefore, differences in yield stability among genotypes would need to be considered in a breeding program.

No significant differences were found among genotypes in percentage of dry matter of the biomass. The average dry matter at harvest over the four-year period was 460 g kg^{-1} of fresh matter. Different genotypes had different canopy heights; however, these differences were consistent in 1986 and 1990 (data not shown), i.e. genotype–environment interactions were not significant.

All genotypes had a similar crude protein concentration averaging 110 g kg^{-1} of dry matter. This crude protein concentration is substantially lower (about 25% less) than that previously reported by Bransby *et al.*[4] In their research sericea lespedeza was harvested twice instead of once. In this study, samples were taken when plants were fully mature but still had a variable amount of leaves. It is certain that lower nitrogen concentrations could be obtained if harvests occurred in late November to early December, when all leaves have been shed. However, biomass yields would also be reduced.

The NDF concentration was significantly different among genotypes. The NDF concentration ranged between 443 and 623 g kg^{-1} with an average of 524 g kg^{-1}. The distribution of sericea lespedeza genotypes for NDF concentration is presented in Fig. 2. Genotypes with the highest biomass yield had a NDF concentration ranging between 470 g kg^{-1} (73-162-17) and 537 g kg^{-1} (75-2-3) (Table 3).

The ADF, lignin, and cellulose concentrations were not significantly ($P = 0.07$, 0.96, and 0.08, respectively) different among genotypes. The average values were 438 g kg^{-1} for

Table 4. Pearson correlation coefficients among quality traits

	NDF	ADF	Lignin	Hemicellulose	Cellulose	Holocellulose
Crude protein	−0.592[b]	−0.635[b]	−0.114	−0.263[a]	−0.503[b]	−0.474[b]
NDF	—	0.800[b]	0.038	0.748[b]	0.750[b]	0.905[b]
ADF		—	0.061	0.201	0.773[b]	0.616[b]
Lignin			—	0.003	−0.236[a]	−0.152
Hemicellulose				—	0.366[b]	0.795[b]
Cellulose					—	0.855[b]

[a,b]Indicates significant differences at $P = 0.05$ and $P = 0.01$, respectively.

Table 5. Genetic variance and broad sense heritability of crude protein, NDF, ADF, hemicellulose, lignin, cellulose, and holocellulose (sum of hemicellulose and cellulose) concentration in the biomass of 81 sericea lespedeza genotypes

Trait	Genetic variance	Heritability (%)
Crude protein	0	0
NDF	7.22	41
ADF	2.04	25
Lignin	0	0
Hemicellulose	2.02	32
Cellulose	2.00	23
Holocellulose	6.60	32

ADF, 108 g kg^{-1} for lignin, and 328 g kg^{-1} for cellulose.

Hemicellulose concentration was significantly different among genotypes and ranged between 27 and 157 g kg^{-1} with an average of 87 g kg^{-1} (Fig. 2). Genotypes with the highest biomass yield exhibited hemicellulose concentrations between 37 g kg^{-1} (AU L11) and 127 g kg^{-1} (R186-79-289-7) (Table 3).

Holocellulose concentration was significantly different among genotypes and ranged between 323 and 527 g kg^{-1} with an average of 415 g kg^{-1} (Fig. 2). The genotypes with the highest biomass yield had a holocellulose concentration ranging between 346 (AU L2) and 450 g kg^{-1} (73-162-17) (Table 3). Analysis of holocellulose yield per hectare showed no differences among genotypes. The average yield was 2.3 Mg ha^{-1}.

Pearson's correlation coefficients indicated that lignin was not correlated to other quality traits, with the exception of cellulose. Significant correlation coefficients were found between pairs of all the other quality traits measured, except ADF–hemicellulose (Table 4). The negative correlations between crude protein concentration and NDF, ADF, and hemicellulose indicate that crude protein tended to be lower in genotypes that had greater NDF, ADF, and hemicellulose values. The positive and highly significant correlation between NDF and ADF indicated that when one of these traits increases, the other also increases. The lack of correlation between ADF and hemicellulose and the positive correlation between NDF and hemicellulose indicated that hemicellulose concentration is independent of ADF but closely related to NDF. The high value of the correlation coefficient between NDF and holocellulose indicates that holocellulose changes parallel those of NDF (Table 4).

Calculation of genetic variances from the analysis of variance showed that there is no genetic variance among the genotypes tested for crude protein and lignin concentration (Table 5). Broad sense heritability estimates give a measure of the relative importance of the genetic and environmental variation. The medium value of broad sense heritability for NDF indicated that genetic variation exists in the group of genotypes tested that could be used in a selection program to increase (in the case of biomass production) or decrease (if the objective is forage production) NDF. The smaller broad-sense heritability values obtained for the other traits indicate that the variability available is limited. However, the large correlation coefficients between NDF and ADF, hemicellulose, cellulose, and holocellulose indicated that changes in NDF concentration will bring about correlated changes in other quality traits.

In summary, variability for biomass yield and for some quality traits considered important for biofuel production were measured in 81 sericea lespedeza genotypes. Thus, it is possible to select genotypes within the breeding lines tested that would be particularly adapted for some methods of biofuel production. Screening of accessions from the National Plant Germplasm System should be conducted to determine their variability for lignin and crude protein concentration. If accessions with lower levels are found, recombination, using genetic procedures, could be conducted to obtain plants with reduced concentration of lignin and crude protein.

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