ADAPTATION, BIOLOGY, AND CONTROL OF SERICEA LESPEDEZA (*Lespedeza cuneata*), AN INVASIVE SPECIES

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TABLE OF CONTENTS

LIST OF TABLES

Table Page

Chapter I

Chapter II

Chapter III

Chapter IV

Chapter V

Chapter VI

LIST OF FIGURES

Figure Page

Chapter I

Chapter II

Chapter III

Chapter IV

INTRODUCTION

Chapters I through VI of this thesis were written to facilitate submission for publication in Weed Technology, a journal of the Weed Science Society of America.

Chapter I

DNA Fingerprinting of Sericea Lespedeza (*Lespedeza Cuneata*) Accessions

DNA Fingerprinting of Sericea Lespedeza (*Lespedeza cuneata*) Accessions

Abstract: An experiment was conducted to assess the genetic relationship of 17 accessions of sericea lespedeza using DNA amplification fingerprinting (DAF). The DAF technique utilized four DAF primers with 49 amplicons amplified through these four primers. DAF results indicated that most of the sericea lespedeza accessions used in this experiment were genetically similar (average SC of 0.883). However, three accessions identified with DAF, which were China, Gasyn, and South Carolina were genetically dissimilar. Results from DAF distinguished four genetic groups within the sericea lespedeza accessions, which were based on the sources coming from a breeding program, commercial seed company source, sources from states other than Oklahoma, and Oklahoma sources. The group of accessions coming from commercial seed companies and field collections from states other than Oklahoma were the most genetically similar (average SC of 0.984). Korean lespedeza (South Carolina source), which was included as a positive comparative control, was the most genetically distinct when compared to all 17 accessions of sericea lespedeza (average SC of 0.354). These results indicated that although the genetic base was narrow, accessions had a genetic uniqueness influenced by management and environment/population sources. This may provide germplasm impacts in those states where management of sericea lespedeza is an issue.

Nomenclature: Sericea lespedeza, *Lespedeza cuneata* (Dumont) G. Don. #[1] LESCU.

Additional index words: Accessions, genetics.

Abbreviations: DAF, DNA amplification fingerprinting; PCR, polymerase chain reaction; SC, similarity coefficient.

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[1] Letters following this symbol are a WSSA-approved computer code from *Composite List of Weeds*, Revised 1989. Available only on computer disk from WSSA, 810 East 10th Street, Lawrence, KS 66044-8897.

INTRODUCTION

Sericea lespedeza has both chasmogamous (open-pollinated) and cleistogamous (self-pollinated) flowers, both producing seed. Differences in plant morphological and phenotypic characters exist based on plants that produce one or the other flowering types (Cope 1966a; 1966b; 1971). Although more than half of the seed are from cleistogamous flowers, the potential for heterosis and genetic-crossing between different accessions or populations exists (Cope 1966b). Increased sericea lespedeza performance, such as forage and seed yield (Cope 1966b; 1971; Donnelly 1955), exist in those plants that exhibit increased heterotic expression. Cope (1966a; 1966b; 1971) also concluded that environment can potentially influence the degree of genetic-outcrossing and heterotic expression. This potential for genetic-outcrossing and hybrid vigor along with different location/environment influences on sericea lespedeza may lead to potential differences in management strategies from one population to another.

In many cases, efforts were made and continue to be made to genetically improve sericea lespedeza through traditional plant breeding programs to enhance yield, palatability and/or disease resistance (Cope 1966a, 1966b,1971; Ohlenbusch et al. 2001). Seed, of sometimes unknown genetic origin, can be purchased for planting, further increasing the spread of this species. Because of the potentially diverse genetic base of this introduced species, some of the information written about one accession/biotype of sericea lespedeza may very well be accurate; however, these data or information may not be applicable for all accessions/biotypes of sericea lespedeza growing in another part of the country. Sundberg et al. (2002) reported that sericea lespedeza collected from 16 different sites within Kansas had significant genetic variation. They identified nine unique genotypic groups and determined that there was significant genetic variation among the populations. Sericea lespedeza may exhibit genotypic and phenotypic differences within Oklahoma and between sericea lespedeza plants collected elsewhere in the U.S.; however, no information regarding these differences could be found in the literature.

Different techniques have been used to evaluate the genetic relationships among plants (Caetano-Anolles et al. 1997; Cole and Biesboer 1992; Sundberg et al. 2002; Pester et al. 2003). Pester et al. (2003) used randomly amplified polymorphic DNA (RAPD) and amplified fragment length polymorphism (AFLP) markers to evaluate the genetic diversity among 8 U.S. and 50 Eurasian jointed goatgrass (*Aegilops cylindrica* L.) accessions. They concluded that jointed goatgrass had limited genetic diversity. A low genetic variation was found in roundhead lespedeza (*Lespedeza capitata* Michx.) populations with the use of allozyme studies (Cole and Biesboer 1992). Caetano-Anolles et al. (1997) used DNA amplification fingerprinting (DAF) to genetically differentiate bermudagrass (*Cynodon*) species off-types. However, there are advantages and disadvantages for the different techniques (Yerramsetty et al. 2005) and there has been no standard technique established for the detection of genetic variability or relationships among sericea lespedeza accessions. The DAF technique is a very high-resolution, low-cost, reproducible, and successful method (Yerramsetty et al. 2005) that produces several-fold more DNA polymorphisms per primer compared to the other techniques (de Vienne et al. 2003).

The objective of this experiment was to provide basic information on the potential genetic diversity of sericea lespedeza. The first objective of this experiment was to evaluate the usefulness of the DAF technique for genetic differentiation among different accessions of sericea lespedeza. Another objective was to determine if the genetic associations relate to genetic improvements within sericea lespedeza, location within the U.S., or different environment/population groupings.

MATERIALS AND METHODS

Plant Materials. Seed of sericea lespedeza accessions were obtained from the sources listed in Table 1. Accessions will be the catch-all term for all lines, biotypes, populations, genetic improvements, or selections of sericea lespedeza and will be used throughout this paper. The sources used were based on availability of improved accessions from the plant genome sources (National Center for Genetic Resources Preservation (NCGRP) and Plant Genetic Resources Conservation Unit (PGRCU)), seed companies, as well as field collections from various states by other scientists. The sources characterize genetically improved accessions, accessions of low and highly desirable traits, different environmentally influenced biotypes, and population clusters. About 25 to 50 seed from each accession were planted in 16 cm diameter pots containing Sta-Green All Purpose Potting Mix[1] with a 0.13 N-0.04 P-0.09 K fertilizer ratio. After several weeks of growth, one of the sources (South Carolina) was verified to be Korean lespedeza [*Kummerowia stipulacea* (Maxim.) Makino] and was retained and used in the experiment as a “positive” control for comparison of genetic relation to the 17 sericea lespedeza accessions. All plants (from seed) were greenhouse grown (about 2 months) until they were mature enough for collection of the leaf material used for DNA extraction. One sericea lespedeza accession (Fort Riley) was collected from live plants growing at the military base of Fort Riley, KS. The leaf material collected at this site was transported to the laboratory at Stillwater, OK in liquid nitrogen and was later maintained in a -86 C freezer until needed for DNA extraction.

DNA Isolation. About 1 g of fresh leaf material was clipped from live plants of each accession and placed into sealable plastic bags. One g of wet weight leaf tissue took about 50 to 75 trifoliate leaves, which were collected from small to medium (younger) trifoliate leaves that contained more DNA material for isolation. The collected leaf tissue was frozen in liquid nitrogen and ground in a mortar and pestle to a fine powder consistency. Genomic DNA was isolated from 100 mg of the powdered leaf tissue using the DNeasy Plant Mini-extraction Kit[2] according to protocol directions provided in the kit. Assessment of the DNA concentration was conducted spectrophotometrically at 260 nm, with concentration quality assessed by the 260/280 ratio. None of the 17 accessions of sericea lespedeza or the Korean lespedeza DNA extracts exhibited a 260/280 ratio less than 1.8. The genomic DNA was suspended to a final concentration of 5 ng/µL in 0.5X TE and stored at 4 C. Quality of the DNA was further assessed by the use of TBE agarose gel electrophoresis. All accessions exhibited single DNA bands at high molecular weight on the gels and showed no sign of DNA degradation.

PCR Amplification. Four DAF primers (Table 2) were used to fingerprint the 18 lespedeza accessions used in this experiment. The master-mix mixture for the polymerase chain reaction (PCR) amplification consisted of 2.5 U of Qiagen *Taq* polymerase,[2] 10X PCR buffer (including $MgCl_2$) providing a final concentration of 1.5 m*M*, 250 µ*M* dNTP, 1.5 µ*M* DAF primers,[3] and 1 µL of template DNA, including sterile distilled water for a final made volume of 20 µL. An initial denaturing temperature of 94 C for 60 s was used for the DNA template. Following the initial denaturation, the PCR program proceeded at 94 C for 30 s, 30 C for 30 s, and 72 C for 30 s, with 39 cycles. At the end of the PCR programs 39th cycle, a final extension at 72 C for 60 s was performed. Visualization of the PCR products was performed on a 1% TBE agarose gel impregnated with ethidium bromide at a final concentration of 0.5 µg/ml.

The agarose gel was visually assessed to assure that the fingerprint intensity of all lanes were about equal. All of the agarose gels (for all primer-template runs) exhibited distinct and strong banding patterns.

Denaturing Polyacrylamide Electrophoresis. Separation of the PCR products was performed on a 20 cm long 6% acrylamide denaturing PAGE gel using a Bio Rad Protean II apparatus.[4] The PAGE gel consisted of Long Ranger Acrylamide,[5] 5X TBE, and 7.1 *M* urea. Polymerization of the gel was accomplished by adding 650 µL of 10% ammonium persulfate (APS) and 65 µL of TEMED. A combined mixture of 5 µL of PCR product and 10 µL of loading buffer with bromophenol blue tracking dye were loaded onto the gel. A 1 Kb ladder, serving as molecular marker, and a negative control containing the master-mix only (void of DNA) were loaded on either side of the PCR amplicon lanes. Gel electrophoresis proceeded at 50 V until the tracking dye strain reached three-quarters of the gel length. The gel was removed and stained with Sybr Gold using a Sybr Gold Nucleic Acid Gel Stain[6] according to the protocol and manufacturer directions. Sybr

Gold staining was conducted at 1/20000 dilution in 200 ml of TBE buffer. Following the staining procedure a picture of the PAGE gel was taken on a Gel-Doc system. All 18 accession PCR products were run on the same gel for accurate band-to-band comparisons. All of these procedures were replicated twice for each DAF primer.

Data Profiling and Analysis. After production of the PAGE gel picture image, electrophoretic bands of less than 1 Kb were scored visually as either being present (1) or absent (0) for each of the lespedeza accessions. Data were entered in an Excel spreadsheet and imported into the NTSYS software version 2.0[7] for cluster analysis. All NTSYS program cluster analysis was performed using the unweighted pair group algorithm (UPGMA) within the SAHN module. The SIMQUAL module was used to generate similarity coefficients (Table 3). PCR amplification, gel electrophoresis and staining, and data profiling and analysis was replicated twice for the DAF primers, all showing similar results.

RESULTS AND DISCUSSION

DAF produced 49 bands that were scored for analysis (Figure 1 and Table 2). Polymorphisms, meaning that the bands are absent in at least one or more accessions, were found in 80% (39 bands) of the accessions using DAF.

The DAF results indicated that the 17 sericea lespedeza accessions were closely related (average SC of 0.883) (Figures 1 and 2 and Table 3). However, DAF results showed that two of the sericea lespedeza accessions, China (average SC of 0.812) and Gasyn (average SC of 0.803)) as well as Korean lespedeza (South Carolina source; average SC of 0.354) were genetically distinguishable from the other accessions of sericea lespedeza. With DAF analysis, closely related accessions were grouped into five clusters, which include: South Carolina 1, Muskogee, Kentucky, Alabama, and Pennsylvania (Group 1, average SC of 0.984); Serala, Arlington, Serala 76, AU Lotan, and Interstate 76 (Group 2, average SC of 0.923); Research Range (S17), Research Range (S6), Fort Riley, Stillwater (NE), and Hominy (Group 3, average SC of 0.923); China and Gasyn (Group 4, SC of 0.857); and South Carolina (Group 5).

Group 1 consisted of the collection from commercial seed companies and field collections from states other than Oklahoma. Within this group, South Carolina 1, Muskogee, and Kentucky were the most genetically similar (SC of 1.000). Group 2 consisted of accessions from breeding programs, that produced genetically improved lines for production purposes. Even though the dendrogram analysis (Figure 2) indicated that Serala was more closely related to members of Group 1, Serala was included in Group 2 based on the results of the similarity coefficient analysis and the direct association to accessions from breeding programs. The results distinguishing the improved accessions (Group 2) indicated that breeding programs have impacted sericea lespedeza genetics, which have given rise to different phenotypic, morphological, and performance characteristics compared to accessions that have not been genetically influenced through the breeding programs. Group 3 accessions were from Oklahoma and Kansas field collections. Even though the accessions from Oklahoma (Group 3) are genetically similar, they are not genetically identical (average SC of 0.904). Even those collected from rangelands around Stillwater, OK (Research Range S17, Research Range S6, and Stillwater NE) contain genetic uniqueness compared to each other (average SC of 0.932).

Group 4 consisted of the China accession, which was one of the germplasm sources for introduction of sericea lespedeza into the United States. The China accession, when compared to the other sericea lespedeza accessions had an average SC of 0.812, was most related to Research Range (S6) (SC of 0.898), and was least related to Alabama (SC of 0.776). Gasyn (Group 4) was an early improved accession of sericea lespedeza. Gasyn's relation to the other sericea lespedeza accessions was indicated by an average SC of 0.803, was most related to China (SC of 0.857), and was least related to Pennsylvania (SC of 0.755). The final accession (Group 5) was the South Carolina lespedeza, which was actually a different lespedeza species (Korean lespedeza [*Kummerowia stipulacea* (Maxim.) Makino]) and was used as a comparative control against the sericea lespedeza accessions. This Korean lespedeza was genetically distinguishable from all 17 sericea lespedeza accessions with an average SC of 0.354.

Based on these results, the DAF technique was useful in differentiating among sericea lespedeza accessions. DAF analysis showed that sericea lespedeza accessions from improved genetic breeding lines, different states, different commercial seed company sources, and different population regions within the same state were genetically similar. However, there were genetic differences, that could be segregated based on influences from such things as breeding programs or environmental/population parameters that separate the accessions into genetically unique groups.

These genetic differences may explain differences in performance (forage or seed yield, tannin content, etc.) and management (response to herbicides, burning, grazing, etc) of sericea lespedeza that are encountered from one state to another. The genetic differences may also impact control of sericea lespedeza in pasture and rangeland sites; particularly if seed or genetics from commercial seed sources carrying potentially undesirable plant characteristics (high tannins, increased forage yield, increased competition/interference, or increased seed production) are disseminated to areas or states where the control management of sericea lespedeza is taking place. This is particularly important from a control management standpoint, since sericea lespedeza has been shown to be a very competitive invasive species with pastures and rangeland species (Dudley and Fick, 2003; Kalburtji and Mosjidis, 1992; Kalburtji and Mosjidis, 1993a and 1993b) and further competitive enhancement is not wanted if sericea lespedeza is to be controlled.

SOURCES OF MATERIALS

[1] All purpose potting mix, Sta-Green, Spectrum Group, Division of United Industries Corp., P.O. Box 142642, St. Louis, MO 63114-0642.

[2] DNeasy Plant Mini-extraction Kit and Qiagen *Taq* polymerase, Qiagen Sciences Inc., 19300 Germantown, Germantown, MD 20874.

[3] DAF primers, Integrated DNA Technologies Inc., 1710 Commercial Park, Corelville, IA 52241.

[4] Bio Rad Protean II apparatus, Bio-Rad Laboratories Inc., 3300 Regatta Blvd., Richmond, CA 94804-7440.

[5] Long Ranger Acrylamide, Cambrex Bio Science Inc., 191 Thomaston Street, Rockland, ME 04841.

[6] Sybr Gold Nucleic Acid Gel Stain, Molecular Probes, 29851 Willow Creek Rd.,

Eugene OR 97402.

[7] NTSYS software version 2.0, Exeter Software, 47 Route 25A, Suite 2, Setauket, NY 11733-2870.

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Pester, T.A., S.M. Ward, A.L. Fenwick, P. Westra, and S.J. Nissen. 2003. Genetic diversity of jointed goatgrass (*Aegilops cylindrica*) determined with RAPD and AFLP markers. Weed Sci. 51:287-293.

Yerramsetty, P.N., M.P. Anderson, C.M. Taliaferro, and D.L. Martin. 2005. DNA fingerprinting of seeded bermudagrass cultivars. Crop Sci. 45:772-777.

Table 1. Lespedeza accessions use in this experiment.

Accession label	Inventory number	Source and Location[a]	Plants used[b]
Alabama	———	Moorer Seed Co., Pratt AL	42
Arlington	NSSL 22655 01 SD	USDA, ARS; NCGRP[a], Fort Collins CO	16
AU Lotan	NSSL 115803 01 SD	USDA, ARS; NCGRP, Fort Collins CO	17
China	1 PI 90356	USDA, ARS, SPRIS; Univ of GA, PGRCU[c], Griffin GA	12
Fort Riley[c]	———	Military Base, Fort Riley KS	20
Gasyn	NSSL 22985 01 SD	USDA, ARS; NCGRP, Fort Collins CO	23
Hominy	———	Roadside; HWY 99, South of Hominy OK	18
Interstate 76	NSSL 103826 01 SD	USDA, ARS; NCGRP, Fort Collins CO	12
Kentucky	———	Dr. Bill Witt; Hopkins Co.; near Mortons Gap KY	17
Muskogee	———	Sunburst Seed Co., Muskogee OK	27
Pennsylvania	———	Herbiseed Co., Hiram OH	19
Research Range	———	Section 6; OSU Research Range; Stillwater OK	17
Research Range (S17)	———	Dr. Dave Engle; Section 17; OSU Research Range, Stillwater OK	14
Serala	NSSL 43596 01 SD	USDA, ARS; NCGRP, Fort Collins CO	29
Serala 76	NSSL 103825 01 SD	USDA, ARS; NCGRP, Fort Collins CO	23
South Carolina[d]	———	Outside Pride Seed Co., Salem OR	34
South Carolina 1	A 200-C	Kaufman Seeds Co., Ashdown AR	27
Stillwater (NE)	———	Pasture, Northeast of Stillwater OK	20

[a] Abbreviations: ARS, Agricultural Research Service; NCGRP, National Center for Genetic Resources Preservation; OSU, Oklahoma State University; PGRCU, Plant Genetic Resources Conservation Unit; SPRIS, State park Resource Information System; USDA, United States Dept. Of Agriculture.

[b] Number of plants used for DNA extraction.

[c] This accession was the only one where plant genomic material (fresh leaf) was collected directly from the field; all others were collected from seed grown plant material from a greenhouse.

[d] This accession of lespedeza was a Korean lespedeza and was used in the experiment as a “positive” comparative control against the accessions of sericea lespedeza.

Table 2. Nucleotide sequence of the DNA amplification fingerprinting (DAF) primers used in this experiment.

Primer label	Primer sequence	Total DAF loci[a]	Polymorphic loci[b,c]
DAF9110	CAGAAACGCC	11	7
DAF9111	GAAACGCC	17	13
DAF9112	GTAACGCC	9	8
DAF9113	GTAACCCC	12	11

[a] The total DAF loci are averaged over the replications for the different DAF primers

[b] Polymorphic loci are obtained from scoring those bands which are absent in at least one or more of the 18 lespedeza accessions in this experiment.

[c] The polymorphic loci are averaged over the replications for the different DAF primers.

Table 3. Similarity coefficient table using DNA amplification fingerprinting (DAF) analysis.

Accessions	SC 1	AL	China	S17 R R	Musk	PA	KY	S6 R R	Hominy	SC	Arling	Gasyn	Inter 76	AU Lotan	Serala 76	Serala	(NE) Stillwater	Fort Riley
South Carolina 1	1.000																	
Alabama	0.980	1.000																
China	0.796	0.776	1.000															
Res Range (S17)	0.898	0.918	0.816	1.000														
Muskogee	1.000	0.980	0.796	0.898	1.000													
Pennsylvania	0.980	0.959	0.776	0.878	0.980	1.000												
Kentucky	1.000	0.980	0.796	0.898	1.000	0 980	1.000											
Research Range	0.898	0.878	0.898	0.918	0.898	0.878	0.898	1.000										
Hominy	0.878	0.898	0.796	0.898	0.878	0.857	0.878	0.898	1.000									
South Carolina	0.327	0.306	0.408	0.347	0.327	0.347	0.327	0.429	0.327	1.000								
Arlington	0.878	0.898	0.796	0.857	0.878	0.857	0.878	0.898	0.878	0.367	1.000							
Gasyn	0.776	0.796	0.857	0.796	0.776	0.755	0.776	0.837	0.776	0.429	0.857	1.000						
Interstate 76	0.898	0.918	0.776	0.878	0.898	0.878	0.898	0.878	0.857	0.306	0.898	0.796	1.000					
AU Lotan	0.878	0.898	0.796	0.857	0.878	0.857	0.878	0.857	0.878	0.327	0.918	0.776	0.939	1.000				
Serala 76	0.918	0.939	0.796	0.898	0.918	0.898	0.918	0.898	0.918	0.327	0.959	0.816	0.939	0.959	1.000			
Serala	0.939	0.959	0.776	0.878	0.939	0.918	0.939	0.837	0.898	0.306	0.898	0.796	0.878	0.898	0.939	1.000		
Stillwater (NE)	0.918	0.898	0.878	0.898	0.918	0.898	0.918	0.980	0.878	0.408	0.918	0.857	0.898	0.878	0.918	0.857	1.000	
Fort Riley	0.878	0.857	0.878	0.898	0.878	0.857	0.878	0.980	0.918	0.408	0.918	0.816	0.857	0.878	0.918	0.857	0.959	1.000

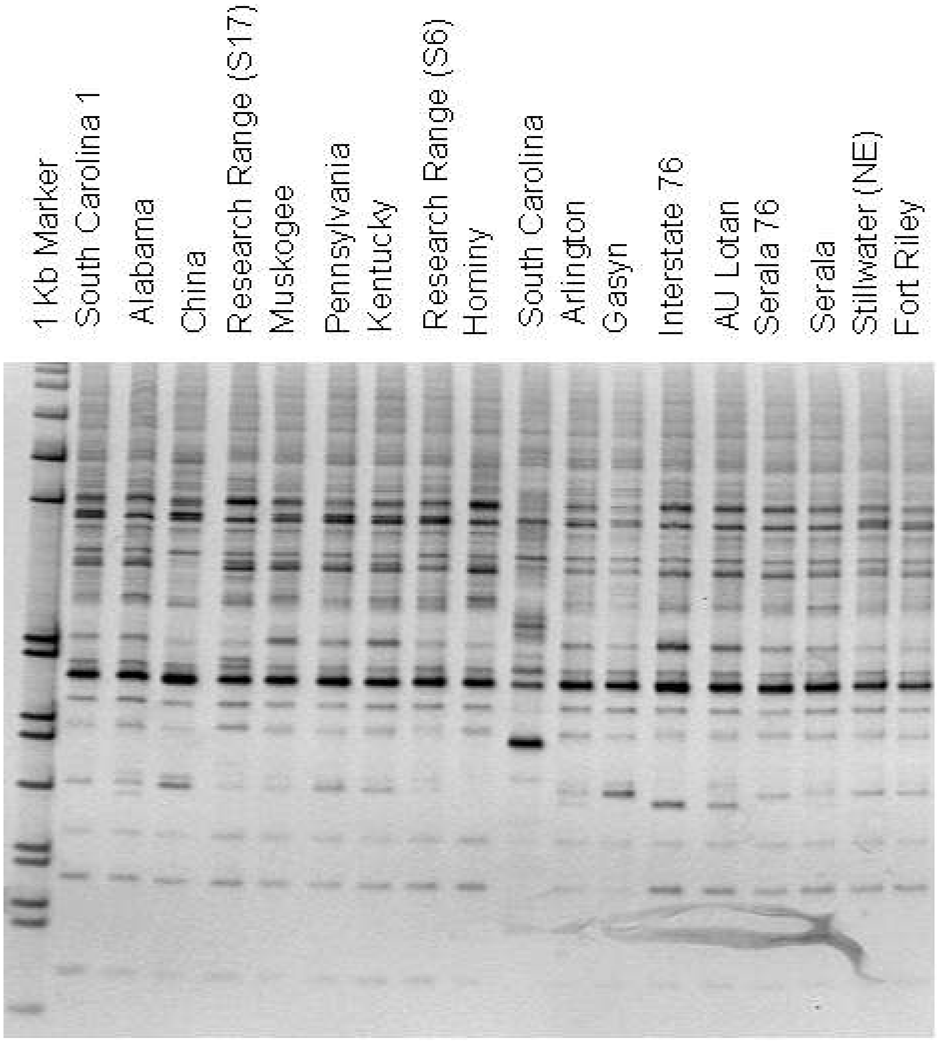

Figure 1. DNA amplification fingerprinting (DAF) electrophoresis gel stained with Sybr Gold containing polymerase chain reaction (PCR) amplicons from 18 accessions of lespedeza (primer 9111).

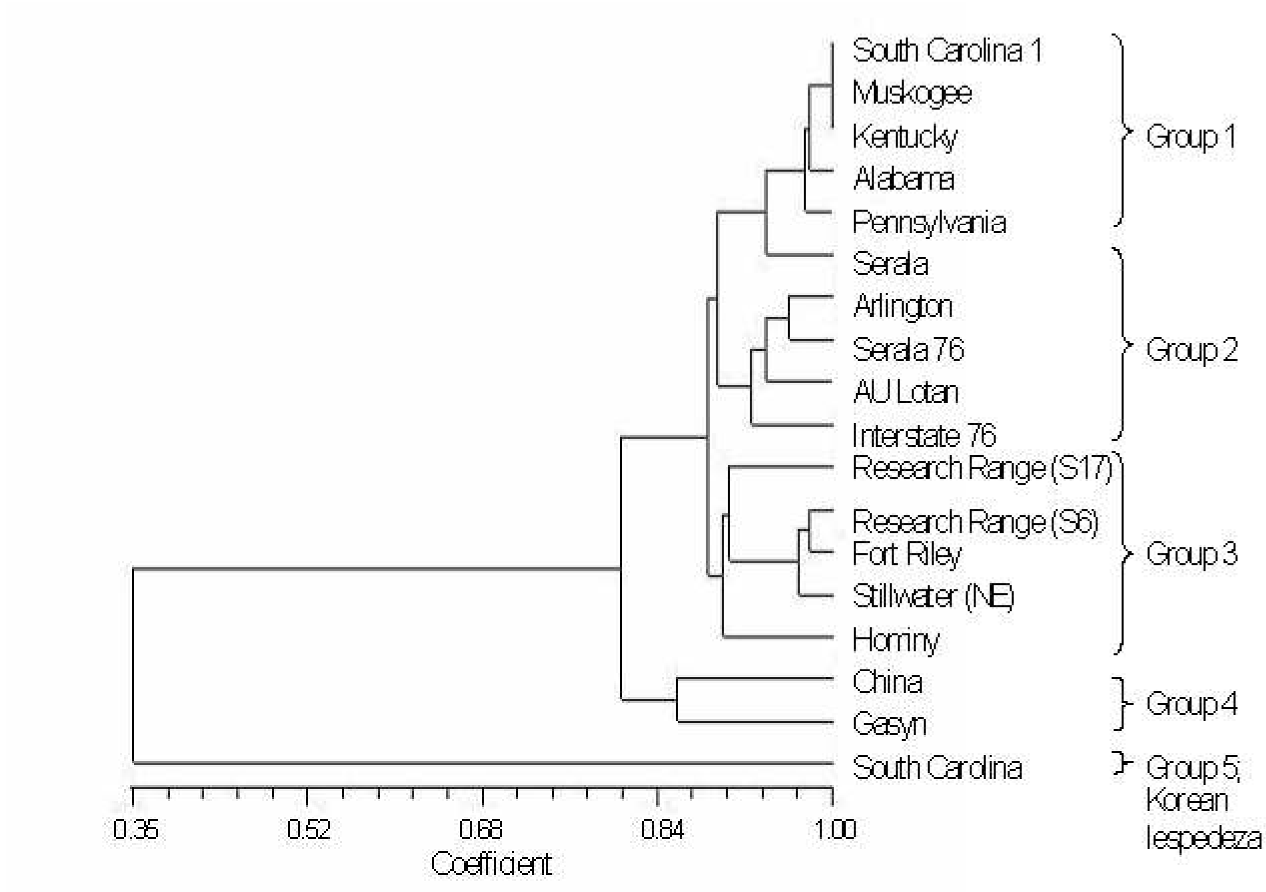

Figure 2. Dendrogram of DNA amplification fingerprinting (DAF) analysis of 18 lespedeza accessions.

Chapter II

A Measure of Sericea Lespedeza Adaptation to Soils or Locations Relative to Soil Chemical and Physical Properties

A Measure of Sericea Lespedeza Adaptation to Soils or Locations Relative to Soil Chemical and Physical Properties

Abstract: Three field experiments were conducted at the Range Research Station and a site near Lake Carl Blackwell located west of Stillwater, OK, and on a privately-leased pasture located northeast of Stillwater in 2003 to measure the relationship of soil chemical and physical variables to zones of sericea lespedeza presence, absence, and along a transitional zone. The experiment was conducted to evaluate the phenomena of why sericea lespedeza grew well in one area, abruptly stopped it's infestation along a particular well defined line, and was not present on an adjacent area. The soil chemical variables of organic matter, pH, nitrate-N, potassium, manganese, calcium, magnesium, boron, cations, phosphorus, conductivity, sodium, chloride, sulfate, zinc, iron, and copper and the soil physical variables of sand, silt, and clay were analytically measured by soil profile depth within the three zones, soil depth alone, and among the sericea lespedeza presence, absence, and transitional zones. Soil profile depths evaluated were 0 to 15, 15 to 30, 30 to 60, and 60 to 90 cm. Significant differences among the soil depths were detected in 17 of the 20 soil variables measured. The presence or absence of sericea lespedeza was associated with soil pH, conductivity, sulfate, iron, magnesium, sodium, and chloride concentrations. Lower soil pH and concentrations of conductivity, magnesium, sodium, and chloride favored the presence of sericea lespedeza. The measurement of total plant species and the percent composition did not appear to be affected by the soil properties measured except for sericea lespedeza. The presence or absence of sericea lespedeza was associated with some of the soil properties measured; however, it is unclear whether sericea lespedeza was better adapted to sites with specific soil properties or whether sericea lespedeza invaded an area which other plants were not occupying because they lacked the adaptation to these sites.

Nomenclature: Sericea lespedeza, *Lespedeza cuneata* (Dumont) G. Don. #[2] LESCU.

Additional index words: Growth zone, percent plant composition, soil chemical and physical variables, soil profile depth.

Abbreviations: ANOVA, analyses of variance.

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[2] Letters following this symbol are a WSSA-approved computer code from *Composite List of Weeds*, Revised 1989. Available only on computer disk from WSSA, 810 East 10th Street, Lawrence, KS 66044-8897.

INTRODUCTION

Invasive plant species are characterized as plants that are introduced intentionally or unintentionally into areas where they are not native. They often establish rapidly and aggressively in these new environments and can exhibit unexpected growth tendencies, that allows the plant to proliferate, persist, and spread. Invasion and interference between the invasive species and native or previously established desirable plant species can reduced plant species diversity, or reduced populations of desired plants. Invasive species can be very competitive and are generally able to thrive in new environments because of factors such as being free of natural pests. Often insects or diseases, that keep them in balance in their native habitats, are often lacking in new environments. Invasive plant species have the potential to affect the ecological balance and functions such as soil characteristics, biological interactions, landscape features, species diversity, and nutrient cycling. Invasive species may exhibit high seed production, rapid growth and maturity rates, often establish, spread and interfere with native species easily, and are difficult and costly to control. Therefore, the study and understanding of an invasive plant species is crucial for understanding the soil and environmental parameters of habitats this species might invade, and determining the ecological implications of the spread of an invasive species into new areas.

Sericea lespedeza, also known as Chinese lespedeza, is a warm-season perennial legume that was intentionally introduced into the United States in 1896 from eastern Asia for experimental forage production. In the 1940's, it was widely planted and established for erosion control, land reclamation, wildlife food and cover, and livestock forage and hay. It was unintentionally introduced into United States pastures or fields as a contaminant in seed used as part of the Conservation Reserve Program during the 1980's (Ohlenbusch et al. 2001). Sericea lespedeza is the only perennial lespedeza of agricultural importance in the U.S. (Magness et al. 1971). The plant can be found in 35 states and has been reported as far north and east as Maine, south to include all of Florida, then west to central Texas, and north to Nebraska (USDA-NRCS 2002). It has also been reported in Oregon and Hawaii. Researchers in Kansas have tried to survey the severity of the weed and have estimated that sericea lespedeza infests about 280,000 ha in that state. On July 1, 2000 it was declared a state-wide noxious weed in Kansas (Anonymous 2003).

Sericea lespedeza seedlings are considered weak or poor competitors with other spring and summer grasses and dicot plant species. However, once established, sericea lespedeza is recognized for its tolerance to drought, due to its deep rooted and long-lived nature (Ohlenbusch et al. 2001). It is also recognized for it’s tolerance to acidic (Mkhatshwa and Hoveland 1991; Ohlenbusch et al. 2001) and low fertility soils (Lynd and Ansman 1993; Wilson 1954) and for it having few insect and disease problems (Ohlenbusch et al. 2001). Although, able to establish and grow on poor soils, it will grow abundantly on fertile, well drained soils. Wilson (1954) reported that sericea lespedeza can produce satisfactory yields over several seasons without the addition of lime or fertilizer.

It has been documented that soil chemical and physical conditions have been influenced by and have imparted an influence on sericea lespedeza (Cline and Silvernail

1997; Kalburtji et al. 1999; Lynd and Ansman 1993; Mkhatshwa and Hoveland 1991; Stitt et al. 1946; Wilson 1954). Kalburtji et al. (1999) investigated the loss of litter mass and nutrient (N, P, K, Ca, Mg, Cu, Fe, Mn, Zn, B, Mo, and Co) release with comparisons made between high and low tannin sericea lespedeza. They reported that there was a higher release of nutrients from sericea lespedeza litter when the litter was buried 5 cm deep versus laying on the soil surface and that this higher release was from the low tannin lespedeza.

Soil type or chemical conditions impact the presence or growth of sericea lespedeza (Cline and Silvernail 1997; Lynd and Ansman 1993; Mkhatshwa and Hoveland 1991; Stitt et al. 1946; Wilson 1954). The tannin content, number of shoots per plant, height, leafiness, dry matter, and yield of newly planted sericea lespedeza vary when grown on different soil types in North Carolina (Stitt et al. 1946). The tannin content was also shown to vary with additions of phosphorus fertilizer (5.41% at 50 lb P_2O_5 versus 5.09% at 150 lb P_2O_5) and potassium fertilizer (6.68% at 0 lb K_2O versus 5.86 at 60 lb K_2O) to Alabama soils (Wilson 1954). However, Wilson (1954) reported no differences in the 1950 first cutting plant production due to soil type with the exception to the Boswell soil type. Addition of lime on the first year of a 20 yr sericea lespedeza experiment conducted in Oklahoma resulted in triple the growth and nitrogen fixation of sericea lespedeza during the second and subsequent 10 yr of the experiment (Lynd and Ansman 1993). Lynd and Ansman (1993) reported that sericea lespedeza average nodule weights were higher with Ca, CaP, and CaPK additions compared to the plants receiving no treatment. They also concluded that lime additions may increase the availability of limited plant nutrients, especially for the fixed and unavailable soil phosphorus and essential trace elements. Mkhatshwa and Hoveland (1991) reported that N-fertilization had no effect on forage yield of sericea lespedeza. They also reported that forage yields were high on the very acid soils (pH of 4.0 to 4.8) of the middle and highveld (a veld is a wide-open plateau grassland in Africa) of Swaziland. However, at the lowveld location (soil pH of 8.0), forage yields were low and plants died after 2 yrs. Cline and Silvernail (1997) reported that “Serala” sericea lespedeza [*Lespedeza juncea* (L.F.) Var. sericea (Mig.)] could survive at pH levels of 4.1 to 4.3 and actually preferred to grow in acid soils of Kentucky. They determined that “Serala” sericea lespedeza growth was reduced when grown on soils acidified with sulfur under the condition of water-extractable manganese levels exceeding 1.3 mM or calculated Mn^{2+} activity exceeded 0.4 mM. “Serala” sericea lespedeza growth was also lowest in nonacidified soil with pH values near 6.0 (Cline and Silvernail 1997).

In Cowley County, KS, about 26,000 ha or 17% of the rangeland in the Silliman and Maccarone (2005) survey area contained invasive sericea lespedeza. They determined that the level of infestation ranged from sparse to severe, with 50% of the study area being of the sparse and scattered level. With an investigation of the spatial distribution of sericea lespedeza within the study area, they determined that sericea lespedeza was primarily found in areas that contained ponds, streams, or greater than 1% forest cover. They hypothesized that sericea lespedeza’s association with water and forest was due to water acting as a collection and dispersal mechanism and the movement of wildlife within forest cover acted as a mechanism for seed dispersal. They reported no association between different soil types and the presence or absence of sericea lespedeza. Silliman and Maccarone (2005) concluded that areas where water or forest cover are present are at a higher risk for infestation by invasive sericea lespedeza.

Invasive sericea lespedeza can be found in rangelands, pastures, forests, or roadsides within Oklahoma. Sericea lespedeza infestations can often appear as sharply defined patches of growth within an area. There is no apparent visual or ecological evidence or reason why sericea grows in and up to one particular area but does not grow within the adjacent area. The objective of this experiment was to determine if this phenomenon could be answered with a full assessment of soil properties. The objectives of this experiment were to measure sericea lespedeza adaptation to soils or locations (sericea presence, transitional, and sericea absence zones) relative to soil chemical and physical properties. The second objective was to relate plant species presence and percent composition to the sericea lespedeza presence, transitional, and sericea lespedeza absence zones.

MATERIALS AND METHODS

Three field experiments were conducted at the Range Research Station and a site near Lake Carl Blackwell located west of Stillwater, OK and on a privately-leased pasture located northeast of Stillwater in 2003. The experiment on the Range Research Station was conducted on a Coyle and Zaneis (taxadjunct soil type) (fine-loamy, siliceous, thermic Udic Argiustolls; fine-loamy, mixed, thermic Udic Argiustolls). The soil at the Range Research Station had a pH range of 6.0 to 7.9 and an organic matter content range of 1 to 2.4% within the 0-90 cm soil depth, respectively. The experiment near Lake Carl

Blackwell was conducted on a Grainola-Lucien complex (taxadjunct) (fine, mixed, thermic Vertic Haplustalfs; loamy, mixed, thermic, shallow Typic Haplustolls). The soil at this location had a pH range of 5.5 to 7.9 and an organic matter content range of 1 to 2.4% within the 0-90 cm soil depth, respectively. The experiment on the privately-leased pasture was conducted on a Renfrow loam (fine, mixed, thermic Udertic Paleustolls). The soil at this pasture had a pH range of 5.5 to 8.0 and an organic matter content range of 0.5 to 2.4% within the 0-90 cm soil depth, respectively.

All three experiment areas were moderately to heavily infested (12 to 40 plants/m^2) with mature sericea lespedeza. However, there were areas within all three locations where sericea lespedeza was not present. Three zone designations or treatments were assigned to areas based on the presence and absence of sericea lespedeza, which were the "sericea lespedeza present zone," "transitional zone," and the "sericea lespedeza absent zone" (Figure 1). A 15 m transect line was established directly on and parallel with the area of transition between sericea lespedeza plant presence and sericea lespedeza absence. A second 15 m transect line was established 10 m within the area of sericea lespedeza growth and presence and was parallel to the transitional zone/transect line. A third 15 m transect line was established 10 m within the area absent of sericea lespedeza growth or presence and was also parallel to the transitional zone/transect line (Figure 1).

The experiment was arranged as a randomized complete block design with the three locations treated as replications. Fifteen or more soil core samples collected to a depth of 90 cm along the transect line were randomly collected with the use of a hydraulic soil exploration probe.[1] Soil samples were collected at the Range Research Station, Lake

Carl Blackwell, and at the pasture northeast of Stillwater, on September 17, 15, and 9, respectively. Each soil core sample was separated into four soil depth sections, which were 0 to 15 cm, 15 to 30 cm, 30 to 60 cm, and 60 to 90 cm. The soil samples collected from the four soil depths and in the three transects at each location totaled 12 soil samples per site. The entire three site experiment consisted of 36 soil samples. Fifteen or more soil cores were required to produce a composite sample necessary for laboratory analyses of the experimental soil variables. The composite soil samples from each soil depth and the experimental locations were shipped to a contract laboratory[2] for chemical and physical analysis (Table 1). A list of the methods and sources for the various soil chemical and physical analysis is shown on Table 2. The soil chemical and physical variables were then related to soil depth across all zones of growth, soil depth alone, and to the three zones of growth alone. However, no interactions between the various soil chemical and physical variables (such as soil pH and iron concentration interactions) were conducted or statistically analyzed.

Plant species presence and percent composition were determined with the use of two 0.25 m^2 quadrates/transect line, that were randomly placed along each transect line. Visual identification of plant species present and percent estimation of species composition was determined within each quadrate. Species composition was based on a visual estimation of percent ground cover imposed by each plant species. Data on the plant species present and percent composition were collected at all three locations on September 22. The two quadrate samples were later compiled or averaged together for statistical analysis and data presentation. The plant species present and their percent composition were then related to the three treatments designation zones. All of these procedures were repeated for each location within the experiment.

Data from all three locations were subjected to analysis of variance (ANOVA) using PROC MIXED procedure (SAS 2002). To statistically analyze the relationship of soil chemical and physical variables to soil depth across all zones of growth, depth within zone was treated as a repeated measure and location was treated as a random effect within the model. The relationship of soil variables to either soil depth alone or to the percent composition of plant species was analyzed by treating the location by zone as a repeated measure. The relationship of soil variables to zones of growth alone was analyzed by treating the location by depth as a repeated measure. To determine location effect on treatment (zone), ANOVAs combined over locations as F-test for all treatment and location by treatment interactions were performed. No significant location by treatment interaction was detected for any of the variables measured; therefore, all variables measured were pooled over the three locations. Treatment means were separated using Fisher's protected LSD at P = 0.10.

RESULTS AND DISCUSSION

The results of the relationship of the various soil variables to soil depth among all three zones shows that there were significant differences with 13 of the 20 variables measured (Table 1). Seven variables were not different according to site or depths. Those were percent silt, nitrate-N, potassium, manganese, calcium, boron, and cations (Table 1). Table 1 was included to show numerical trends and any significant differences as they relate to the soil depth within each zone and this combination compared across all three zones. When the soil measurements were averaged across the three sericea lespedeza zones and the three experimental sites, there were no differences in the nitrate-N, potassium, and boron concentrations (Table 2).

There were significant differences detected when the soil variables, which were pooled over all soil core depths and experimental locations, were related to the sericea lespedeza present, transitional, and sericea lespedeza absent zones (Table 3). The analysis or results of Table 3 takes into account the combined four soil depth ranges and the three experimental locations and relates these combined variable concentrations to the three zones. Among the three sericea lespedeza zones, the soil composition of percent sand, silt, clay, and organic matter at the three sites were similar. As expected, the percent clay generally increased with depth and the percent organic matter decreased with depth. These factors did not seem to be associated with the presence or absence of sericea lespedeza.

The analysis for nitrate-N, manganese, calcium, and total cations did not differ among sericea lespedeza zones or among soil depths; therefore, these factors did not appear to be associated with the presence or absence of sericea lespedeza (Table 3). Even though zone differences were detected for organic matter, phosphorus, zinc, copper, and boron, there was likely no real or remarkable association of these variables with the presence and/or absence of sericea lespedeza. This conclusion was based on all the results (Tables 1 through 3) and the small numerical differences detected between concentrations across the three zones

Soil pH ranged from 5.7 to 7.5 across all soil depths and zones (Table 1). Soil pH numerically increased as soil depth decreased. A significant difference in soil pH occurred in the sericea lespedeza absent zone with the lowest soil depth being 1.2 higher than the upper most soil depth. A comparison across the zones of growth at 30 to 60 cm soil depth showed a significantly higher soil pH within the sericea lespedeza absent zone (7.1 pH) compared to 5.9 within the sericea lespedeza present zone. The sericea lespedeza absent zone also had a 1.3 higher soil pH concentration than the sericea lespedeza present zone at the lowest soil depth.

Soil pH was more acidic in nature near the soil surface (Table 2). With each increase in depth through the soil profile, a 0.3 to 0.4 increase in pH occurred. The pH of the soil was significantly lower in the sericea lespedeza present zone compared to the transitional and sericea lespedeza absent zones (Table 3). With the transition from the sericea lespedeza absent zone to the transitional zone and from the transitional zone to the sericea lespedeza present zone, soil pH decreased by 1.1 and 0.7, respectively. The results from Tables 1 to 3 suggest that sericea lespedeza presence may be associated with soil pH. These data support the conclusions of Mkhatsha and Hoveland (1991) and Ohlenbusch et al. (2001) that sericea lespedeza can grow on more acidic soils. These results are not supported by the results of Lynd and Ansman (1993) where an addition of lime increased the growth as well as nitrogen fixation of sericea lespedeza. Reports such as the one generated by USDA-NRCS (2002) also showed that sericea lespedeza can grow in many areas of the United States with many different soil types (pH ranges). The results may also be viewed with respect to soil pH influence on or association with other plant species; where the lower soil pH hinders the presence and/or growth of other plant species and allows sericea lespedeza to invade, grow, and persist.

The conductivity concentration (mmho/cm) is an indirect measurement of electrical conductivity from ions such as potassium, calcium, magnesium, sodium, and chloride ions that were measured in this experiment. At the three sites of this experiment, sericea lespedeza was present when soil tested low or void in electrical conductivity. However, when the concentration increased, the sericea lespedeza appeared to be absent (Table 1). The conductivity across all soil depths within the sericea lespedeza absent zone were numerically higher compared to the other two zones. There was also a significantly higher conductivity concentration within the lowest two soil depths of the sericea lespedeza absent zone compared to the upper two soil depths within the other two zones.

The relationship of conductivity concentration pooled over all zones and locations to each soil core depth (Table 2) showed conductivity increased as soil depth increased. This same relationship was shown with calcium, magnesium, sodium, and chloride ions. The conductivity concentration at the lowest soil depth was 0.80 mmho/cm, which was significantly different from 0.10 and 0.26 mmho/cm conductivity concentrations at the two upper soil depths, respectively.

Conductivity concentrations within the sericea lespedeza absent zone were 0.91 and 0.68 mmho/cm higher than the concentrations within the sericea lespedeza present and transition zones, respectively (Table 3). The result of a significantly higher conductivity concentration within the sericea lespedeza absent zone was likely associated with the higher concentrations of magnesium, sodium, and chloride ions. It is interesting that sericea lespedeza appeared to exhibit a response to magnesium, sodium, and chloride ions and that these three ions showed an increase in concentration as soil depth increased (Tables 1 to 3). These data suggest that sericea lespedeza is able or prefers to grow in soils with lower concentrations of magnesium, sodium, and chloride based salts. Data from Tables 1 to 3 also suggest that the absence of sericea lespedeza may be associated with the higher salt concentration within the lower two soil depths of the sericea lespedeza absent zone.

The concentration of soil sulfate at the lowest soil depth within the sericea lespedeza absent zone (424 mg/kg) was significantly greater than all of the other soil depths and zones (concentration range of 6 to 81 ppm), with the exception of the 212 mg/kg concentration at 30 to 60 cm depth within the sericea lespedeza absent zone (Table 1).

Sulfate concentration increased from 9 mg/kg within the 0 to 15 cm depth to a significantly high concentration of 157 mg/kg within the 60 to 90 cm depth (Table 2). The results of Table 3 indicate that as the zone contained less sericea lespedeza the sulfate concentration increased. The sericea lespedeza absent zone, which contained 181 mg/kg of sulfate, was 165 and 173 mg/kg higher than the concentrations of the transitional and sericea lespedeza present zones, respectively. The data from Tables 1 to 3 suggest that sericea lespedeza may inhabit areas with lower sulfate concentration and the lack of sericea lespedeza presence was associated with the higher sulfate concentration within the lower two soil profile depths.

The concentration of soil iron across all soil depths and zones ranged from 8.5 mg/kg at 60 to 90 cm depth within the sericea lespedeza absent zone to 64.9 mg/kg at 0 to 15 cm depth within the sericea lespedeza present zone (Table 1). The concentration of iron generally decreased with depth within the respective zones and the concentration within the sericea lespedeza zone was significantly higher than the concentrations within the transitional and sericea lespedeza absent zones.

Iron concentration decreased as soil depth increased, with a resulting range of concentration from 45.3 mg/kg at 0 to 15 cm soil depth to 12.2 mg/kg at 60 to 90 cm depth (Table 2). The concentration of iron decreased 11.7 mg/kg as the zone transitioned from the sericea lespedeza present to the transitional zone and decreased 4.4 mg/kg from the transitional to sericea lespedeza absent zone (Table 3). A significant zone effect occurred with the sericea lespedeza present zone having a significantly higher concentration of iron compared to either the transitional or sericea lespedeza absent zones. The results from Tables 1 through 3 suggest that sericea lespedeza prefers to grow in areas with a higher concentration of soil iron and that the association with iron concentration was found within the 0 to 15 cm soil depth profile of the sericea lespedeza present zone.

Analysis results of the relationship of plant species present and the percent composition to the three growth zones showed that there were no significant differences detected for any of the species, with the exception of sericea lespedeza (Table 4). Sericea lespedeza comprised 75% ground cover (composition) and was significantly higher within the sericea lespedeza present zone. The transitional zone contained 10% sericea lespedeza, which was not significantly different from the zone with no sericea lespedeza present. Even though there was no significant differences detected with the other graminoid, forb, or woody species, additional data were derived from the results. Within the graminoid species, the total number of species present increased as the zones transitioned from the sericea lespedeza present to the transitional zone and from the transitional zone to the sericea lespedeza absent zone. Within the graminoid group, there were 9 species and 17.4% ground cover, 10 species and 53.1% ground cover, and 13 species and 34.8% ground cover within the sericea lespedeza present, transitional, and sericea lespedeza absent zones, respectively. The percent composition was also numerically higher in 7 of the graminoid species within the sericea lespedeza absent zone compared to only 4 species with higher values within the sericea lespedeza present zone. In the forb and woody species group there were 8 species and 89.9% ground cover, 10 species and 26.5% ground cover, and 9 species and 14.8% ground cover within the sericea lespedeza present, transitional, and sericea lespedeza absent zones, respectively. The total number of species present (species richness) also increased as the zones progressed from sericea lespedeza present through sericea lespedeza absent. There were 17 total species accounted for within the sericea lespedeza present zone, 20 species within the transitional zone, and 22 total species within the sericea lespedeza absent zone. A conclusion from this data was sericea lespedeza may influence graminoid, forbs, and woody species presence and overall species richness. However these data could not detect differences in percent composition of the graminoid, forbs, or woody species across the zones, except for sericea lespedeza. The difference in sericea lespedeza was expected since the experimental area was based on the sericea lespedeza density and zonal differences within the experimental areas.

It has been documented by other researchers that sericea lespedeza growth and production can both influence and be influenced by soil types or soil chemistry. It has also been documented that sericea lespedeza can influence the vegetative landscape through interference with other plants. Based on the results of this experiment, there were soil variables that were associated with the presence and/or absence of sericea lespedeza within a landscape. However, the phenomena and results of why sericea lespedeza grows well in one area, abruptly stops growth at one particular area, and was not present within an adjacent area was difficult to interpret. This difficulty arose from trying to conclude whether the plant was associated with or influenced from the soil variable or whether the soil variable was influenced by the plant. This same issue can be questioned with the relationship of sericea lespedeza and other plant species. The answer may possibly be that one single variable was not the total influencing factor of whether sericea lespedeza was present or absent in an area. There are possibly multiple variables, combinations of variables, or variable interactions that influence plant invasion, presence, or persistence.

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[1] Giddings Machine Co., Fort Collins CO; Model HD-GSRP-S; 4.45 cm diameter probe.

[2] Ward Laboratories, Inc.; Kearney, NE 66848-0788.

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Table 1. Relationship of soil variables to soil depth within three zones of sericea lespedeza presence; data pooled over three locations.[a]

	Sericea lespedeza zone											
	Present				Transitional				Absent			
	Soil depth (cm)				Soil depth (cm)				Soil depth (cm)			
Measurement	0-15	15-30	30-60	60-90	0-15	15-30	30-60	60-90	0-15	15-30	30-60	60-90
Sand (%)	51 a	47 a-c	41 a-c	40 a-c	48 a-c	42 a-c	38 c	39 bc	50 ab	43 a-c	37 c	37 c
Silt (%)	29 a	28 a	28 a	27 a	29 a	26 a	26 a	26 a	28 a	27 a	28 a	25 a
Clay (%)	20 e	26 b-e	31 a-c	33 a-c	24 c-e	32 a-c	37 a	35 ab	22 de	30 a-d	34 ab	39 a
Organic matter (%)	2.4 a	1.7 b-d	1.6 cd	1.3 de	2.3 ab	1.7 b-d	1.4 de	1.2 de	2.1 a-c	1.4 de	1.1 de	09 e
Soil pH	5.7 e	5.8 de	5.9 c-e	6.2 b-e	5.9 c-e	6.4 b-e	6.8 a-c	7.1 ab	6.3 b-e	6.7 a-d	7.1 ab	7.5 a
Nitrate-N (mg/kg N)	0.9 a	0.4 a	0.3 a	0.3 a	0.3 a	0.2 a	0.2 a	0.3 a	0.7 a	0.3 a	0.3 a	0.4 a
Potassium (mg/kg K)	120 a	94 a	106 a	111 a	113 a	98 a	105 a	107 a	94 a	90 a	96 a	96 a
Manganese (mg/kg Mn)	11.1 a	5.1 a	5.1 a	4.5 a	7.4 a	5.7 a	4.9 a	5.5 a	7.5 a	4.2 a	3.7 a	4.5 a
Calcium (mg/kg Ca)	747 a	843 a	982 a	1046 a	821 a	957 a	1048 a	1068 a	668 a	843 a	857 a	1416 a
Magnesium (mg/kg Mg)	244 d	348 d	471 b-d	566 a-d	381 cd	565 a-d	742 a-c	761 ab	354 d	605 a-d	754 a-c	856 a
Boron (mg/kg B)	0.61 a	0.46 a	0.52 a	0.59 a	0.55 a	0.71 a	0.73 a	0.68 a	0.79 a	0.72 a	0.92 a	0.85 a
Cations (me/100g)	11.5 a	12.5 a	14.4 a	12.7 a	10.9 a	12.3 a	14.4 a	13.7 a	8.8 a	12.9 a	13.1 a	17.2 a
Phosphorus (mg/kg P)	2.3 a	2.0 ab	1.7 a-c	1.3 bc	2.0 ab	1.3 bc	1.0 c	1.0 c	2.0 ab	1.0 c	1.0 c	1.0 c
Conductivity (mmho/cm)	0.00 c	0.00 c	0.00 c	0.11 c	0.07 c	0.16 c	0.28 c	0.53 bc	0.25 c	0.61 bc	1.15 ab	1.77 a
Sodium (mg/kg Na)	27 c	42 c	73 c	111 c	84 c	212 bc	378 ab	404 ab	229 bc	416 ab	537 a	629 a
Chloride (mg/kg Cl)	9 c	5 c	4 c	4 c	8 c	9 c	24 bc	33 bc	22 c	47 bc	80 ab	105 a
Sulfate Ca-P (mg/kg S)	10 b	9 b	6 b	5 b	9 b	6 b	6 b	43 b	9 b	81 b	212 ab	424 a
Zinc (mg/kg Zn)	1.08 a	0.18 c	0.16 c	0.15 c	0.66 b	0.17 c	0.16 c	0.13 c	0.81 b	0.21 c	0.15 c	0.18 c
Iron (mg/kg Fe)	64.9 a	25.9 cd	20.3 de	16.7 d-f	39.6 b	17.5 d-f	12.3 ef	11.4 ef	31.5 bc	13.0 ef	10.4 ef	8.5 f
Copper (mg/kg Cu)	0.73 a	0.48 ab	0.42 ab	0.34 b	0.53 ab	0.31 b	0.25 b	0.22 b	0.48 ab	0.29 b	0.31 b	0.23 b

[a] Means within a row followed by the same letter are not significantly different according to Fisher's protected LSD at P=0.10.

Table 2. Relationship of soil variables pooled over all locations for each soil core depth.[a]

		Soil Depth (cm)			
Measurement	Method[b]	0-15	15-30	30-60	60-90
Sand (%)	Gee and Bauder (1986)	50 a	44 ab	39 b	39 b
Silt (%)	Gee and Bauder (1986)	29 a	27 ab	27 ab	26 b
Clay (%)	Gee and Bauder (1986)	22 c	29 b	34 ab	36 a
Organic matter (%)	Combs and Nathan (1998)	2.3 a	1.6 b	1.3 be	1.1 c
Soil pH	Watson and Brown (1998)	5.9 c	6.3 be	6.6 ab	6.9 a
Nitrate-N (mg/kg N)	Lachat Instruments (1995)	0.6 a	0.3 a	0.3 a	0.3 a
Potassium (mg/kg K)	Brown and Warncke (1998a)	108 a	94 a	102 a	104 a
Manganese (mg/kg Mn)	Whitney (1998a)	8.7 a	5.0 b	4.6 b	4.8 b
Calcium (mg/kg Ca)	Brown and Warncke (1998b)	746 b	881 b	962 ab	1177 a
Magnesium (mg/kg Mg)	Brown and Warncke (1998b)	326 c	506 be	656 ab	728 a
Boron (mg/kg B)	Watson (1998)	0.65 a	0.63 a	0.72 a	0.71 a
Cations (me/100g)	Sum of Cation Method[c]	10.4 b	12.6 ab	13.9 a	14.5 a
Phosphorus (mg/kg P)	Frank et al. (1998)	2.1 a	1.4 b	1.2 b	1.1 b
Conductivity (mmho/cm)	Whitney (1998b)	0.10 b	0.26 b	0.48 ab	0.80 a
Sodium (mg/kg Na)	Brown and Warncke (1998b)	114 c	223 be	329 ab	381 a
Chloride (mg/kg CI)	Gelderman et al. (1998)	13 b	21 ab	36 ab	47 a
Sulfate Ca-P (mg/kg S)	Combs et al. (1998)	9 b	32 b	75 ab	157 a
Zinc (mg/kg Zn)	Whitney (1998a)	0.85 a	0.19 b	0.16 b	0.15 b
Iron (mg/kg Fe)	Whitney (1998a)	45.3 a	18.8 b	14.3 be	12.2 c
Copper (mg/kg Cu)	Whitney (1998a)	0.58 a	0.36 b	0.33 be	0.27 c

[a] Means within a row followed by the same letter are not significantly different according to Fisher's protected LSD at P = 0.10.

[b] Sources and methods used for the various designated soil analyses.

[c] Sum of cations = (7.0 - BpH) * 10 + mg/kg K/390 + mg/kg Ca/200 + mg/kg Mg/120 + mg/kg Na/230.

Table 3. Relationship of soil variables averaged over all soil core depths and locations within the zones of sericea lespedeza.[a]

	Sericea lespedeza zone		
Measurement	Present	Transitional	Absent
Sand (%)	45 a	42 a	42 a
Silt (%)	28 a	27 a	27 a
Clay (%)	28 a	32 a	31 a
Organic matter (%)	1.7 a	1.6 a	1.4 b
Soil pH	5.8 b	6.5 a	6.9 a
Nitrate-N (mg/kg N)	0.5 a	0.2 a	0.4 a
Potassium (mg/kg K)	107 a	105 ab	94 b
Manganese (mg/kg Mn)	6.4 a	5.9 a	4.9 a
Calcium (mg/kg Ca)	904 a	974 a	946 a
Magnesium (mg/kg Mg)	407 b	612 a	642 a
Boron (mg/kg B)	0.54 b	0.67 ab	0.82 a
Cations (me/100g)	12.8 a	12.8 a	13.0 a
Phosphorus (mg/kg P)	1.8 a	1.3 b	1.2 b
Conductivity (mmho/cm)	0.03 b	0.26 b	0.94 a
Sodium (mg/kg Na)	63 c	270 b	453 a
Chloride (mg/kg Cl)	5 b	19 b	64 a
Sulfate Ca-P (mg/kg S)	8 b	16 b	181 a
Zinc (mg/kg Zn)	0.39 a	0.34 ab	0.28 b
Iron (mg/kg Fe)	31.9 a	20.2 b	15.8 b
Copper (mg/kg Cu)	0.49 a	0.33 b	0.33 b

[a] Means within a row followed by the same letter are not significantly different according to Fisher's protected LSD at $P = 0.10$.

Table 4. Plant species present and percent composition relative to the three zones.[a]

Species		Sericea lespedeza zone		
Common name	Bayer code	Present	Transitional	Absent
——————— graminoides ———————		———————————————	%	———————————————
Annual threeawn	ARKOL	0.8 a	3.3 a	6.7 a
Bermudagrass	CYNDA	0.0 a	0.0 a	0.8 a
Bulrush	SCPHA	0.8 a	0.0 a	0.0 a
Fall panicum	PANDI	0.0 a	0.0 a	1.7 a
Fall witchgrass	LEPCO	1.7 a	0.8 a	0.8 a
Hairy panicgrass	PANHI	0.8 a	0.8 a	0.0 a
Indiangrass	SOSNU	3.3 a	5.8 a	3.3 a
Japanese brome	BROJA	0.0 a	0.0 a	0.8 a
Little bluestem	ANOSC	1.7 a	18.3 a	10.8 a
Old-World bluestem	BOTIS	0.0 a	15 a	0.8 a
Prairie sedge	CRXFE	0.8 a	0.8 a	2.5 a
Purple threeawn	ARKLS	1.7 a	3.3 a	1.7 a
Scribner’s panicum	PANOL	5.8 a	4.2 a	3.3 a
Sideoats grama	BOBCU	0.0 a	0.0 a	0.8 a
Tall dropseed	SPZAS	0.0 a	0.8 a	0.8 a
—————— forbs and woodies ————				
Annual broomweed	GUEDR	2.5 a	2.5 a	0.8 a
Ashy sunflower	HELMO	0.0 a	0.0 a	0.8 a
Buckbrush	SYMOR	0.8 a	0.0 a	0.0 a
Common yarrow	ACHMI	0.0 a	0.8 a	0.0 a
Cudweed	GNAOB	0.8 a	0.8 a	0.0 a
Dotted gayfeather	LTSPU	0.0 a	0.0 a	0.8 a
Heath aster	ASTER	0.8 a	3.3 a	3.3 a
Hedge parsley	TOIAR	0.0 a	0.0 a	0.8 a
Louisiana wormwood	ARTLU	2.5 a	0.0 a	0.0 a
Missouri goldenrod	SOOMS	1.7 a	1.7 a	1.7 a
Poorjoe	DIQTE	0.0 a	0.8 a	0.0 a
Rigid goldenrod	SOORI	0.0 a	0.0 a	0.8 a
Sericea lespedeza	LESCU	75.0 a	10.0 b	0.0 b
Slender lespedeza	LESSL	0.0 a	0.8 a	0.0 a
Smooth sumac	RHUGL	0.0 a	0.8 a	0.0 a
Western ragweed	AMBPS	5.8 a	5.0 a	5.8 a

[a] Means within a row followed by the same letter are not significantly different according to Fisher's protected LSD at P = 0.10.

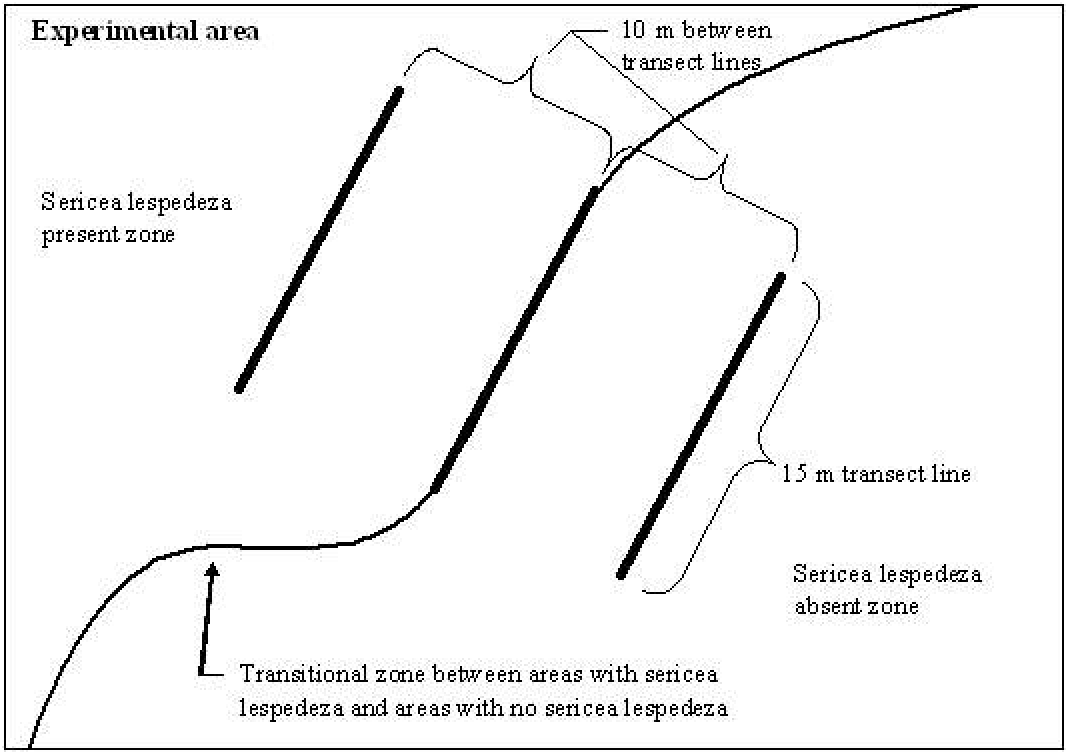

Figure 1. Experimental area design depicting the placement and spacing of the transect lines within the sericea lespedeza present zone, transitional zone, and sericea lespedeza absent zone.

Chapter III

Evaluation of Sericea Lespedeza Growth and Establishment

Conversion from Seedling to Perennial Habit

Evaluation of Sericea Lespedeza Growth and Establishment Conversion from Seedling to Perennial Habit

Abstract: Two field experiments were conducted at the Agronomy Research Station at Stillwater, OK in 2004 and 2005 to measure the effects of top-growth removal (clipping) on sericea lespedeza seedling's ability to become a perennial and regrow. Treatments consisted of 16 weekly clipping intervals beginning 1 wk after seedling emergence. The measurements collected from these clipping treatments were plants regrowing following clipping, plant height, stem branching, flowering, and seed production. The morphological character of stem structure (simple versus branched) was closely associated with seedling age and ability to readily regrow after clipping. The highest percent of sericea lespedeza seedlings regrowing occurred during week 12 in 2004 with 81% regrowth and week 11 in 2005 with 91% regrowth. However, sericea lespedeza seedlings exhibited about 2% (2004) and 13% (2005) of plants regrowing following top-growth removal after only 1 wk of growth. Based on these results for plant regrowth potential, removal of the seedlings top-growth prior to initiation of the branched stem growth stage, or about 7 to 8 wk old seedlings, may lead to the greatest potential for non-herbicide seedling control or management for this species. Seedlings were able to produce flowers at 10 to 12 wks of age and seed from 13 to 15 wks of age. Based on the flower and seed structure data, clipping sericea lespedeza seedling plants before 12 to 14 wks would prevent seed production from occurring, thus preventing further persistence of sericea lespedeza in areas where it is not desired.

Nomenclature: Sericea lespedeza, *Lespedeza cuneata* (Dumont) G. Don. #[3] LESCU.

Additional Index Words: Branched stem, flowering production, phenology, seed production, simple stem, top-growth removal, weekly interval clipping.

Abbreviations: ANOVA, analysis of variance.

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[3] Letters following this symbol are a WSSA-approved computer code from *Composite List of Weeds*, Revised 1989. Available only on computer disk from WSSA, 810 East 10th Street, Lawrence, KS 66044-8897.

INTRODUCTION

Sericea lespedeza is a perennial legume that reproduces by both seed and vegetative crownbud regrowth, which produce new shoots each year (McKee and Hyland 1941). Sericea lespedeza is also reported to reproduce vegetatively from root sprouting (Jordan et al. 2002); however, no other authors could be found that reported this phenomena. Sericea lespedeza typically yields 230 to 1140 kg of seed/ha (Pieters 1934), with about 660,000 seed/kg with seed set from July to Sept (Radford et al. 1968). Sericea lespedeza grows about 0.8 to 1.5 m tall. The strigose stems grow in an erect or strongly ascendent growth stature. At maturity, the stems are woody and fiberous with stiff, sharp, flattened bristles.

Seed germination may be inhibited by compounds in the seed coat (Logan et al. 1969). Results from their research showed that germination was reduced by the addition of both high and low tannin seed coat extracts to the growth media; however, extracts from the seed coats of the higher tannin lines contained more inhibitor, reducing germination to a greater extent than extracts from the seed coats with low tannin. They also concluded that delayed germination of high tannin sericea lespedeza was due to a seed coat inhibitor and that seed coat scarification or removal increased germination. They further reported that radicle elongation was reduced due to the seed coat extracts from both the low and high tannin sources. The low seed germination and slower seedling emergence, but early growth of sericea lespedeza under native conditions is a protective mechanism, which causes delayed germination and growth until adequate moisture is available to leach the inhibitor from the seed and seedling. Qiu et al. (1995)

attributed one aspect of sericea lespedeza's low and slow seed germination to a temperature dependency for germination. They reported that optimum seed germination occurred when temperatures ranged between 20 and 30 C. Seed dormancy from the inhibitory seed coat and temperature dependency for germination, allows the soil seed bank to build-up, with continuous germination occurring over many years.

Biological information is limited concerning sericea lespedeza seedlings. No scientific, biological information has been reported concerning sericea lespedeza seedling's (established from seed) ability to regrow and persist if the plants have their top-growth removed. Other perennial weed species, such as silverleaf nightshade (*Solanum elaeagnifolium* Cav.) (Boyd and Murray 1982) and hogpotato (*Hoffmanseggia densiflora* Benth. ex. Gray) (Hackett and Murray 1987) have shown a positive correlation between seedling maturity and seedling ability to regrow after the above-ground biomass was removed. Boyd and Murray (1982) also showed that removal of silverleaf nightshade seedling shoots had an effect on plant height, dry weight, and fruit production. Similar effects on plant production parameters were seen with hogpotato (Hackett and Murray 1987).

Objective one of this experiment was to establish foundational knowledge on the biological attributes of sericea lespedeza so that future management approaches are practical and effective. Objective two was to determine sericea lespedeza seedling's ability to develop into perennial plants. The third objective was to evaluate parameters such as plant height, stem branching, flowering, and seed production as they relate to seedling maturity.

METHODS AND MATERIALS

Two field experiments were initiated in the spring of 2004 and 2005 at the Agronomy Research Station at Stillwater, OK. The soil at this location was a Kirkland silt loam (fine, mixed, thermic Udertic Paleustolls) with a pH of 6.7 and an organic matter content of 1.4%. The experiment was arranged as a randomized complete block design with four replications in 2004 and five replications in 2005. Plots were 2 m by 2 m with a 16-plant grid pattern arrangement where plants were equally spaced 50 cm apart (Figure 1). A total of 15 to 20 seed were sown 0.3 to 0.5 cm deep at each of the 16 grid intersections in each plot on May 13, 2004 and June 9, 2005. Due to low or no seedling emergence with a May 2005 planting date, sericea lespedeza was replanted on June 9, 2005, which resulted in a later emergence date. After emergence on June 11, 2004 and July 12, 2005, seedlings were thinned to 16 plants/plot. Plots were irrigated from planting until shortly after seedling emergence. After, emergence, irrigation was halted to approximate natural field conditions that sericea lespedeza seedlings would encounter and to limit experimentally manipulated environmental conditions on the growth and development of the seedlings. Unwanted weeds were removed from the plots by hand.

Treatments consisted of clipping all 16 plants per plot once over the length of a 16 wk clipping period. Sixteen seedlings per replicate were clipped at the soil surface (below any leaf or cotyledon structures) beginning 1 wk after emergence, with subsequent plots being clipped at weekly intervals over the 16 wk treatment schedule. These treatments were established to measure the effects of top-growth removal on the percent of seedlings that regrew, plant height, stem branching, flowering, and seed production. Seedling regrowth was evaluated as the percent of plants regrowing averaged from the 16 plants/plot with data collected in November of each year. Plants were considered as resprouted when a trifoliate leaf growth appeared. Seedling height was recorded during each scheduled clipping treatment and were based on the median height of the 16 plants/plot within each replicate. The height of the seedlings that had regrown were taken after the last treatment clipping period (November 9, 2004 and November 4, 2005) and were based on the average height of the 16 plants/plot within each replicate. The percent of plants per plot with branched stem growth structure, flowers, and seed were collected during each initial treatment period and were based on the average of the 16 plants/plot within each replicate.

Data from both years were subjected to analyses of variance (ANOVA) using the PROC MIXED procedure (SAS 2002). To determine year effect on treatment (week of clipping after emergence), ANOVAs combined over location as F-test for all treatment and year by treatment interactions were performed. A significant year by treatment interaction was detected for all variables measured; therefore, all variables measured are discussed separately for each year. Treatment means were separated using Fisher's protected LSD at $P = 0.05$.

RESULTS AND DISCUSSION

During 2004, seedlings clipped from 1 to 16 WAE possessed the ability to regrow; however, the percent of plants that regrew was very low (2 to 14%) for weeks 1 through 6 and week 16 (Figure 2). The first six clipping periods along with the 7th wk transitional stage were associated with the simple stem growth structure or no branching of the sericea lespedeza seedling’s stem. An increase in the percent of plants that regrew began after week 6 (8%) and proceeded to week 9 (80%) where a plateau in regrowth occurred through week 15 (73%). Initiation of the branched stem growth stage occurred during week 8 or during the period when the percent of plants regrowing was increasing (Table 1 and Figure 2). The greatest percent of plants that regrew occurred from week 9 to week 15 (80 to 73 %, respectively), with the initiation of flowering and seed production occurring at week 12 and 15, respectively. A rapid decrease in the percent of seedlings that regrew occurred from week 15 (73%) to week 16 (8%), which was likely due to initiation of plant dormancy following seed production.

For 2005, a greater percentage of plants that regrew occurred during the simple stem growth stage compared to the 2004 results (averages of 25% and 11%, respectively) (Figures 2). The percent of plants that regrew ranged from 13 to 41% during the simple stem growth stage (Figure 2). Initiation of the branched stem growth stage began during week 7 with 17% of the seedlings regrowing (Table 1 and Figure 2). From week 7 through week 11, a rapid increase in the percent of seedlings regrowing occurred, with maximum regrowth potential occurring in week 11 with 91% of the seedlings regrowing. Flower development was initiated in week 10. A rapid decline in the percent of seedlings regrowing (88 to 4%) occurred from week 12 to week 13, which was likely influenced by seed development and initiation of plant dormancy.

There was no significant difference in plant height (regrowth) for any of the 16 clipping periods during 2004 (Table 1). However, in 2005, seedlings were taller from weeks 1 through week 11, compared to the later clipping treatments of weeks 12 through week 16. In 2005, seedling regrowth height ranged from 0 to 15 cm tall. However, seedling regrowth height was greater in those plants that had a longer period of time for top-growth production and had regrown from week 1 with 12 cm tall seedlings to week 11 with 9 cm tall seedlings. Branching of the stem structure of sericea lespedeza plants began around week 8 with 13% and during week 7 with 40% branched stem plants/plot for years 2004 and 2005, respectively. Stem branching proceeded rapidly, after the initial onset of this morphological character, with greater than 87% stem branching plants/plot occurring after week 11. Sericea lespedeza plants began to form flowers in week 12 (September 2, 2004) with 19% plants/plot and in week 10 (September 23, 2005) with 26% plants/plot. Seed or fruiting structure appearance followed the same pattern as flower presence, with year 2005 beginning slightly before 2004. Seed appeared during week 15 (September 23, 2004) with 59% plants/plot and during week 13 (October 14, 2005) with 94% plants/plot.

The two experiments (years) could not be statistically pooled together, which was likely due to the later planting date in 2005, environmental variation between years, or a combination of these or other unknown conditions. However, there were some plant physiological and morphological characteristics that were patterned the same in both years. In both years, there were 3 wks between the branched stem growth stage and flower production. The results also showed that there was a 3 wk period between flowering and seed production. This was very significant from both a biological and management view-point. Sericea lespedeza seedlings are capable of producing seed during the first growing season, even with later emergence. The capability of seed production, along with the ability of becoming a perennial plant, both add to sericea lespedeza’s impact and characteristics as an invasive weed species.

These results suggest that the morphological character of stem structure (simple versus branched) was closely associated with seedling age and ability to regrow. Based on the results for seedling regrowth potential, removal of the seedlings top-growth prior to initiation of the branched stem growth stage, or approximately 7 to 8 week old seedlings, leads to the greatest potential for non-herbicide seedling control or management for this species. Based on the flower and seed structure presence data, clipping or mowing sericea lespedeza seedling plants before 12 to 14 weeks would prevent seed production from occurring, thus preventing further persistence of sericea lespedeza in areas where it is not desired.

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Table 1. Effect of top removal at weekly clipping intervals, following seedling emergence, on the phenological growth characteristics of sericea lespedeza.[a]

	At clipping									
Clipping	Height		Stem branching		Flowering		Seed production		Regrowth height	
interval	2004	2005	2004	2005	2004	2005	2004	2005	NOV. 2004	NOV. 2005
WAE	cm		% plants/plot						cm	
1	0.5 n	0.5 f	0 f	0 e	0 d	0 d	0 c	0 b	5	12 ab
2	3.5 m	3.5 ef	0 f	0 e	0 d	0 d	0 c	0 b	9	15 a
3	5.1 k	3.5 ef	0 f	0 e	0 d	0 d	0 c	0 b	4	12 ab
4	4.8 l	4.8 ef	0 f	0 e	0 d	0 d	0 c	0 b	3	9 ab
5	15.2 j	5.7 d-f	0 f	0 e	0 d	0 d	0 c	0 b	8	8 bc
6	15.2 j	8.9 de	0 f	2 e	0 d	0 d	0 c	0 b	6	10 ab
7	21.6 i	12.7 d	6 ef	40 d	0 d	0 d	0 c	0 b	9	7 b-d
8	24.1 h	37.8 ab	13 e	87 bc	0 d	0 d	0 c	0 b	7	7 b-d
9	33.0 g	28.9 c	50 d	78 c	0 d	0 d	0 c	0 b	7	9 ab
10	40.6 f	32.3 bc	78 c	79 c	0 d	26 c	0 c	0 b	9	11 ab
11	45.7 d	31.1 bc	100 a	98 ab	0 d	76 b	0 c	0 b	8	9 ab
12	55.9 c	37.6 ab	98 a	100 a	19 c	95 a	0 c	0 b	4	6 b-d
13	55.9 c	38.4 ab	97 a	97 ab	73 b	94 a	0 c	94 a	3	2 cd
14	43.2 e	42.4 a	87 b	91 ab	98 a	93 a	0 c	93 a	3	0 d
15	66.0 a	40.4 a	100 a	98 ab	100 a	96 a	59 b	96 a	2	1 d
16	62.2 b	42.7 a	100 a	100 a	100 a	96 a	95 a	96 a	1	0 d
									NS	

[a] Means followed by the same letters are not significantly different according to the Fisher's protected LSD comparison (P = 0.05).

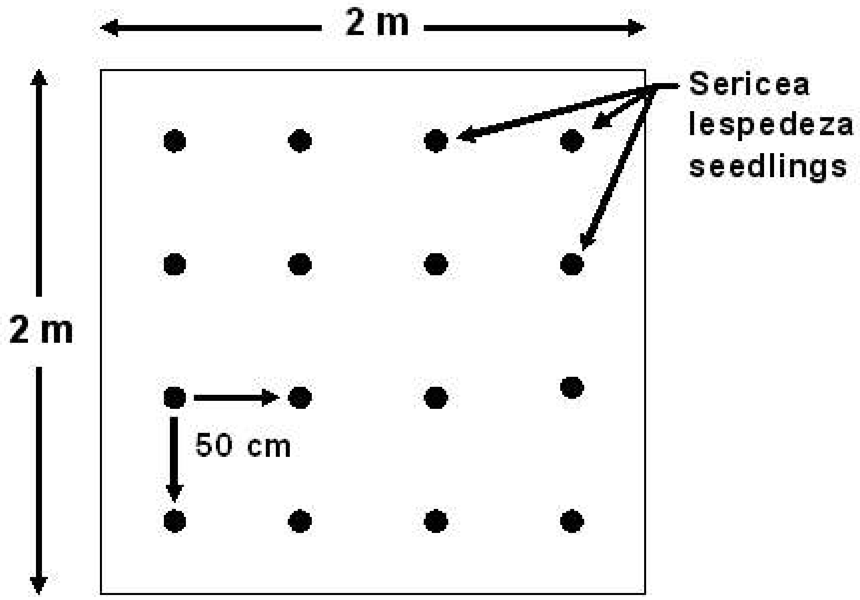

Figure 1. Individual plot design depicting the plot dimensions and spacing between sericea lespedeza seedling sites.

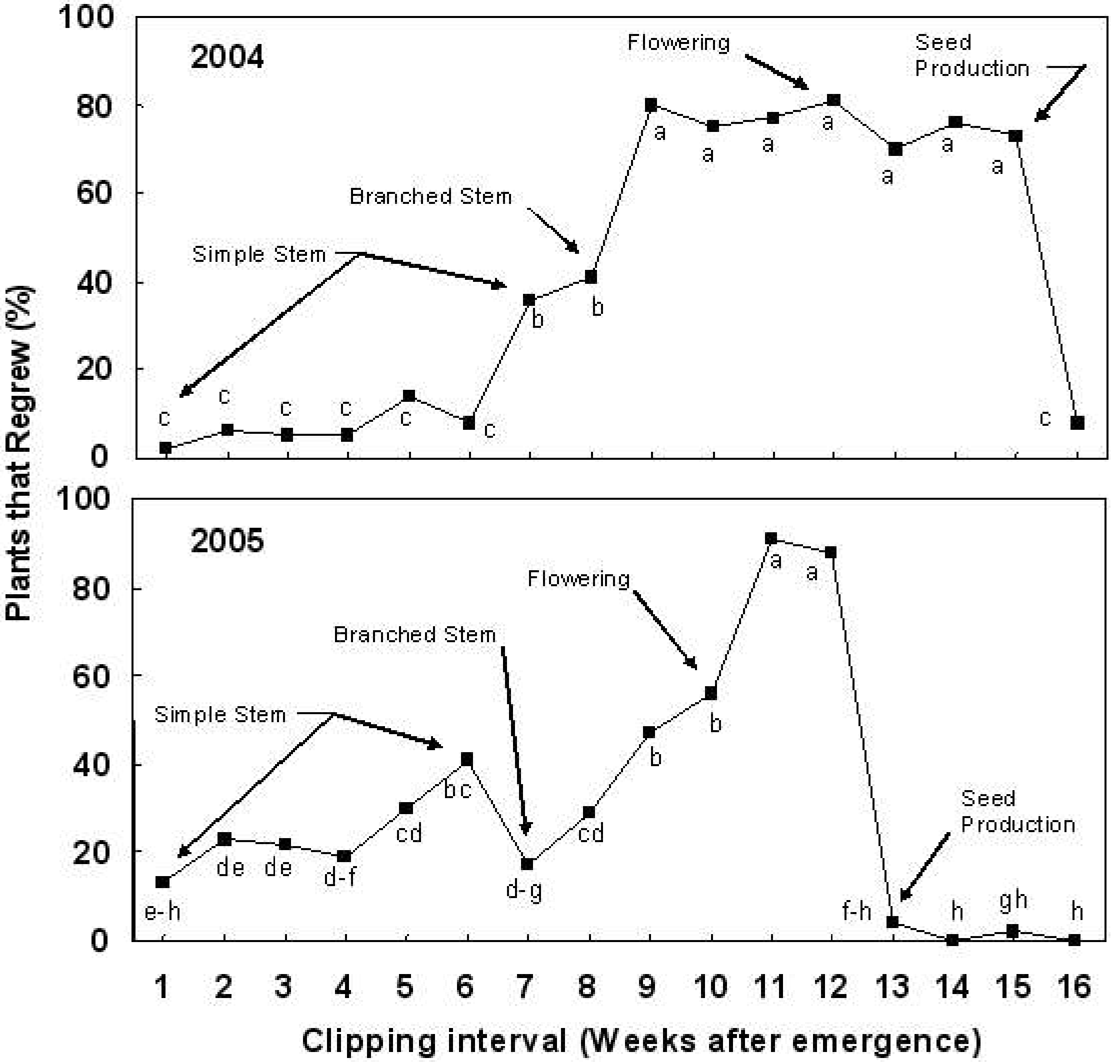

Figure 2. Effect of clipping interval, after seedling emergence, on the percent of sericea lespedeza seedlings that regrew for 2004 and 2005. Phenological stages are depicted with observational arrows and indicate the transitional stages of seedling development. Values sharing the same letter along the line are not significantly different according to Fisher's protected LSD comparison (P = 0.05).

Chapter IV

Monthly Measurement of Sericea Lespedeza Root Total Nonstructural Carbohydrates, Crude Protein, Fat, Ash, Neutral Detergent Fiber and Stem Condensed Tannin Concentrations

Monthly Measurement of Sericea Lespedeza Root Total Nonstructural Carbohydrates, Crude Protein, Fat, Ash, Neutral Detergent Fiber and Stem Condensed Tannin Concentrations

Abstract: Three field experiments were conducted on the Range Research Station near Stillwater, OK in 2004 and 2005 and on a privately-leased pasture in 2004 to measure the monthly root concentrations of total nonstructural carbohydrates (TNC), crude protein (CP), fat, ash, and neutral detergent fiber (NDF) of sericea lespedeza. Condensed tannins were also measured monthly on the aerial plant parts of sericea lespedeza. Sericea lespedeza root TNC decreased from 31% and CP decreased from 15% CP in March to the lowest value in June with average TNC and CP concentrations of 20 and 9%, respectively. Total nonstructural carbohydrates increased 11% from June through October, at which time TNC began to decline due to initiation of leaf senescence and plant dormancy. Crude Protein increased 5% from June through November before a decline occurred. Fat concentrations were variable over the year with the lowest concentrations occurring at plant dormancy, early plant growth, and at flower and seed developmental growth stages. Root ash concentrations were fairly constant over the months of January through May and August through December (4.57% average concentration) and was highest in June (9.7%). Root NDF concentrations were highest (56 to 60%) over the active growth months of sericea lespedeza but declined with flower/seed production and plant dormancy. Stem tannin concentrations increased from 0.1 to 2.5% with active summer growth (April through September) and decreased from

2.5 to 0.4% from flower/seed production through initial plant dormancy (September through November). Knowledge pertaining to monthly concentrations of sericea lespedeza root and stem fractions provide information on maturity and production as they relate to plant growth cycles and can be useful in the development of management and control strategies.

Nomenclature: Sericea lespedeza, *Lespedeza cuneata* (Dumont) G. Don. #[4] LESCU.

Additional index words: Dormancy, root concentrations, stem concentration, tannin.

Abbreviations: ANOVA, analysis of variance; CP, crude protein; NDF, neutral detergent fiber; TNC, total nonstructural carbohydrates.

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[4] Letters following this symbol are a WSSA-approved computer code from *Composite List of Weeds*, Revised 1989. Available only on computer disk from WSSA, 810 East 10th Street, Lawrence, KS 66044-8897.

INTRODUCTION

Despite a growing body of research evaluating sericea lespedeza's agronomic potential, little is known about it's biology as it pertains to control management strategies. Understanding the cyclic nutritional status and concentrations of aerial plant structures are important for production as well as for control purposes. However, understanding the fluctuating nutritional status and concentrations of below-ground structures (crowns and roots) provides a biological or ecological foundation for further research and strategies for the management of the particular plant species. Such information is useful for predicting periods of energy storage, energy use, or plant production and the plants ability to regrow and persist following a stress event. No published information could be found on sericea lespedeza root structure concentrations and only a small amount of published information is available on sericea lespedeza aerial structure fraction concentrations (Donnelly and Anthony 1973; Fales 1984; Mosjidis et al. 1990; Mosjidis 1996; Windham et al. 1988). Published information from Donnelly and Anthony (1973), Fales (1984); Mosjidis et al. (1990), Mosjidis (1996), and Windham et al. (1988) showed no year-long analysis of aerial structure concentrations and all research dealt with cultivated or improved sericea lespedeza.

Total nonstructural carbohydrates (TNC) are fractions from the cell content and include organic acids, sugars, starch, fructans, and some oligosaccharides (Hall 1998; Harris 2006). TNC represent the primary stored energy source for biennial and perennial plants. This energy reserve is important for both plant survival and for producing new plant tissue when energy demand exceeds production through photosynthetic means

(Smith 1969). Smith (1969) showed that alfalfa (*Medicago sativa* L.) root tissue TNC concentrations ranged from 7 to 47.9% with values obtained being dependant on the sample preservation and TNC extraction methods. Narra et al. (2004) used TNC as an indirect indicator of stress on growth and physiological responses in creeping bentgrass (*Agrostis palustris* Huds.). Root TNC concentrations has been used as a predictor of plant vigor and yield (Buwai and Trlica 1977). They reported that multiple defoliation events depleted root TNC levels and negatively affected the herbage yield and vigor of both grass and broadleaf plants investigated in the experiment. They concluded that defoliation deprives the plant's ability to produce food and store excess energy (TNC) within the roots. Since sericea lespedeza regrows each year from perennial crownbuds and the fact that roots are the primary storage organs for the energy used for aerial plant regrowth, management strategies pertaining to the depletion of the TNC may negatively impact plant yield and overall persistence.

Other plant fractions of interest are crude protein (CP), fat, ash, and neutral detergent fiber (NDF). The CP fraction of plants are often divided into soluble, degraded, and undegraded protein classes, which are based primarily on how the proteins are degraded by ruminant animals (Rayburn 1996). Another classification method groups CPs into true or nonprotein nitrogen sources, which are used to produce energy (Broderick 1996). The ash content of plants is a measure of the mineral content. Plant minerals are classified as endogenous (minerals within plant tissue) or exogenous (minerals bound to the plant surface such as silica) (Hoffman 2005). Neutral detergent fiber (NDF) are fiber fractions of cell walls and structure and include lignin, cellulose, and hemicellulose (Hall 1998;

Harris 2006). NDF is often used as a measure of forage quality. As the plant matures, the cell wall (NDF) to cell content (TNC) ratio increases (Petzen 2004). Fischbach et al. (2005) showed that the legume, Illinois bundleflower [*Desmanthus illinoensis* (Michx.) MacM. Ex B.L. Robins. & Fern.], contained 18% crude protein and 35.2% NDF within aboveground biomass at the mid-July early flowering period. Mosjidis (1996) investigated concentrations of crude protein and NDF found in aboveground biomass of sericea lespedeza and reported that sericea lespedeza tissue contained an average of 11% crude protein and 52.4% NDF.

Plant tannins are classified as condensed tannins (CT) and hydrolyzable tannins. Condensed tannins are naturally occurring and are the most common type of tannin found in legumes. Condensed tannins are found in both the leaves and stems of sericea lespedeza. However, the leaves of sericea lespedeza contain two to three times the concentration of CTs compared to the stems (Donnelly and Anthony 1973). Mosjidis et al. (1990) determined that tannins were found in the vacuoles of paraveinal mesophyll cells (cells involved with photosynthetic transport) and suggested that tannins could be involved in physiological processes or are a form of storage for excess photosynthates. Condensed tannins are polyphenolic substances that are responsible for the decreased palatability and utilization of sericea lespedeza forage by herbivors. An astringent and distasteful attribute is also associated with tannins (Alldredge 1994; Clarke et al. 1939). Condensed tannins have the ability to disrupt both protein and energy digestion and metabolism due to the formation of tannin complexes with proteins, carbohydrates, enzymes, and microbial products, which allows the complex to bypass ruminal degradation. Some of the bypassed materials are rendered useless to the ruminant animal, while others are only available for absorption in the lower digestive tract (Gamble et al. 1996; Makkar 2003; Petersen and Hill 1991; Reed 1995). Condensed tannin analysis can be used to evaluate sericea lespedeza effects on herbivore consumed forage digestibility (Terrill et al. 1990) and forage quality (Cope and Burns 1974).

There are no standards or baseline CT concentrations which establish optimal concentrations for intake, digestion efficiency, or animal performance. Some browsing herbivorous mammals that consume a diet containing more forbs, trees, and shrubs that are more likely to contain tannins, have a mechanism for dealing with the inhibitory effects that come with consuming tannin-rich foods. Some of these mammals produce proline-rich proteins (PRPs) in their saliva that are able to complex with tannins and allow the PRP-tannin complex to pass through the animal's digestive tract intact. Mammals consuming more of a grass diet (grazers) typically consume less tannins and are not capable of producing PRPs to complex with tannins in the mouth (Alldredge 1994; Makkar 2003). Petersen and Hill (1991) determined that the inhibition of cellulase enzymes by tannin complexes was noncompetitive in nature and could be overcome by the addition of nitrogen-containing supplements with higher affinities for tannins. The use of goats for the control of sericea lespedeza as well as other brushy and weedy species has shown promise (Hart 2001; Puchala et al. 2005). When Angora goats were feed either diets containing tannin-rich sericea lespedeza or crabgrass/tall-fescue, both dry matter intake and digestible dry matter intake were higher while methane produced by the goats was lower for the lespedeza diet (Puchala et al. 2005).

Sericea lespedeza tannin concentration increases in the summer and decrease to lower levels in the fall (Stitt and Clarke 1941; Windham et al. 1988). Windham et al. (1988) showed that, during the 3 mo sericea lespedeza tannins were investigated, there were greater fluctuations in the tannin content of high-tannin compared to the low-tannin accessions. They reported that there was a peak in tannin concentration for the high and low-tannin accessions during the month of August; however, the low-tannin accessions did not decline in October. Fluctuations in CT concentrations is influenced by time of the growing season and plant maturity (Cope and Burns 1974; Donnelly 1959) with increases in tannin concentration associated with higher mean daily temperature and decreased precipitation (Donnelly 1959). Field experiments showed that tannin content, shoots per plant, height, dry matter, leafiness, and yield of sericea lespedeza varied significantly when compared to different soil types.

Breeding programs have been conducted to lower the tannin content of sericea lespedeza used for forage production. The improved accessions of sericea lespedeza are termed “low-tannin”. Comparisons of the tannin content has shown that there are differences in the tannin content of those sericea lespedeza accessions that are considered low-tannin from those that are high-tannin (Cope and Burns 1974; Donnelly and Anthony 1973; Fales 1984; Terrill et al. 1990; Terrill et al. 1994; Windham et al. 1988). Within these scientific articles, there is great variability in the classification or ranking of sericea lespedeza into high or low-tannin types. Various low-tannin values or ranges reported were 2.1 to 4.0% (Cope and Burns 1974), 4.5 to 5.2% (Donnelly and Anthony 1973), 3.46 to 5.49% (Fales 1984), 3.0 to 3.6% (Terrill et al. 1990), 2.4 to 6.6% (Terrill et al. 1994), and 2.8 to 5.3% (Windham et al. 1988). Various values reported as high-tannin were 2.9 to 3.7% (Cope and Burns 1974), 10.4 to 10.8% (Donnelly and Anthony 1973), 14.52 to 24.87% (Fales 1984), 5.9 to 7.8% (Terrill et al. 1990), 5.0 to 10.6% (Terrill et al. 1994), 8.0 to 12.5% (Windham et al. 1988). However, there has been no reported standardized range of values that can be used to definitively classify either cultivated or wild/invasive sericea lespedeza accessions as either being low or high tannin types.

All previously reported research pertaining to sericea lespedeza fraction concentrations (TNC, CP, NDF, or CT) were evaluated only for certain months and were confined only to the active growing season with measurements being conducted on cultivated, 1 to 5 yr-old aerial plant biomass with the goal of improving sericea lespedeza for forage production. The first objective of this experiment was to measure the monthly root concentrations of total nonstructural carbohydrates (TNC), crude protein, fat, ash, and neutral detergent fiber (NDF) as well as aerial plant structure condensed tannins (CT) of non-cultivated, well established, and invasive sericea lespedeza. The second objective of this experiment was to use the results of this experiment to provide foundational information pertaining to the bio-ecology of sericea lespedeza and use the results obtained in evaluating the hypotheses of management and control of invasive sericea lespedeza through depleting energy, energy translocation, or beneficial use periods used to maximize control strategies

MATERIALS AND METHODS

Three field experiments were conducted at the Range Research Station near Stillwater, OK in 2004 and 2005 and on a privately-leased pasture in 2004. The two experiments on the Range Research Station were conducted on a Coyle loam (fine-loamy, siliceous, thermic Udic Argiustolls) with a pH and organic matter content range of 5.6 to 7.8 and 1 to 3%, respectively. The experiment on the privately-leased pasture was conducted on a Renfrow loam (fine, mixed, thermic Udertic Paleustolls) with a pH and organic matter content range of 6.1 to 7.8 and 1 to 3%, respectively.

The experimental design was a randomized complete block with the three locations serving as replications. Treatments consisted of 12 mo where 18 or more mature sericea lespedeza plants were randomly excavated from the ground with the use of a long-handled shovel. Monthly plant collections were made on or near the 15th of each month. While excavating the plants, care was taken to retain as much of the root mass and crown as possible. Eighteen or more plants were required in order to produce a composite sample of 454 g dry weight of roots and 454 g dry weight of stems necessary for laboratory analysis of the experimental variables. After plant collections were made, the plant roots and stems were separated with hand clippers and were rinsed clean of soil and foreign material with water. Plant material was then dried in a forage dryer for 1 wk and was then shipped to a contract laboratory (A&A Laboratories, Inc.; Springdale, AR 72764) for analysis of the specific plant components. The plant components analyzed were sericea lespedeza root concentrations of TNC, CP, fat, ash, and NDF as well as aerial plant structure CT. These specific plant components as well as the laboratory methods used for the analysis are shown in Table 1.

The root portion of the plant consisting of root and crown structures will be collectively referred to here and throughout this paper as ‘roots’. Aerial plant structures consisting of sericea lespedeza woody stem, trifoliate leaves (when present), and any flower and seed structures (when present) will be collectively referred to here and throughout this paper as 'aerial structures'.

Data from all three locations were subjected to analysis of variance (ANOVA) using PROC MIXED procedure (SAS 2002). Location as well as year within location were treated as random effects within the model. To determine year effect on treatment (month), ANOVAs combined over locations as F-test for all treatment and year by treatment interactions were performed. No significant year by treatment interaction was detected for any of the variables measured; therefore, all variables measured were pooled over the three locations. Treatment means were separated using Fisher's protected LSD at $P = 0.05$.

RESULTS AND DISCUSSION

There was seasonal variability in the TNC of sericea lespedeza roots (Figure 1). With the stimulation or resumption of crownbud growth beginning in March and April, there was a significant decline in TNC through the month of June. This decrease corresponded to sericea lespedeza plants utilization of stored root carbohydrates for the production of aerial stem and leaf production until maximum photosynthesis was reached during the growing season. The results showed that TNC was lowest in June, being approximately 11% lower compared to February, March, September, or October when TNC was the highest.

Root TNC increased from about 24 to 31% from July to September, respectively. This increase corresponded to sericea lespedeza plants with maximum aerial growth, ability to sustain active aerial growth, and the ability to transport and store unused carbohydrates back into the root structure. The plants were likely storing carbohydrates in the roots, during this period of time, in preparation for energy demanding flower and seed production, which occurred during September and October and prior to plants returning to winter dormancy. This was further evidenced by the results of a 5% reduction in TNC following seed production in October followed by the initiation of plant dormancy in November.

Crude protein concentration within the roots of sericea lespedeza followed a similar pattern as TNC concentrations (Figures 1 and 2). The months of February and March resulted in 15% root CP with a 6% decline occurring from March through June (Figure 2). The lowest CP concentration occurred in June (about 9% CP), which corresponded to the lowest TNC concentration; both indicating sericea lespedeza plants diminished storage of root energy (Figures 1 and 2). A 5% increase in CP occurred from June through November, at which point the plants began the dormancy period.

Root crude fat showed a great deal of variation from January to December (Figure 3). Sericea lespedeza crown and roots were able to metabolically store crude fat into their structures. The initiation of growth of the crown in March and April facilitated a 0.52% reduction in fat from April to May. With active aerial structure growth, fat was accumulated in the roots until about 0.85% was reached in June. There was a 0.36% reduction in crude fat from July until flower production initiation in September. Similar to the results for CP, the roots were able to accumulate crude fat into their structure prior to plant dormancy; as indicated by the 0.87% crude fat concentration in November.

The measurement of mineral content of the root structure, or the ash concentration, was fairly constant over the months of January to May as well as from August to December (Figure 4). There was a 1.9% deviation from highest to lowest concentration over these months. However, the ash concentration was significantly higher in June (9.7 %) and July (7.6%). The high concentration in the month of June was likely indicative of low concentrations and use of TNC and CP by the aerial structures and increased uptake of mineral fractions during this active growth period.

Monthly concentrations of root NDF showed an inverse relationship to TNC (Figures 1 and 5). Neutral detergent fiber was approximately 7 to 11% higher in the months of April through August compared to February and March (Figure 5). Neutral detergent fiber was 3 to 7% lower from September through November compared to April through August, which exhibit higher NDF concentrations. These results indicate that over the months of April to August, the roots contained more cell structure components such as cellulose, hemicellulose, and lignin fractions.

The monthly tannin concentrations were relatively low and constant over the dormant months of November to April (Figure 6). However, with the resumption of growth or crownbud stimulation in March and April, a slight increase in tannins began in the May. There was a 2.4% increase in tannin concentration from April until the highest concentration of 2.5% was reached in September. The slight decrease in tannin concentration from June to July may correspond to the growth structure transformation from plants with a simple stem (unbranched, vertically ascending main stem) to plants with more of a branched stem growth structure (branched, horizontal and vertically ascending branches). This transformation in sericea lespedeza growth stage was also described by Koger et al. (2002).

Tannin concentrations increased with active aerial structure production. As the plant produced more stem and more importantly a higher leaf to stem ratio, an increased tannin concentration occurred. Tannins also increased over months with higher temperature and lower precipitations. Donnelly (1959) showed similar results where tannins increased as the season progressed, temperatures increased, precipitation decreased, and plant maturity increased. Beginning in September, the influence of flower and seed production, leaf senescence, as well as initiation of plant dormancy facilitated an approximate 2.1% reduction in tannin concentration through the month of November. The results also suggest that in December, or during plant dormancy, the dormant stem was able to remetabolize tannins slightly (0.4% higher compared to November).

All of the tannin concentrations were low (Figure 6) compared to other previously used analysis methods and tannin concentration results obtained from researchers such as Stitt and Clarke (1941), Terrill et al. (1994), Terrill et al. (1989), Terrill et al. (1990), and Windham et al. (1988). The low tannin concentrations obtained in this experiment may be due to the tyrosine method used to analyze the CT. Terrill et al. (1990) and Terrill et al. (1994) both showed that preservation methods as well as extraction and analysis methods can influence the tannin concentration results obtained. Terrill et al. (1990) and Terrill et al. (1994) showed that tannin concentration was decreased when sericea lespedeza plant material was dried. The procedure (used in this experiment) of drying sericea stem material prior to tannin analysis may have lowered the tannin content compared to wet biomass material concentrations. Results of DNA amplification experiments comparing germplasm from the locations used in this experiment to genetically improved lines (low-tannin accessions) showed that all three locations were genetically different from the improved accessions (Farris et al. 2004). An experiment conducted by Puchala et al. (2005) near Langston, OK, which is located about 12 miles from the experiments located on the Range Research Station, contained wild and invasive sericea lespedeza and was reported to be the high-tannin type. Based on the DNA results and the proximity of this experiment to the high-tannin sericea lespedeza found near the Puchala et al. (2005) experiment, the assumption was made that the wild and invasive sericea lespedeza used in this experiment were of the high-tannin type. Even though this assumption was not completely validated, the overall monthly trends of tannin concentrations are of more importance to timing of management strategies over the growing seasons of sericea lespedeza.

Based on the monthly CT concentrations, the best management practices for control of sericea lespedeza in pasture and rangeland situations should be conducted when tannin concentrations are at their lowest. The management strategies of grazing standing plant biomass or feeding hay should be conducted between May and June when tannins are low, leaves are young, and stems are less woody and fibrous. Clarke et al. (1939) has shown that the astringent nature of the tannins within the forage, which decreases palatability and utilization by grazers, increased from spring through the summer months (May 29 to July 31). It seems possible that multiple harvests over the growing season would decrease the tannin content of the forage due to the production of new foliage.

However, results from Donnelly (1959), Cope and Burns (1974), and Wilson (1954) showed that tannin concentration increased with successive harvest. Therefore, management strategies using grazing alone could possibly be hindered if the choice was made to graze season-long, due to the fact that grazing animals preferentially avoid sericea lespedeza with higher tannin content. However, the practice of multiple harvest for sericea lespedeza hay production could be a viable option. Multiple harvests for hay would not only keep the forage young (more palatable), lower stature, and deplete the energy reserves of the plant, but can also be field cured, which has been documented as lowering the tannin content and increasing the palatability and consumption of the forage (Terrill et al. 1989).

Management strategies such as multiple defoliations through grazing, hay harvest, mowing, or prescribed burning for the control of sericea lespedeza are likely best facilitated when root reserves of TNC and CP are at the lower concentrations. Based on the experimental results, this management period was from initiation of active growth (April) to early growth production (June). After this period, the reserves of TNC and CP began to increase; therefore control management through the biological, mechanical, or cultural applications may be reduced. Buwai and Trlica (1977) reported that plant vigor and yield of both grass and broadleaf species were reduced when root TNC was reduced through intensive multiple defoliation events. It is also hypothesized that control strategies for established perennial sericea lespedeza would be more effective if translocated herbicides were applied from July to October. Translocated herbicides applied to the foliage during this time period may facilitate the translocated movement of the herbicide into the root structure; with a greater probability of complete and long-term control of the entire plant (both stem and root kill).

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Table 1. Laboratory methods used for sericea lespedeza root and stem concentration analyses.

Component analyzed [a]	Structure measured	Method number	Method
Total Nonstructural carbohydrates (TNC)	Root	———	Mary Beth Hall; Univ of Florida Calculation[b]
Protein (crude) (CP)	Root	990.03	A.O.A.C.[c] Official Combustion Method
Fat (crude)	Root	920.39	A.O.A.C. Official Ether Extract Method
Ash	Root	942.05	A.O.A.C. Official Ash Method
Neutral Detergent Fiber (NDF)	Root	5.1	N.F.T.A.[c] Determination of Amylase NDF by Refluxing Method
Tannin (condensed)	Stem[d]	———	HACH Company Tyrosine Method

[a] Concentration measurements are percentage of dry plant structure weight and were obtained from a 18+ plants/location/month composite sample.

[b] Calculation: TNC = 100% - (CP+NDF+Fat+Ash)

[c] Abbreviation: A.O.A.C., Association of Official Analytical Chemists; N.F.T.A., National Forage Testing Association.

[d] Stem measurements were obtained from combined stem plus leaf (when present) plus flower and seed (when present) concentrations.

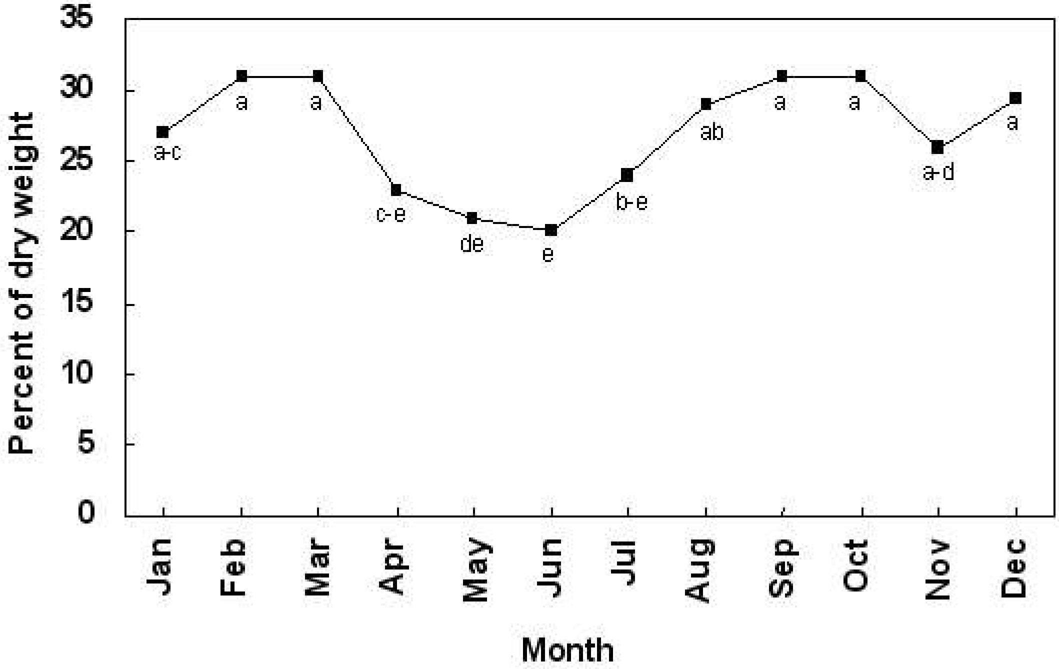

Figure 1. Monthly analysis of sericea lespedeza root total nonstructural carbohydrate concentration (percent of dry weight). Values sharing the same letter along the line are not significantly different according to Fisher's protected LSD comparison (P = 0.05). Data pooled over three locations of the experiment.

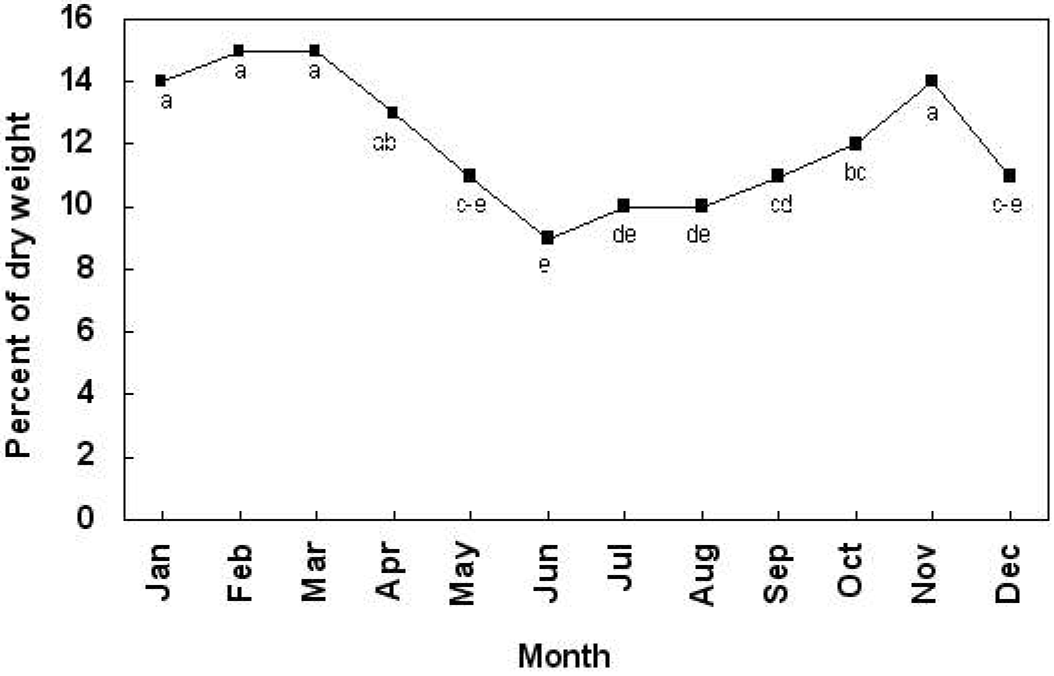

Figure 2. Monthly analysis of sericea lespedeza root crude protein concentration (percent of dry weight). Values sharing the same letter along the line are not significantly different according to Fisher's protected LSD comparison (P = 0.05). Data pooled over three locations of the experiment.

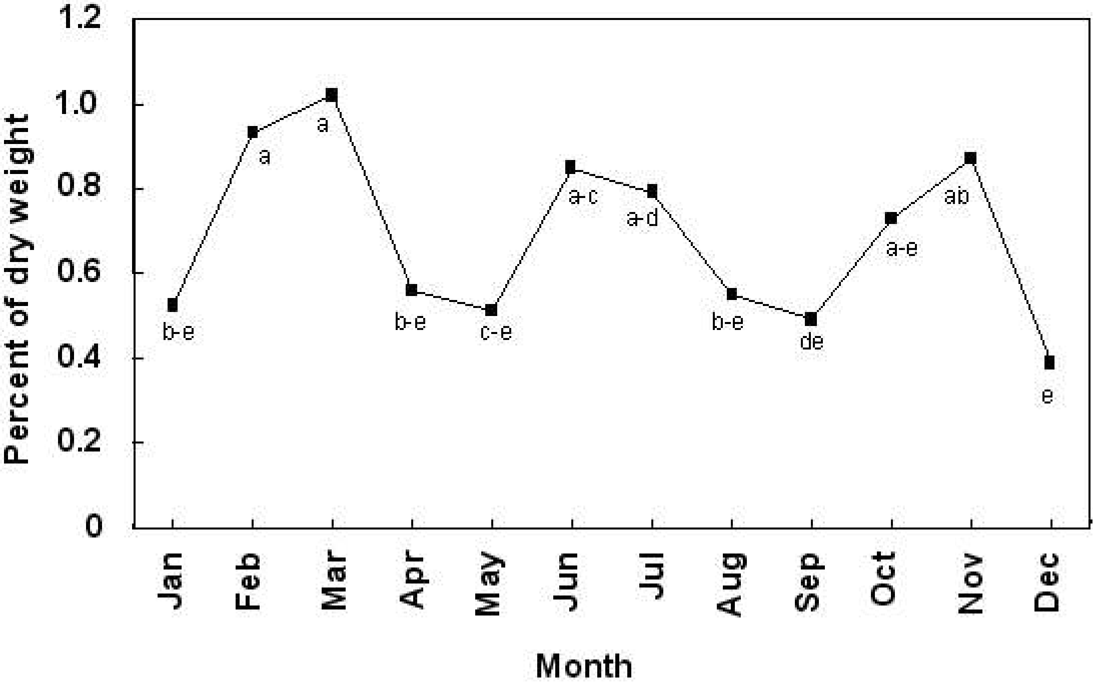

Figure 3. Monthly analysis of sericea lespedeza root crude fat concentration (percent of dry weight). Values sharing the same letter along the line are not significantly different according to Fisher's protected LSD comparison (P = 0.05). Data pooled over three locations of the experiment.

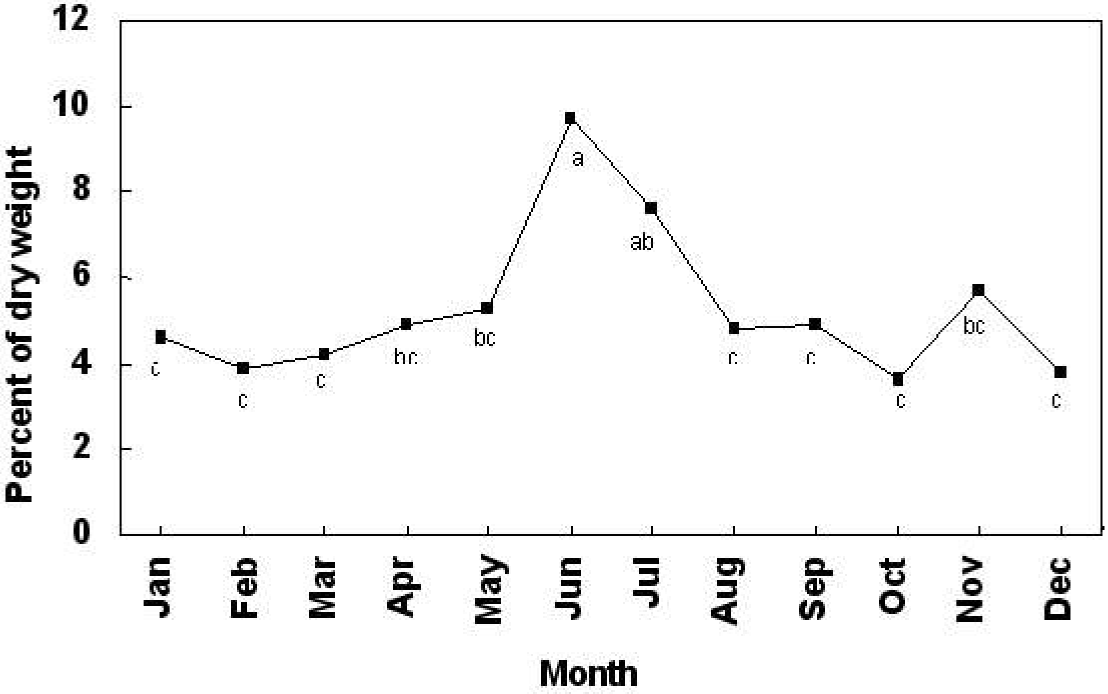

Figure 4. Monthly analysis of sericea lespedeza root ash concentration (percent of dry weight). Values sharing the same letter along the line are not significantly different according to Fisher's protected LSD comparison (P = 0.05). Data pooled over three locations of the experiment.

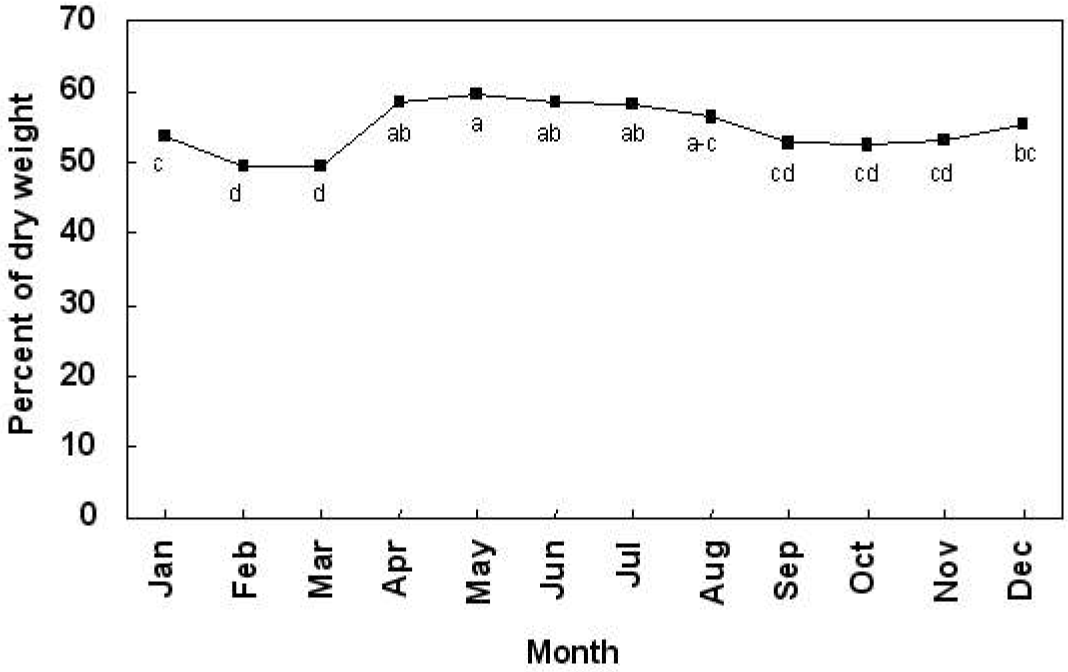

Figure 5. Monthly analysis of sericea lespedeza root neutral detergent fiber concentration (percent of dry weight). Values sharing the same letter along the line are not significantly different according to Fisher's protected LSD comparison ($P = 0.05$). Data pooled over three locations of the experiment.

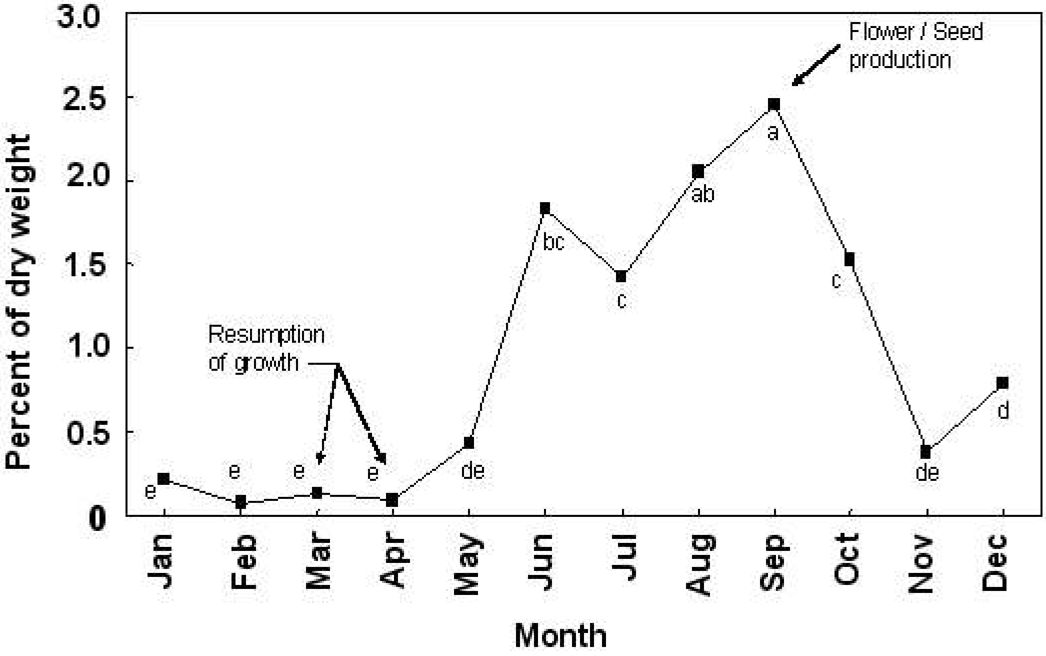

Figure 6. Monthly analysis of sericea lespedeza stem condensed tannin concentration (percent of dry weight). Values sharing the same letter along the line are not significantly different according to Fisher's protected LSD comparison (P = 0.05). Data pooled over three locations of the experiment.

Chapter V

Control of Seedling Sericea Lespedeza (*Lespedeza cuneata*) with Herbicides

Control of Seedling Sericea Lespedeza (*Lespedeza cuneata*) with Herbicides

Abstract: Two field experiments were conducted at the Agronomy Research Station near Stillwater, OK in 2004 and 2005 to identify and evaluate herbicides applied preplant incorporated, preemergence, early postemergence, or late postemergence for the control of seedling sericea lespedeza. Trifluralin, applied preplant incorporated, controlled seedlings 77 (15 WAE) and 63% (16 WAE) in 2004 and 2005, respectively. Flumioxazin, imazapic, fluometron, diuron, sulfentrazone, atrazine, metribuzin, and metolachlor applied preemergence, all provided greater than 86% seedling control at 15 and 16 WAE in both years. Diclosulam, applied preemergent, controlled seedlings 47% at 15 WAE in 2004 and 91% control at 16 WAE in 2005. In 2004, triclopyr, metsulfuron-methyl, glyphosate, picloram, dicamba, and 2,4-D amine plus picloram (tank-mix) applied early postemergence, controlled 90 to 100% of the sericea lespedeza seedlings at 15 WAE. However, in 2005, only triclopyr, metsulfuron-methyl, glyphosate, and 2,4-D amine plus picloram (tank-mix) showed greater than 80% control at 16 WAE. Triclopyr, applied late postemergence, controlled seedlings 100% at 15 and 16 WAE, in both years. In 2004, dicamba plus 2,4-D (premix) and glyphosate were the only other herbicides which provided greater than 75% control at 15 WAE. These data suggest that there were preemergence applied herbicides that were effective for the control of seedling sericea lespedeza. These data also suggest that triclopyr was the most effective postemergence applied herbicide for the control of seedling sericea lespedeza. The data also showed that the overall level of control of seedling sericea lespedeza decreased as

the season progressed and the plant matured.

Nomenclature: Sericea lespedeza, *Lespedeza cuneata* (Dumont) G. Don. #[5] LESCU.

Additional index words: Above-ground biomass, herbicide, live-stem counts, percent control, prescribed burn, sericea lespedeza seedlings.

Abbreviations: ANOVA, analyses of variance; EPOST, early postemergence; LPOST, late postemergence; PRE, preemergence; PPI, preplant incorporated; WAE, weeks after emergence.

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[5] Letters following this symbol are a WSSA-approved computer code from *Composite List of Weeds*, Revised 1989. Available only on computer disk from WSSA, 810 East 10th Street, Lawrence, KS 66044-8897.

INTRODUCTION

Sericea lespedeza, also known as Chinese lespedeza, is a summer perennial legume which was intentionally introduced into the United States in 1896 from eastern Asia for experimentation in hay and grazing production. In the 1940's it was broadly planted and established for erosion control, land reclamation, wildlife food and cover, and livestock forage and hay. It was unintentionally introduced into pastures or fields as a contaminant in seed used as part of the Conservation Reserve Program during the 1980's (Ohlenbusch et al. 2001). Sericea lespedeza is the only perennial lespedeza of agricultural importance in the U.S. (Magness et al. 1971). The plant can be found in 35 states and has been reported as far north and east as Maine, south to include all of Florida, then west to central Texas, and north to Nebraska (USDA-NRCS 2002). It has also been reported in Oregon and Hawaii. Researchers in Kansas have tried to survey the severity of the weed and have estimated that sericea lespedeza infests approximately 160,000 ha in that state (Ohlenbusch et al. 2001).

Sericea lespedeza grows approximately 0.8 to 1.5 m tall. The strigose stems grow in an erect or strongly ascendent growth stature. At maturity, the stems are woody and fiberous with stiff, sharp, flattened bristles present. Sericea lespedeza can reproduce by seed as well as spread vegetatively from regrowth from perennial crown buds, which produce new shoots each year (McKee and Hyland 1941). Sericea lespedeza is also reported to reproduce vegetatively from root sprouting (Jordan et al. 2002); however, no other authors could be found that reported this phenomena. Sericea lespedeza typically yields 230 to 1140 kg of seed/ha (Pieters 1934), with approximately 660,000 seed/kg with seed set from July to Sept (Radford et al. 1968).

Sericea lespedeza seedlings are considered weak and poor competitors with other spring and summer grasses and broadleaf plant species. However, once established, sericea lespedeza is recognized for its tolerance to drought, due to its deep rooted and long-lived nature (Ohlenbusch et al. 2001). Although, able to establish and grow on poor soils, it will grow abundantly on fertile, well drained soils.

Moderate infestations of mature sericea lespedeza reduced forage biomass of native grass and bermudagrass by 71 and 49%, respectively (Koger and Stritzke 2003) and has also been reported as being allelopathic (Cope 1982; Kalburtji and Mosjidis 1992). Sericea lespedeza residue, added to the soil, reduced dry weight and nitrogen concentration of bermudagrass biomass 17 and 28%, respectively (Kalburtji and Mosjidis 1992). However, the plant does not appear to exhibit auto-allelopathy since the germination and seedling growth of sericea lespedeza was not hindered when grown in association with established sericea lespedeza plants (Cope 1982).

Control programs have utilized mechanical, cultural, fire/grazing interactions, and chemical means to reduce populations of sericea lespedeza, often with mixed success and frequent failure. Various herbicides and herbicide application timing regimes have been evaluated for sericea lespedeza control. Dicamba, 2,4-D, and clopyralid did not reduce mature sericea lespedeza stem density during it's first growing season (Altom et al. 1992). Altom et al. (1992) and Koger et al. (2002) reported that early application of triclopyr and fluroxypyr reduced stem density of established sericea lespedeza. Koger et al. (2002) reported that the two herbicides applied at the branched-stem growth stage provided the most consistent, long-term control of sericea lespedeza. They further reported that metsulfuron was effective in controlling sericea lespedeza when applied at the flowering growth stage. When glyphosate was used in combination with prescribed burning, sericea lespedeza returned to abundance levels equal to or exceeding the pretreatment presence after being controlled for 2 years (Jordan et al. 2002). Jordan and Jacobs (2003) determined that applying glyphosate through a wiper application method was effective for the control of tall and mature sericea lespedeza but small plants as well as seedlings were able to escape the applicator and glyphosate herbicide. Sericea lespedeza was controlled 75 to 100% when glyphosate (1.1 or 2.2 kg/ha) was applied at flowering (August to September) (Yonce and Skroch 1989).

Differences or inconsistencies have occurred with the use of herbicides for the control of sericea lespedeza. Altom et al. (1992) reported different levels of sericea lespedeza control, which were based on significant location differences. They also showed that the level of control increased with increasing rates of selected herbicides. Yonce and Skroch (1989) reported inconsistencies in the results from early and mid-season applications of glyphosate compared across locations. They also showed that differences within specific locations were due to rate as well as the glyphosate application date.

Research has been conducted evaluating herbicide control methods for mature sericea lespedeza in pastures and rangeland situations as well as for the control of weeds in seedling and mature sericea lespedeza used for forage production. However, no research has been conducted evaluating the control of seedling sericea lespedeza. Various research results have shown that with the control of the mature plant, seedlings become a problem due to the eventual reinfestation of sericea lespedeza into the area. Therefore, the objective was to identify and evaluate herbicides applied PPI, PRE, EPOST, as well as LPOST that would control seedling sericea lespedeza.

MATERIALS AND METHODS

Two field experiments were conducted on the Agronomy Research Station located near Stillwater, OK in 2004 and 2005. The experiments were conducted on a Easpur loam (fine-loamy, mixed, superactive, thermic Fluventic Haplustolls) with a pH of 7.1 and an organic matter content of 0.6%.

The experimental design for both experiments was a randomized complete block with three replications in 2004 and four replications in 2005. The experiment area was tilled and cultipacked to ensure a firm seedbed prior to planting. Sericea lespedeza was planted with a Brillion seeder at a depth of 0.5 to 1.0 cm and a seeding rate of 30 kg/ha on May 10, 2004 and 39 kg/ha on April 14, 2005. Plots were 1.6 m wide by 3.1 m long. Herbicide treatments were applied with a tractor-mounted compressed air sprayer that delivered 140 L/ha. Irrigation was applied using an overhead side-roll sprinkler system, as judged necessary, to both experimental areas during the spring months to ensure adequate germination, emergence, and seedling growth as well as to activate preplant incorporated (PPI) and preemergence (PRE) herbicide treatments.

Herbicide treatments evaluated for the control of seedling sericea lespedeza were based on PPI, PRE, early-postemergence (EPOST), as well as late-postemergence (LPOST) application timings (Tables 1 through 6). Only two of the herbicides used in this experiment (triclopyr and metsulfuron-methyl; postemergence only) are currently labeled for control of sericea lespedeza; therefore, all herbicides and rates used were determined based on the highest labeled rates for other respective crops. A list of the herbicides, adjuvants, rates, and application timings are shown in Tables 1 through 6. In 2004, the herbicide applied PPI was made before planting, PRE applications were made 2 d after planting, EPOST applications were made about 5 wks after emergence (WAE), and LPOST applications were made about 9 WAE. In 2005, the herbicide applied PPI was made before planting, PRE applications were made immediately after planting, EPOST applications were made about 4 WAE, and LPOST applications were made about 9 WAE. Unwanted grass and broadleaf weeds were controlled with clethodim at 0.154 kg ai/ha plus crop oil concentrate at 1.0% v/v and imazamox at 0.053 kg ai/ha plus crop oil concentrate at 1.0% v/v, respectively. Unpublished data collected by the author in other preliminary research concluded that both clethodim and imazamox could be safely applied to sericea lespedeza without causing injury to the sericea lespedeza.

Control ratings were made by visually estimating the percent control and were based on a scale of 0 (no control) to 100% (all seedlings dead and/or absent). Visual estimates of percent control were based on comparisons between treated and non-treated (check) plots. Sericea lespedeza plant height was collected on plants within the untreated check plots at the time rating data were collected. Plant height data were only reported to show untreated seedling growth after emergence as well as height on rating dates. For the 2004 experiment, visual control ratings were taken June 30, July 23, July 30, August 24, September 3, and September 21, which corresponds to 3, 6, 7, 11, 12, and 15 WAE. For the 2005 experiment, visual control ratings were taken June 14, July 12, July 19, August

5, August 19, and September 9, which corresponds to 4, 8, 9, 11, 13, and 16 WAE.

Data collected on the percent control of seedling sericea lespedeza from both experiments were subjected to analysis of variance (ANOVA) using the PROC MIXED procedure (SAS 2002). To determine year effect on treatment (herbicide), ANOVAs combined over experiments as F-test for all treatment and year by treatment interactions were performed. A significant year by treatment interaction was detected; therefore, the two experimental years were analyzed and will be discussed separately. Treatment means were separated using Fisher's protected LSD at P = 0.05. Data were analyzed with statistical comparisons made between herbicides within the PPI, PRE, EPOST, and LPOST; however these data and statistics are not shown.

RESULTS AND DISCUSSION

Emergence of the seedling sericea lespedeza occurred on June 10 and May 16 for the 2004 and 2005 experiments, respectively. Trifluralin controlled sericea lespedeza seedlings 77% (3 to 15 WAE) in 2004 and 89% (3 WAE) to 63% (16 WAE) in 2005 (Tables 1 and 4). Trifluralin was included in these experiments to evaluate the level of seedling control from a mechanically incorporated dinitroanaline herbicide; however, it is understood that this is not a practical treatment for pasture or rangelands.

In both years, all of the herbicide treatments applied preemergence provided greater than 60% control of sericea lespedeza 3 to 4 WAE (Tables 1 and 4). In both years, flumioxazin, imazapic, fluometron, diuron, sulfentrazone, atrazine, metribuzin, and metolachlor applied as preemergence treatments, provided 96 to 100% control at 3 to 4 WAE and 80 to 100% control at 15 to 16 WAE. However, the levels of control from prometryn and diclosulam at 15 WAE in 2004 and prometryn at 16 WAE in 2005 were all less than 53%. The data pertaining to the herbicide treatments applied PPI and PRE suggest that triflurin, flumioxazin, imazapic, fluometron, diuron, sulfentrazone, atrazine, metribuzin, metolachlor, and diclosulam have the potential (if commercially labeled) and are effective for the control of seedling sericea lespedeza.

Triclopyr, applied EPOST, provided a high level of control throughout the rating periods of both years, with 100% seedling control (Tables 2 and 5). In 2004, the metsulfuron-methyl, glyphosate, picloram, dicamba, and the 2,4-D plus picloram (tankmix) treatments provided less than 63% control at 6 and 7 WAE (Table 2). However, by 11 WAE and through 15 WAE, there was 87% or greater control of seedling sericea lespedeza when using the before-mentioned herbicides. The only other treatments within the 2004 EPOST application group showing greater than 75% control during the season were the 2,4-D plus dicamba (tankmix) and paraquat herbicides. The 2,4-D plus dicamba (tankmix) treatment controlled the seedlings 78 and 77% at the 11 and 12 WAE rating dates, respectively. However, the 2,4-D plus dicamba (tankmix) treatment provided only 68% control 15 WAE. The paraquat treatment showed a high level of control from 6 (97%) to 12 WAE (80%). However, the seedlings began to overcome the effects of paraquat by 15 WAE through plant regrowth and a resulting 62% control.

The level of control from herbicides applied as EPOST treatments were less in 2005 compared to 2004, with the exception of triclopyr (Tables 2 and 5). Triclopyr provided 100% seedling control 9, 11, 13, and 16 WAE, which was similar to the level of control obtained in 2004 (Table 5). Triclopyr, metsulfuron-methyl, glyphosate, 2,4-D amine plus picloram (tank-mix), and paraquat herbicides were the only treatments that resulted in greater than 68% seedling control 16 WAE. The level of control from the metsulfuron-methyl treatment increased from 29% at 9 WAE to 80% at 16 WAE. The glyphosate treatment resulted in 75% control at 11 WAE; however, the level of control decreased to 73% at 13 WAE and 68% at 16 WAE. The 2,4-D amine plus picloram (tank-mix) treatment resulted in 48% control at 13 WAE but increased to an 80% level of seedling control at 16 WAE. Similar to the 2004 experiment results, the paraquat treatment showed seedling control of 90% at 9 WAE and 78% at 13 WAE; however, seedling regrowth decreased the level of control to only 29% by 16 WAE.

Triclopyr resulted in the highest level of control within the LPOST application timing group with 100% control at 15 WAE in 2004 and 16 WAE in 2005 (Tables 3 and 6). Only two other herbicide treatments and one rating collection date in 2004 resulted in seedling control greater than 75% (Table 3). These two herbicide treatments were dicamba plus 2,4-D (premix) with 78% control and glyphosate with 75% control at 15 WAE. No other herbicides within the EPOST application group of the 2005 experiment, except triclopyr, resulted in an acceptable level of control (Table 6).

With a comparison of the PRE, EPOST, and LPOST treatment application timings, differing levels of seedling sericea lespedeza control became apparent (Tables 1 through 6). The use of herbicides applied PRE provided a high level of control of seedling sericea lespedeza over the entire growing season. Specific examples showing the differences between herbicides applied PRE versus EPOST were with the atrazine and diclosulam treatments where the treatments applied PRE in 2004 resulted in 93% (atrazine) and 47%

(diclosulam) control compared to the treatments applied EPOST showing only 50% (atrazine) and 12% (diclosulam) control at 15 WAE, respectively (Tables 1 and 2). Comparing the 2004 imazapic PRE versus LPOST applied treatments, the PRE applied treatment showed 100% control (15 WAE) and the LPOST applied treatment resulted in a great decline in the level of control with only 8% at 15 WAE (Tables 1 and 3). Results from the 2005 experiment were similar with the PRE applied treatments resulting in higher levels of control compared to the treatments applied EPOST or LPOST (Tables 4 through 6). When comparisons were made between identical herbicide treatments used in the 2004 EPOST and LPOST application timings, all of the herbicide treatments applied EPOST, except triclopyr (same in both), dicamba plus 2,4-D (premix), bromoxynil, and bentazon, resulted in a higher level of control at 15 WAE (Tables 2 and 3). In 2005, a comparison of these same herbicides showed a higher level of control with the treatments applied EPOST compared to the treatments applied LPOST, with the exception of triclopyr (same in both), dicamba plus 2,4-D (premix), 2,4-D amine plus dicamba (tank-mix), dicamba, 2,4-D amine, pyrithiobac, and 2,4-DB amine (Tables 5 and 6). Thus, these data suggest that seedling sericea lespedeza becomes more difficult to control with herbicides as the season progresses and the plant matures.

Based on the herbicides used and results of this experiment, the EPOST and LPOST application data suggest that triclopyr is the most effective herbicide for the control of emerged seedling sericea lespedeza. The treatment containing 2,4-D amine plus picloram (tank-mix) applied EPOST was also effective for the control of emerged seedling sericea lespedeza. Triclopyr and metsulfuron-methyl are commercially labeled and are effective for the control of established, mature sericea lespedeza (Altom et al. 1992; Koger et al. 2002). In some years, such as in 2004, glyphosate, picloram, and dicamba can be effective as EPOST applied herbicides and glyphosate and dicamba plus 2,4-D can be effective as LPOST applied herbicides for the control of seedling sericea lespedeza. The variability in the level of control from some of the herbicides, with specific example to glyphosate, are similar to the results discussed by Yonce and Skroch (1989). They determined that there was variability in the level of sericea lespedeza control when using glyphosate, which was due to conditions such as application timing and location. The differences in the level of control from year to year (as shown in the 2004 and 2005 experiment results) with glyphosate, picloram, dicamba, and dicamba plus 2,4-D (premix) are possibly due to environmental variation, variation in seedling growth, unseen seedling stress, or a combination of these or other unknown conditions. However, there were no apparent visual signs of large variation in seedling growth characteristics or seedling stress during either year of the experiment.

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Table 1. Effects of herbicide treatment applied PPI or PRE on the control of seedling sericea lespedeza - (2004).[a,b]

			Sericea lespedeza control					
			Plant height (cm)					
			1-5	15-27	5-33	30-50	50-60	55-76
	Treatment		WAE					
Herbicide	Rate	Timing	3	6	7	11	12	15
	kg ai/ha		%					
Trifluralin	1.12	PPI	77 ab	82 b	83 bc	83 a-c	80 a-c	77 a-c
Flumioxazin	0.107	PRE	100 a	100 a	100 a	100 a	100 a	100 a
Imazapic	0.105	PRE	97 a	100 a	100 a	100 a	100 a	100 a
Fluometron	2.24	PRE	100 a	100 a	100 a	100 a	100 a	98 a
Diuron	2.24	PRE	100 a	100 a	100 a	98 a	98 a	98 a
Sulfentrazone	0.278	PRE	100 a	100 a	100 a	98 a	98 a	95 a
Atrazine	2.24	PRE	100 a	98 a	100 a	95 a	95 a	93 a
Metribuzin	0.84	PRE	98 a	95 a	95 ab	93 ab	92 ab	88 a
Metolachlor	1.93	PRE	98 a	95 a	98 a	93 ab	92 ab	87 ab
Prometryn	2.7	PRE	83 ab	77 b	73 c	62 bc	72 bc	53 bc
Diclosulam	0.0003	PRE	60 b	78 b	77 c	58 c	65 c	47 c

[a] Means followed by the same letters are not significantly different according to Fisher's protected LSD at P = 0.05.

[b] Abbreviations: PPI, preplant incorporated (applied May 10, 2004); PRE, preeemergence (applied May 12, 2004); WAE, weeks after emergence (emergence on June 10, 2004).

Table 2. Effects of herbicide treatment applied EPOST on the control of seedling sericea lespedeza - (2004).[a,b]

				Sericea lespedeza control				
				Plant height (cm)				
				15-27	5-33	30-50	50-60	55-76
Treatment				WAE				
Herbicide	Rate	Adjuvant	Timing	6	7	11	12	15
	kg ai/ha			%				
Triclopyr	6.7	—	EPOST	100 a	100 a	100 a	100 a	100 a
Metsulfuron-methyl	0.017	NIS	EPOST	17 d-f	55 c	100 a	98 a	98 ab
Glyphosate	1.4	—	EPOST	63 bc	95 ab	95 ab	95 ab	95 a-c
Picloram	0.56	NIS	EPOST	37 c-e	43 c-e	88 a-c	93 a-c	93 a-c
Dicamba	0.035	—	EPOST	30 c-f	50 cd	88 a-c	92 a-c	92 a-c
2,4-D amine + Picloram	2.24 + 0.56	NIS	EPOST	45 cd	63 bc	87 a-c	90 a-c	90 a-d
2,4-D amine + Dicamba	2.24 + 0.035	NIS	EPOST	38 c-e	53 c	78 a-c	77 a-d	68 a-e
Dicamba + 2,4-D	0.56 + 1.57	—	EPOST	32 c-f	37 c-f	62 b-d	63 a-e	65 a-e
Paraquat	1.14	NIS	EPOST	97 ab	98 a	88 a-c	80 a-d	62 b-e
2,4-DB amine	1.68	—	EPOST	50 cd	37 c-f	52 c-e	48 d-g	60 c-e
Pyrithiobac	0.107	NIS	EPOST	33 c-f	40 c-e	63 a-d	53 c-f	53 d-f
Atrazine	2.24	COC	EPOST	43 cd	68 a-c	52 c-e	60 a-e	50 ef
2,4-D amine	2.24	NIS	EPOST	5 ef	18 d-g	30 d-f	55 b-f	42 e-g
Bromoxynil	1.12	COC	EPOST	5 ef	0 g	13 f	12 g	17 fg
Diclosulam	0.0003	—	EPOST	3 ef	3 fg	20 ef	15 fg	12 g
Bentazon	1.12	COC	EPOST	0 f	10 e-g	15 ef	23 e-g	8 g

[a] Means followed by the same letters are not significantly different according to Fisher's protected LSD at P = 0.05.

[b] Abbreviations: EPOST, early postemergence (applied July 16, 2004); COC, crop oil concentrate at 1.0% (v/v); NIS, nonionic surfactant at 0.25% (v/v); WAE, weeks after emergence (emergence on June 10, 2004).

Table 3. Effects of herbicide treatment applied LPOST on the control of seedling sericea lespedeza - (2004).[a,b]

				Sericea lespedeza control		
				Plant height (cm)		
				30-50	50-60	55-76
Treatment				WAE		
Herbicide	Rate	Adjuvant	Timing	11	12	15
	kg ai/ha			%		
Triclopyr	6.7	—	LPOST	92 a-d	100 a	100 a
Dicamba + 2.4-D	0.56 + 1.57	—	LPOST	63 ab	68 ab	78 ab
Glyphosate	1.4	—	LPOST	60 a-c	66 ab	75 a-c
2.4-D amine + Dicamba	2.24 + 0.035	NIS	LPOST	48 b-e	62 bc	63 b-d
Metsulfuron-methyl	0.017	NIS	LPOST	50 b-d	58 bc	60 b-e
Picloram	0.56	NIS	LPOST	38 b-g	52 b-d	53 b-e
Dicamba	0.035	—	LPOST	17 e-g	52 b-d	47 b-f
2,4-D amine + Picloram	2.24 + 0.56	NIS	LPOST	45 b-f	42 b-e	43 c-g
2,4-D amine	2.24	NIS	LPOST	32 b-g	42 b-e	40 d-h
Pyrithiobac	0.107	NIS	LPOST	33 b-g	37 b-e	37 d-h
Bromoxynil	1.12	COC	LPOST	25 d-g	22 de	32 d-h
2,4-DB amine	1.68	—	LPOST	30 c-g	37 b-e	32 d-h
Carfentrazone-ethyl	0.017	NIS	LPOST	52 b-d	28 c-e	27 e-h
Halosulfuron	0.035	NIS	LPOST	10 g	12 e	18 f-h
Bentazon	1.12	COC	LPOST	17 e-g	18 de	12 gh
Imazamox	0.053	COC	LPOST	8 g	15 e	10 gh
Imazapic	0.105	NIS	LPOST	13 fg	18 de	8 h

[a] Means followed by the same letters are not significantly different according to Fisher's protected LSD at P = 0.05.

[b] Abbreviations: LPOST, late postemergence (applied August 16, 2004): COC, crop oil concentrate at 1.0% (v/v); NIS, nonionic surfactant at 0.25% (v/v); WAE, weeks after emergence (emergence on June 10, 2004).

Table 4. Effects of herbicide treatment applied PPI or PRE on the control of seedling sericea lespedeza - (2005).[a,b]

			Sericea lespedeza control					
			Plant height (cm)					
			1-5	7-33	8-33	8-53	25-71	38-64
Treatment			WAE					
Herbicide	Rate	Timing	4	8	9	11	13	16
	kg ai/ha		%					
Trifluralin	1.12	PPI	89 b	81 b	74 b	71 c	69 c	63 b
Flumioxazin	0.107	PRE	100 a	100 a	100 a	100 a	100 a	99 a
Imazapic	0.105	PRE	100 a	100 a	100 a	100 a	100 a	100 a
Fluometron	2.24	PRE	100 a	100 a	100 a	100 a	98 a	98 a
Diuron	2.24	PRE	96 ab	96 ab	94 a	94 ab	91 a	89 a
Sulfentrazone	0.278	PRE	99 ab	96 ab	95 a	96 ab	94 a	94 a
Atrazine	2.24	PRE	99 ab	91 ab	88 ab	81 bc	81 ab	80 ab
Metribuzin	0.84	PRE	98 ab	93 ab	91 ab	93 ab	93 a	91 a
Metolachlor	1.93	PRE	98 ab	93 ab	93 ab	91 ab	91 a	86 a
Prometryn	2.7	PRE	69 c	49 c	26 c	45 d	34 c	30 c
Diclosulam	0.0003	PRE	90 ab	93 ab	94 a	94 ab	95 a	91 a

[a] Means followed by the same letters are not significantly different according to Fisher's protected LSD at P = 0.05.

[b] Abbreviations: PPI, preplant incorporated (applied April 14, 2005); PRE, preeemergence (applied April 14, 2005); WAE, weeks after emergence (emergence on May 16, 2005).

Table 5. Effects of herbicide treatment applied EPOST on the control of seedling sericea lespedeza - (2005).[a,b]

				Sericea lespedeza control			
				Plant height (cm)			
				8-33	8-53	25-71	38-64
Treatment				WAE			
Herbicide	Rate	Adjuvant	Timing	9	11	13	16
	kg ai/ha			%			
Triclopyr	6.7	—	EPOST	100 a	100 a	100 a	100 a
Metsulfuron-methyl	0.017	NIS	EPOST	29 c	39 c	59 cd	80 bc
Glyphosate	1.4	—	EPOST	59 b	75 b	73 c	68 c
Picloram	0.56	NIS	EPOST	10 cd	14 d-g	45 de	70 c
Dicamba	0.035	—	EPOST	0 d	5 e-g	10 f-h	9 ef
2,4-D amine + Picloram	2.24 + 0.56	NIS	EPOST	9 cd	25 c-f	48 de	80 bc
2,4-D amine + Dicamba	2.24 + 0.035	NIS	EPOST	11 cd	30 cd	29 ef	6 ef
Dicamba + 2,4-D	0.56 + 1.57	—	EPOST	14 cd	11 d-g	23 fg	19 de
Paraquat	1.14	NIS	EPOST	90 a	93 ab	78 bc	29 d
2,4-DB amine	1.68	—	EPOST	18 cd	20 c-g	10 f-h	5 ef
Pyrithiobac	0.107	NIS	EPOST	0 d	0 g	3 gh	0 f
Atrazine	2.24	COC	EPOST	14 cd	14 d-g	5 gh	0 f
2,4-D amine	2.24	NIS	EPOST	9 cd	28 c-e	18 f-h	4 ef
Bromoxynil	1.12	COC	EPOST	5 d	19 d-g	5 gh	4 ef
Diclosulam	0.0003	—	EPOST	3 d	8 d-g	4 gh	3 ef
Bentazon	1.12	COC	EPOST	0 d	3 fg	0 h	0 f

[a] Means followed by the same letters are not significantly different according to Fisher's protected LSD at P = 0.05.

[b] Abbreviations: EPOST, early postemergence (applied July 12, 2005); COC, crop oil concentrate at 1.0% (v/v); NIS, nonionic surfactant at 0.25% (v/v); WAE, weeks after emergence (emergence on May 16, 2005).

Table 6. Effects of herbicide treatment applied LPOST on the control of seedling sericea lespedeza - (2005).[a,b]

				Sericea lespedeza control	
				Plant height (cm)	
				25-71	38-64
Treatment				WAE	
Herbicide	Rate	Adjuvant	Timing	13	16
	kg ai/ha			%	
Triclopyr	6.7	—	LPOST	100 a	100 a
Dicamba + 2.4-D	0.56 + 1.57	—	LPOST	29 b-d	30 c-f
Glyphosate	1.4	—	LPOST	43 b	39 c
2.4-D amine + Dicamba	2.24 + 0.035	NIS	LPOST	20 c-f	11 fg
Metsulfuron-methyl	0.017	NIS	LPOST	25 b-e	36 cd
Picloram	0.56	NIS	LPOST	38 bc	63 b
Dicamba	0.035	—	LPOST	20 c-f	15 e-g
2,4-D amine + Picloram	2.24 + 0.56	NIS	LPOST	30 b-d	33 c-e
2,4-D amine	2.24	NIS	LPOST	15 d-g	6 g
Pyrithiobac	0.107	NIS	LPOST	5 fg	3 g
Bromoxynil	1.12	COC	LPOST	9 e-g	0 g
2,4-DB amine	1.68	—	LPOST	31 b-d	16 d-g
Carfentrazone-ethyl	0.017	NIS	LPOST	5 fg	0 g
Halosulfuron	0.035	NIS	LPOST	0 g	0 g
Bentazon	1.12	COC	LPOST	0 g	0 g
Imazamox	0.053	COC	LPOST	0 g	0 g
Imazapic	0.105	NIS	LPOST	13 d-g	18 d-g

[a] Means followed by the same letters are not significantly different according to Fisher's protected LSD at P = 0.05.

[b] Abbreviations: LPOST, late postemergence (applied August 12, 2005): COC, crop oil concentrate at 1.0% (v/v); NIS, nonionic surfactant at 0.25% (v/v); WAE, weeks after emergence (emergence on May 16, 2005).

Chapter VI

Effects of Prescribed Fire and Mowing on the Population Dynamics of Sericea Lespedeza

Effects of Prescribed Fire and Mowing on the Population Dynamics of Sericea Lespedeza

Abstract: A field experiment was initiated near Stillwater, OK on the Range Research Station in 2004 to measure the effects of spring, fall, and combinations of fire return intervals on sericea lespedeza control, production, and compositional relationship to grasses. A second experiment was conducted on a privately-leased pasture near Stillwater, OK in 2005 to evaluate the effects of fire and mowing on seedling establishment, fire and mowing for the control of seedling sericea lespedeza, fire and mowing for the control of mature sericea lespedeza, and if fire or mowing effects the composition of sericea lespedeza to grass within the spatial landscape. The spring 2005 evaluation of sericea lespedeza biomass showed no significant difference between the three non-burned and the September 20, 2004 burn treatments. However, average sericea lespedeza biomass was 1,189 kg/ha or 49% lower and grass biomass was 1,853 kg/ha or 87% lower within the burned treatments compared to the average biomass from the non-burned treatments. These results suggest that following the 2004 fall burn, sericea lespedeza does posses the ability to resprout from perennial crownbuds and then produced aboveground plant tissue during the fall of 2004. On August 2, 2005, all of the treatments that received no fall 2004 prescribed burn, produced 4,640 to 7,050 kg/ha of sericea lespedeza biomass. There was about 42% more sericea lespedeza in the non-burned treatments when averaged and compared to the biomass from the fall 2004 burn treatments. Within the fall 2004 burned treatments, sericea lespedeza biomass ranged from 2,810 to 3,380 kg/ha and was not significantly different compared across the three fall 2004 burn treatment combinations. The results of the second experiment showed no significant sericea lespedeza biomass or stem count differences between any of the treatments. Conclusions derived from these data were seed germination, seedlings, and mature sericea lespedeza were not affected over the first growing season by fire, mowing, response to bare ground, or response to residues left on the soil surface. Results showed that native tallgrass production in the untreated treatment was 5,420 kg/ha, which was significantly higher than all other treatments. These results suggest that spring burning, mowing and removing the litter, and mowing and retaining the litter, negatively affected the growth and production of native grasses.

Nomenclature: Sericea lespedeza, *Lespedeza cuneata* (Dumont) G. Don. #[6] LESCU.

Additional index words: Biomass, control, mowing, prescribed burn, seed, seedling, stem count.

Abbreviations: ANOVA, analyses of variance; TNC, total nonstructural carbohydrate.

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[6] Letters following this symbol are a WSSA-approved computer code from *Composite List of Weeds*, Revised 1989. Available only on computer disk from WSSA, 810 East 10th Street, Lawrence, KS 66044-8897.

INTRODUCTION

Sericea lespedeza, also known as Chinese lespedeza, is a summer perennial legume, which was intentionally introduced into the United States in 1896 from eastern Asia for experimentation for hay and grazing uses. In the 1940's it was broadly planted and established for erosion control, land reclamation, wildlife food and cover, and livestock forage and hay. It was unintentionally introduced into pastures or fields as a contaminant in seed used as part of the Conservation Reserve Program during the 1980's (Ohlenbusch et al. 2001). Sericea lespedeza is the only perennial lespedeza of agricultural importance in the U.S. (Magness et al. 1971). The plant can be found in 35 states and has been reported as far north and east as Maine, south to include all of Florida, then west to central Texas, and north to Nebraska (USDA-NRCS 2002). It has also been reported in Oregon and Hawaii. Researchers in Kansas have tried to survey the severity of the weed and have estimated that sericea lespedeza infests approximately 280,000 ha in that state. On July 1, 2000 it was declared a state-wide noxious weed in Kansas (Anonymous 2003).

Sericea lespedeza grows about 0.8 to 1.5 m tall. The strigose stems grow in an erect or strongly ascendent growth stature. At maturity, the stems are woody and fiberous with stiff, sharp, flattened bristles present. Sericea lespedeza can reproduce by seed as well as spread vegetatively from regrowth from perennial crownbuds, which produce new shoots each year (McKee and Hyland 1941). Sericea lespedeza is also reported to reproduce vegetatively from root sprouting (Jordan et al. 2002); however, no other authors could be found that reported this phenomena. Therefore, in this paper all references to vegetative reproduction will be referring to regrowth from perennial crownbuds. Sericea lespedeza typically yields 230 to 1140 kg of seed/ha (Pieters 1934), with approximately 660,000 seed/kg with seed set from July to Sept (Radford et al. 1968). Sericea lespedeza seedlings are considered weak and poor competitors with other spring and summer grasses and broadleaf plant species (Hoveland et al. 1971). However, once established, sericea lespedeza is recognized for its tolerance to drought, due to its deep rooted and long-lived nature.

The effects of fire on sericea lespedeza seed or mature plants have not been well documented. Simulated fire condition experiments were conducted by Cushwa et al. (1968), Martin et al. (1975), and Segelquist (1971) to evaluate dry heat and moist heat conditions on the germination of sericea lespedeza and other legume species. Cushwa et al. (1968) reported that sericea lespedeza germination percentages were 86, 85, 91, and 27% when exposed to 4 min of moist heat at 45, 60, 70, and 80 C, respectively. However, when the seed were exposed to 4 min of 90 and 98 C moist heat conditions, no sericea lespedeza germination occurred. When sericea lespedeza seed were exposed to 4 min of dry heat at 45, 60, 70, 80, and 90 C, Cushwa et al. (1968) reported that germination percentages were 93, 83, 90, 89, and 83%, respectively. However, with 4 min of dry heat at 100 and 110 C, sericea lespedeza germination decreased to 2 and 0%, respectively. Martin et al. (1975) determined that a 4 min exposure to either dry or moist heat conditions within the temperature range of 90 to 100 C was lethal to all of the legume species seed they evaluated. Segelquist (1971) used sericea lespedeza seed collected near Stillwater, OK and methodology similar to Cushwa et al. (1968) and Martin et al. (1975) to measure the germination. Seed did not germinate when Segelquist

(1971) exposed them to 100 C moist heat for 32 min or more. The research and results of Cushwa et al. (1968), Martin et al. (1975), and Segelquist (1971) all showed that sericea lespedeza seed and germination were affected by differences in temperature, moisture, or a combination of the two. However, with their experiments, which simulate field or fire (heat) conditions, the ability to accurately extrapolate these results to actual field or prescribed fire conditions may not be possible. Therefore, the laboratory simulated results must be further verified through field experimentation to determine if fire scarifies the seed and/or stimulates seedling emergence.

Hotter fire temperatures produced by fine-fuels should effect the seed that are still suspended within aboveground inflorescence more, since temperatures near the soil surface are cooler. Immature seed contain a higher moisture content than mature seed, which facilitates the immature embryos being more likely to be heat-killed at lower temperatures (Brooks 2001). Daubenmire (1968) and Vogl (1974) both documented that flames or heat from grassland fires seldom damage or consume seed on or near the soil surface because of lower temperatures in this area.

Total nonstructural carbohydrates (TNC) represent the primary stored energy source for biennial and perennial plants. This energy reserve is important for both plant survival and for producing new plant tissue when energy demand exceeds production via photosynthesis (Smith 1969). Narra et al. (2004) used TNC as an indirect indicator of stress on growth and physiological responses in creeping bentgrass (*Agrostis palustris* Huds.). Root TNC concentrations have been used as a predictor of plant vigor and yield (Buwai and Trlica 1977). They reported that multiple defoliation events depleted root

TNC levels and negatively affected the herbage yield and vigor of both grass and broadleaf plants investigated in their experiment. They concluded that foliage defoliation diminishes the plants ability to produce food and store carbohydrates within the roots. Due to sericea lespedeza possessing the ability to regrow each year from perennial crownbuds and the fact that roots or crowns are the primary storage organs for the energy used for aerial plant regrowth, management strategies pertaining to the depletion of the TNC should negatively impact plant growth and overall persistence. However, production of more aerial shoots following a defoliation event is a mechanism sericea lespedeza possesses and uses to overcome the potential loss of stored energy through increased photosynthate production. Stitt (1943) compared first harvest to second harvest plants and concluded that second harvest plants produced 2 to 3 times as many shoots per plant.

Control programs have utilized mechanical and cultural means to reduce sericea lespedeza populations, often with mixed success and frequent failure. The use of fire as a tool to defoliate sericea lespedeza can be done. However, according to Ohlenbusch et al. (2001), Stevens (2002), and Vermeire et al. (1998) spring burns have little to no effect on sericea lespedeza due to perennial resprouting and establishment of new seedlings. A late season prescribed burn used to decrease mature plant vigor, consume the current year’s seed, and decrease seedling survival is recommended by Stevens (2002). The use of prescribed fire has also been implicated as being a causative agent for the spread of sericea lespedeza (Griffith 1996). Griffith (1996) stated that annual burning along with overgrazing from continuous stocking lead to bare ground conditions, which favors the establishment of sericea lespedeza seedlings. Statements from other reports and bulletins were that prescribed fire can be used to control sericea lespedeza by overcoming seed dormancy through fire-scarification of the seed; thus promoting seed germination and seedling establishment, which can be controlled by follow-up fire or herbicide treatments (Anonymous 2000; Ohlenbusch et al. 2001; Stevens 2002; Vermeire et al. 1998). However, no experimental results were provided to support those statements made by Anonymous (2000), Griffith (1996), Ohlenbusch et al. (2001), Stevens (2002), or Vermeire et al. (1998).

Various reports have suggested that cutting or mowing can be an effective tool for the control of sericea lespedeza (Smith 2001; Stevens 2002). The recommendation of mowing at the flower bud stage to reduce sericea lespedeza stand vigor and prevent further spread is suggested by Stevens (2002). Both Smith (2001) and Stevens (2002) recommend repeated cutting or mowing applications for two to three consecutive years. Smith (2001) suggests that mowing or cutting conducted when sericea plants are producing flower buds was an effective treatment due to root carbon reserves being at their lowest levels during this developmental stage of growth. However, no data were presented or referenced to support the validity of these statements. An experiment evaluating TNC concentrations monthly throughout a full year showed that sericea lespedeza TNC concentration levels were lowest in June and higher during the months of September to October when flower and seed production occurred (Farris et al. 2006). The results of Farris et al. (2006) conflict with the statements made by Smith (2001) and Stevens (2002), both stating that sericea lespedeza root carbon reserve levels are at their lowest levels during flower production. An experiment involving mowing sericea lespedeza once, twice, or three times annually for three successive years and another treatment of either spring or fall prescribed burning plots once or twice over a 5 yr period was conducted by Jordan et al. (2002). They reported sericea lespedeza was not controlled with successive mowing and the prescribed fire effects were variable. They attributed the poor results from the two types of treatments to sericea lespedeza's capabilities of reestablishment from crownbuds or germination from the vast soil seed bank. When glyphosate was used in combination with prescribed burning, sericea lespedeza returned to abundant population levels equal to or exceeding the pretreatment population presence, after showing control for 2 years (Jordan et al. 2002).

Prescribed fire or mowing may be valuable tools for the control of invasive sericea lespedeza. However, there is limited experimentally based, published results on the direct effect of fire on the seed, seedling emergence, or control of seedling or mature sericea lespedeza with dormant or growing season fire applications. Information on the effects of mowing are also limited. Therefore, an experiment was established with the objective of determining the effects of spring, fall, as well as combinations of fire return intervals on sericea lespedeza control, production, and composition relationship to grasses. A second experiments was established with the objectives of determining the effects of fire and mowing on seedling establishment, fire and mowing for the control of seedlings, fire and mowing for the control of mature sericea lespedeza, and if fire or mowing effects the composition of sericea lespedeza to grass within the spatial landscape.

MATERIALS AND METHODS

Prescribed Spring, Fall, and Combination Burning - Population Dynamics. A field experiment was initiated in the fall of 2004 on the Range Research Station near Stillwater, OK. The experiment on the Range Research Station was conducted on a Coyle loam (fine-loamy, siliceous, thermic Udic Argiustolls) with a pH of 5.6 to 7.8 and 1 to 3% organic matter. The pasture area prior to the prescribed fire was once a tallgrass prairie now dominated by sericea lespedeza (about 10 to 35 sericea lespedeza plants/m^2).

The experiment was arranged as a randomized complete block with four replications. Plots were 10 m by 10 m and were separated by a 4 m wide border between plots. Treatments and data collection will be performed yearly from fall 2004 through fall 2007. However, due to the long-term treatment applications, data collections required for this experiment, and the deadlines for this thesis, only data pertaining to the fall 2004 prescribed burn will be discussed in this paper. A list of the spring, fall, and spring/fall combination prescribed burn treatments are shown in Table 1.

A prescribed burn was conducted on September 20, 2004 to accomplish the fall burn 2004 treatments. Average fire environment and behavior characteristics were an air temperature of 31 C, relative humidity of 32%, wind-speed of 14.5 KPH, rate of fire spread of 0.3 m/s, flame length of 3 m, and a flame depth of 3 m. All fire environment and behavior data were collected within the center 5 m by 5 m of each plot. The prescribed burn consumed all aboveground biomass within the plot.

On March 4 and August 2, 2005, plant biomass samples were collected by clipping all plants at the soil surface inside 0.25 m^2 quadrates. Three quadrates were used in March and four were used in August. The quadrate samples were randomly collected from areas about 2.5 m from the border of each plot. Sericea lespedeza plant material was separated from the grass plants, both were dried in a forage dryer for 1 wk, and then weighed. The biomass was used for making comparisons among 2004 fall burned and non-burned plots.

An unsuccessful test fire conducted outside of the treatment plots and the condition of no to very low fuel loads present within the 2005 spring burn treatment plots, both revealed that a 2005 spring prescribed burn was not possible. Therefore, the proposed prescribed fire shown on Table 1 could not be fulfilled as shown.

A prescribed burn was conducted on September 9, 2005. Average fire environment and behavior characteristics were an air temperature of 32 C, relative humidity of 38%, wind-speed of 9.2 KPH, rate of fire spread of 0.13 m/s, flame length of 2 m, and a flame depth of 3 m . All fire environment and behavior data were collected within center 5 m by 5 m of each plot. The prescribed fire consumed all aboveground biomass from the plot. The 2005 late fall prescribed burn was done on October 25. Average fire environment and behavior characteristics were an air temperature of 20 C, relative humidity of 36%, wind-speed of 1.6 KPH, rate of fire spread of 0.25 m/s, flame length of 1.3 m, and a flame depth of 3 m. All fire environment and behavior data were collected within center 5 m by 5 m of each plot. The prescribed fire consumed all aboveground biomass from the plot. At the time this paper was written, no plant biomass data had been collected for the fall 2005 prescribed burn; therefore, no data is presented comparing the fall 2005 prescribed burn to previous burn applications or to the unburned check. The data presented in this paper only takes into account the fall 2004 prescribed burn compared to other treatments, which shall be considered as non-burned or untreated treatments.

All data involving the three quadrate biomass and stem count samples/plot for the March 4, 2005 sample collection were averaged together for analysis. All data involving the four quadrate biomass and stem count samples/plot for the August 2, 2005 sample collection were averaged together for analysis. Data were subjected to analysis of variance (ANOVA) using the PROC MIXED procedure (SAS 2002). Treatment means were separated using Fisher's protected LSD at P = 0.05.

Prescribed Burning and Mowing - Seedling Establishment and Population Dynamics. A field experiment was conducted on a privately-leased pasture located northeast of Stillwater, OK in 2005. The experiment on this location was conducted on a Renfrow loam (fine, mixed, thermic Udertic Paleustolls) with a pH range of 6.1 to 7.8 and 1 to 3% organic matter. The experimental area was a tallgrass prairie and was light to moderately infested (5 to 25 plants/m^2) with mature sericea lespedeza. The area was chosen based on it's ability to support sericea lespedeza growth and due to the light to moderate infestation of sericea lespedeza. These two conditions allowed additional seed to be applied to treatment plots and comparisons of be made between treatments where over-seeding was performed.

The experiment was arranged as a randomized complete block design with three replications. Plots were 2 m by 2 m with a 2 m alley between each plot. A list of the treatment combinations are shown in Table 2. Treatment combinations were designed to show the effects of prescribed burning or mowing on mature sericea lespedeza plants, seedling sericea lespedeza, whether sericea lespedeza seed germination increased following a fire or mowing application, whether sericea lespedeza seed requires bare ground for increased germination, and whether the treatments influenced the composition of sericea lespedeza to grass.

On March 7 and before the prescribed burn or mowing treatments, two plant biomass samples were collected from each plot to determine if any plot-to-plot sericea lespedeza or grass biomass differences existed. Plant biomass from each plot were collected within two 0.25 m^2 quadrates by clipping all plants at the soil surface. Sericea lespedeza plant material was separated from the grass plants, both were dried in a forage dryer for 1 wk, and then weighed.

On March 15, aboveground plant material within the mowed treatment plots were cut-off about 1.3 cm above soil level using a lawn tractor equipped with a mulching/mowing deck attachment. After the plots were mowed, cut plant materials, litter, and soil surface duff layer were removed from appropriate plots by hand raking. Litter was removed with a hand rake, that exposed more of the soil surface within those plots. For the mowed treatments requiring retention of the litter, all cut plant materials, litter, and soil surface duff layer were left laying on the soil surface to cover as much of the soil surface as possible. Sericea lespedeza seed was dispersed within the required treatment plots using a hand-held centrifically-driven seeder. Sericea lespedeza seed was dispersed within the required plots at a rate on 250 kg/ha. This seeding rate was within the range of typical sericea lespedeza seed yields as described by Pieters (1934). Seed was either dispersed prior to or after the mowing application.

The spring 2005 prescribed burn was done on March 15. Sericea lespedeza seed dispersal methods and rate were the same as those described for the mowed treatment combinations requiring seed. In the burn treatments requiring seed to be dispersed, sericea lespedeza seed was either dispersed prior to or after the burn application.

On July 27, after adequate sericea lespedeza seed germination, seedling emergence, crownbud resprouting, or seedling and mature plant growth had occurred, biomass of sericea lespedeza and grasses as well as stem counts of sericea lespedeza were collected from all plots. Plant biomass from each plot was collected within two 0.25 m^2 quadrates by clipping all plants at the soil surface. The two quadrate samples were randomly collected from areas about 0.5 m from the border within each plot. Sericea lespedeza plant material was separated from the grass plants, both were dried in a forage dryer for 1 wk, and then weighed.

All data involving the two quadrate biomass and stem count samples/plot were averaged together for analysis. Data were subjected to analysis of variance (ANOVA) using the PROC MIXED procedure (SAS 2002). Treatment means were separated using Fisher's protected LSD at $P = 0.05$.

RESULTS AND DISCUSSION

Prescribed Spring, Fall, and Combination Burning - Population Dynamics. The spring 2005 comparison between the non-burned treatments and the fall burn treatments, that were applied on September 20, 2004, showed no significant differences between sericea lespedeza growth in the burned and non-burned treatments (Table 1). The results also showed that grass biomass was, on average, 1853 kg/ha or 87% lower within the burned treatments compared to the unburned treatments. The results of decreased spring 2005 sericea lespedeza and grass production following the previous fall's burn application can be expected since the fire consumed the aboveground plant material. However, fall regrowth of the summer perennial grasses following the fire along with winter annual grass growth accounted for about 13% of the grass biomass on the March 4 sample collection. The dormant plant material, accumulated from sericea lespedeza resprout growth following the fire, accounted for 51% of the biomass collected on March 4. These results suggest that following the 2004 fall burn application, sericea lespedeza does possess the ability to resprout from perennial crownbud regrowth and can produce aboveground plant tissue during the fall of 2004. However, conclusions of the extent of sericea lespedeza control could not be adequately determined from these results due to perennial sericea lespedeza still being dormant when data were collected.

At the time this paper was written, data were limited to the fall 2005 evaluation of the fall 2004 prescribed burn effects on sericea lespedeza and grasses; as well as not all of the treatments had been applied (Table 1). Therefore, all treatments that had not received the fall 2004 prescribed burn may be considered untreated. All of the treatments that received no fall 2004 prescribed burn, produced 4,640 to 7,050 kg/ha of sericea lespedeza biomass. There was about 42% more sericea lespedeza in the five non-burned treatments when averaged and compared to the average biomass from the three fall 2004 burn treatments. Within the three burned treatments, sericea lespedeza biomass ranged from 2,810 to 3,380 kg/ha and was not significantly different compared across the three fall 2004 burn treatment combinations. This data suggest that fall burning does effect and control sericea lespedeza. However, a 58% control of sericea lespedeza would be considered low compared to the 75% effective control standard used for herbicide efficacy. Following the fall burn, regrowth of perennial sericea lespedeza over the growing season not only allowed the plant to establish new top-growth but may have allowed the plant to rebuild it's root carbohydrate reserves. Therefore, follow-up burn treatments may be needed to further decrease the presence of the perennial plant as well as decrease the production of seed.

The data comparing grass production showed that there were no significant difference between any of the treatments (Table 1). These data suggest that fall burning does not negatively affect tallgrass prairie species within 1 yr after the burn event. This conclusion was expected since the fall burn was conducted later in the fall, removed only the aboveground plant material of perennial grass species, and due to native tallgrass species evolving and being maintained with frequent fire use (Engle and Bidwell 2001). These data also suggest that there was no apparent release of grass species production due to the decline in sericea lespedeza production. This condition may be due to the high plant density and production of sericea lespedeza that has occurred at the experimental area for many years. Increased production of the grass species may not be apparent within the first growing season following a fall burn, which may be due to continual or yearly suppression of the grass species production from sericea lespedeza interference. Further monitoring and data collection from the experiment following the second and subsequent growing season growth will be conducted to provide additional results.

Prescribed Burning and Mowing - Seedling Establishment and Population

Dynamics. Results indicate that there were no significant differences in sericea lespedeza or grass dry biomass when comparing plots prior to any treatment applications (Table 2). These comparisons were based primarily on dormant and or senescent plant material from the previous summers growth. However, there were some winter annual grasses within the grass biomass collection. The results of both grass and sericea lespedeza within the experiment area not showing a significant difference was useful information for two important reasons. First, it showed that the experimental area was fairly homogeneous with respect to the growth of both sericea lespedeza and grasses. Secondly, due to the homogeneous nature of plant growth across the experiment, effects from treatments on plant biomass or growth should be more easily differentiated in later plot-to-plot comparative analysis.

Sericea lespedeza biomass and stem counts collected on July 27 resulted in no significant differences between any of the treatments (Table 3). No apparent numerical patterns between the various treatments was detected either. Conclusions derived from this data were seed germination, seedlings, and mature sericea lespedeza were not affected by early-spring burning, mowing, response to bare ground, or response to residues left on the soil surface over the first growing season. The lack of a fire effect or fire-scarification on the seed applied during the first growing season of this experiment does not support the statement made by Anonymous (2000), Ohlenbusch et al. (2001), Stevens (2002), or Vermeire et al. (1998), who stated that fire scarified the seed, which promoted seed germination and seedling establishment. However, this lack of effect does support Ohlenbusch et al. (2001), Stevens (2002), and Vermeire et al. (1998) statements that spring burns have little to no effect on sericea lespedeza due to sericea lespedeza's ability of perennial resprouting. Both the fire and the removal of litter within the mowed treatments produced bare ground, which should increase seed to bare soil contact. However, the results suggest that no significant increase in seedling establishment occurred in areas where more bare ground was established, which does not support the opposing statement made by Griffith (1996). Another conclusion was sericea lespedeza seed, seedlings, or mature plants were not affected by the treatments over the first growing season. It is the author's personal opinion that treatment effects may be noticed during the second or subsequent growing seasons after treatments were applied. Therefore, additional monitoring and data collection following the second growing season's growth is warranted.

There were significant treatment effects on the dry biomass of the grasses (Table 3). The untreated check treatment showed the highest grass biomass value with 5,420 kg/ha, which was significantly different from all other treatments. Within all five treatments where mowing was applied, there was 2,160 to 2,850 kg/ha of dry grass biomass produced. However, there was no significant difference between any of the treatment combinations where mowing was applied. The mowed treatments were not significantly different from any of the burn treatment combinations or the treatment where dispersed seed was the only application. There was no significant difference detected between any of the burn treatment combinations. However, the not burned/not mowed/seed dispersed treatment was 1,990 kg/ha higher in grass biomass compared to the burned/seed dispersed after burn treatment. These results suggest that spring applied burning, mowing and removing the litter, and mowing and retaining the litter, negatively affect the growth and production of native grasses. Other reported scientific literature has shown that native tallgrass prairie species increase production following an early-spring applied burn (Engle and Bidwell 2001; Mitchell et al. 1996). However, both Engle and Bidwell (2001) and Mitchell et al. (1996) concluded that fire effects on quantity and distribution of tallgrass prairie vegetation production can vary based on conditions such as the date of spring burning, year of burn, weather pattern, topography, or location. The lack of a positive growth response of the grasses following the spring burn or mowing applications within this experiment was difficult to address. There were likely many non-apparent factors, such as environment or species-to-species/environment relationships, that were influencing the growth and production of the grasses. No comparisons or conclusions could be made concerning the relationship of sericea lespedeza to grasses due to the lack of treatment effects on sericea lespedeza and the lack of patterned differences between treatments related to the dry biomass of the grasses. Judging the treatment effects and formulating conclusions based on the presented data may be premature. Therefore, additional monitoring and data collection following a second seasons growth is warranted.

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Table 1. Effect of fall 2004 prescribed burn and evaluation of sericea lespedeza and grass population dynamics prior to fall 2005 prescribed burn.[a]

Proposed prescribed burn treatments								March 4, 2005 Dry biomass		August 2, 2005 Dry biomass	
2004	2005[c]			2006			2007				
SEP 20	MAR[b]	SEP 9	OCT 25	APR	SEP	OCT	MAR	Sericea lespedeza	Grass	Sericea lespedeza	Grass
								kg/ha			
Yes	No	No	No	No	No	No	No	1,420 a	220 b	2,810 d	3,140 a
No	Yes	Yes	No	No	No	No	No	2,220 a	1,920 a	5,010 b	3,140 a
Yes	No	No	No	Yes	No	No	No	1,130 a	270 b	3,380 cd	2,570 a
No	No	No	Yes	No	Yes	No	No	2,470 a	2,500 a	4,640 bc	2,560 a
No	No	No	Yes	Yes	No	No	No	—	—	5,050 b	3,750 a
Yes	No	No	Yes	Yes	No	No	Yes	1,220 a	320 b	3,180 d	3,060 a
No	No	No	Yes	Yes	No	Yes	Yes	—	—	7,050 a	2,890 a
No	No	No	No	No	No	No	No	2,650 a	1,950 a	5,220 b	3,830 a

[a] Means within a column followed by the same letter are not significantly different according to Fisher's protected LSD at P = 0.05.

[b] Fuel was insufficient to sustain a prescribed burn; therefore, there was no prescribed burn during the spring of 2005.

[C] Data have not been collected from these burn dates.

Table 2. Evaluation of sericea lespedeza and grass biomass prior to prescribed burn or mowing.[a]

	Dry biomass[b]	
Treatment	Sericea lespedeza	Grass
	kg/ha	
Burned / No seeding	1,140 a	6,150 a
Burned / Seed dispersed prior to burn	1,670 a	5,460 a
Burned / Seed dispersed after burn	1,060 a	3,460 a
No Burn / Not Mowed / Seed dispersed	1,300 a	3,990 a
Mowed (Litter Removed) / No seed dispersed	1,140 a	5,990 a
Mowed (Litter Removed) / Seed dispersed after mowing	530 a	6,150 a
Mowed (Litter Retained) / Seed dispersed prior to mowing	1,960 a	2,730 a
Mowed (Litter Retained) / Seed dispersed after mowing	1,260 a	3,420 a
Mowed (Litter Retained) / No seed dispersed	570 a	5,340 a
Untreated check	2,320 a	4,160 a

[a] Data were collected on March 7, 2005.

[b] Means within a column followed by the same letter are not significantly different according to Fisher's Protected LSD at $P = 0.05$.

Table 3. Effect of sericea lespedeza seed dispersal prior to or after a spring applied prescribed burn or mowing event on the population dynamics of sericea lespedeza and grasses.[a,b]

	Sericea lespedeza		Grass
Treatment	Dry biomass	Stem count	Dry biomass
	kg/ha	stems/ha	kg/ha
Burned / No seed	1,100 a	534,700 a	2,160 bc
Burned / Seed dispersed prior to burn	690 a	380,900 a	3,020 bc
Burned / Seed dispersed after burn	1,020 a	447,800 a	1,390 c
No Burn / Not Mowed / Seed dispersed	700 a	354,200 a	3,380 b
Mowed (Litter Removed) / No seed dispersed	810 a	481,200 a	2,490 bc
Mowed (Litter Removed) / Seed dispersed after mowing	860 a	414,400 a	2,160 bc
Mowed (Litter Retained) / Seed dispersed prior to mowing	1,510 a	594,800 a	2,200 bc
Mowed (Litter Retained) / Seed dispersed after mowing	1,020 a	360,900 a	2,850 bc
Mowed (Litter Retained) / No seed dispersed	900 a	327,500 a	2,770 bc
Untreated check	1,060 a	287,400 a	5,420 a

[a] Data were collected on July 27, 2005.

[b] Means within a column followed by the same letter are not significantly different according to Fisher's Protected LSD at P = 0.05.

VITA

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Title of Study: ADAPTATION, BIOLOGY, AND CONTROL OF SERICEA LESPEDEZA (*Lespedeza cuneata*), AN INVASIVE SPECIES

Pages in Study: 137 Candidate for the Degree of Doctor of Philosophy

Major Field: Crop Science

Scope and Methods of Study: Chapter I: An experiment was conducted to assess the genetic relationship of 17 accessions of sericea lespedeza using DNA amplification fingerprinting (DAF). Chapter II: Field experiments were conducted to measure the relationship of soil chemical and physical variables to zones of sericea lespedeza presence, transitional zone, or sericea lespedeza absent. Chapter III: Field experiments were conducted to measure the effects of 16 weekly interval top-growth removal on sericea lespedeza seedling's ability to become a perennial and regrow. Chapter IV: Field experiments were conducted to measure the monthly root concentrations of total nonstructural carbohydrates, crude protein, fat, ash, and neutral detergent fiber as well as aerial plant structure condensed tannins. Chapter V: Field experiments were conducted to identify and evaluate PPI, PRE, EPOST, and LPOST herbicides for the control of seedling sericea lespedeza. Chapter VI: A field experiment was conducted to measure the effects of mowing as well as prescribed burning on sericea lespedeza control, production, and compositional relationship to grasses.

Findings and Conclusions: Chapter I: DAF indicated that the sericea lespedeza accessions were, overall, genetically similar. However, DAF results distinguished genetic groups within accessions based on the sources coming from breeding programs, commercial seed company sources, sources from states other than Oklahoma, and Oklahoma sources. Chapter II: Sericea lespedeza presence and/or absence was associated with pH, salts, sulfate, iron, magnesium, sodium, and chloride concentrations. Chapter III: Removal of the seedlings top-growth prior to initiation of the branched stem growth stage (about 7-8 week old seedlings) leads to the greatest potential for non-herbicide seedling control or management. Chapter IV: Knowledge pertaining to monthly concentrations of sericea lespedeza root and stem fractions provide information on maturity and production as they relate to plant growth cycles and can be useful in the development of management and control strategies. Chapter V: Results indicate that there were preemergence, early-postemergence, and late-postemergence herbicides that were effective for seedling sericea lespedeza control. Chapter VI: The data suggest that fall burning does effect and control sericea lespedeza to a certain level.

ADVISER'S APPROVAL: Don S. Murray