AN ABSTRACT OF THE THESIS OF

Joan M. Young for the Master of Science Degree in Biology presented on November 30, 2000.

Title : A comparison of *Lespedeza cuneata* (Dumont) G. Don. (sericea lespedeza) with three prairie grasses: *Andropogon gerardi* (Big Bluestem), *Andropogon scoparius* (Little Bluestem), and *Sorghastrum nutans* (Indiangrass).

Abstract approved: 

Lespedeza cuneata was compared to three tall-grass prairie grasses: *Andropogon gerardi*, *Andropogon scoparius*, and *Sorghastrum nutans*. Research involved three major phases: first, to determine the optimum germination conditions for native seed; second, determine the effect of drought stress on the plant compared to the three grasses; and third, determine the effectiveness of different control methods for *Lespedeza cuneata*. Germination of seeds was determined over a range of temperatures and treatments using quartered germination trays to allow the four species to be subjected to the treatment at the same time. The highest percentages of germination were: *Lespedeza cuneata* at 40°C (30%) and a freeze-thaw regime at 30°C (39%); *Andropogon gerardi* at 25°C (72%); *Andropogon scoparius* with Metsulfuron methyl "Escort®" at 30°C

(35%); and *Sorghastrum nutans* with light at 25°C (41%). Xylem pressure experiments with a 26-day drought stress were conducted in quartered pots so available soil moisture to the four species would be the same. *Lespedeza cuneata* appeared to have lower xylem pressure potential and was hardier than the grasses when experiencing water stress, but the test was inconclusive because of laboratory contamination. Control methods involved clipping or burning field plot areas that were infested with *Lespedeza cuneata*. The most effective control method for *Lespedeza cuneata* in reducing stem counts and weights was a treatment of clipping once in June and again in July; the next effective treatment was clipping every 30 days during the season, followed by a treatment of burning twice (spring/fall burn). The control method that was the least effective was a spring burn that seemed to promote the plant. Lespedeza seed germination appears to be promoted by high temperatures and by freezing and thawing, which apparently breaks down the seed coat. The grasses germinate better at cooler temperatures with the seedlings apparently promoted by the herbicide Escort®. *Lespedeza cuneata* appears to tolerate water stress better than the native prairie grasses. And lastly, *Lespedeza cuneata* appears to be repressed by severe clipping twice (once in June and again in July) and promoted by the traditional spring burning of the Flint Hills.

A comparison of *Lespedeza cuneata* (sericea lespedeza) with three prairie grasses: *Andropogon gerardi* (Big Bluestem), *Andropogon scoparius* (Little Bluestem), and *Sorghastrum nutans* (Indiangrass).

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CHAPTER 1 -- INTRODUCTION

Lespedeza cuneata -- Superior Advantage in the Tall-Grass Prairie

Genus: *Lespedeza cuneata* (Dumont) G. Don. (common name, sericea lespedeza)

Family: Fabaceae (Leguminosae)

Class: Magnoliopsida (Dicot)

Division: Magnoliophyta (Flowers Perfect)

Preface

Lespedeza cuneata has become a high-risk invasive species of the tall-grass prairie. The plant can overtake several acres of pasture within a few years; given ten years, whole sections of a pasture can be infested with ramet (primary stem emerging from a colonial plant) numbers rising exponentially from the amount of seed it produces. Its adaptability to our soils and environment is obvious. The plant is listed in the state of Kansas, as of July 1, 2000, as a state-wide noxious weed. This is reported to be one of the first plants listed as both a crop and a noxious weed by the federal government and the state of Kansas, respectively. In order to better understand the plant's means of survival, this thesis will discuss *Lespedeza cuneata* biology and some of its physiology, with special interest in the seed and seedling requirements.

History

The genus name (*Lespedeza*) was originated by the French botanist Michaux to honor the Spanish governor of Florida, Vicente Manuel de Céspedes (governing

c. 1784-1790; also spelled Céspedez depending upon the language). However, when Michaux's Flora Boreali-Americana was published (1802), the "C" was misinterpreted to be an "L" and was published in error "Lespedeza" instead of "Cespedes" (Ricker, 1934; Steam, 1992; and personal communication from The New York Botanical Garden, 1998).

Two apparently unsuccessful importations of the seed from Asia were in 1896 by the North Carolina Experiment Station and in 1900 by the U.S. Department of Agriculture. In 1924, seed was again brought in to produce a forage crop and was recognized to be a successful venture as recorded in the Agricultural Extension Service Bulletin No. 300 (Dodd *et al.*, 1948). *Lespedeza cuneata* was planted in Kansas in the 1930s as a conservation/erosion agent (McGregor *et al.*, 1986).

Since then, several varieties of *Lespedeza cuneata* [with an earlier scientific name of *Lespedeza sericea* (Thunb.) Benth., now invalid, and a common name of sericea lespedeza] have been developed as a perennial hay crop (Guernsey, 1970). The more notable varieties are:

"Common" lespedeza was planted for many years after its introduction into the United States. This apparently is the variety that was introduced into Kansas for wildlife habitat and has since become invasive.

'Arlington' and 'Appalow' (prostrate, minimum maintenance) was developed by the Soil Conservation Service of the U.S. Department of Agriculture.

'Serala' (fine-stemmed, shorter, denser, high-tannin), 'Interstate' (tall, denser, high-tannin), and 'Au Lotan' (tall, fine-stemmed, low-tannin) were developed and released by Auburn University in Alabama. It is interesting to note the high-tannin variety 'Interstate' was a mutant developed and released as a

cultivar with the aid of the Atomic Energy Commission at Oak Ridge, Tennessee (Mosjidis, 1986).

There are now over 87 varieties that have been developed, mostly for decreased tannins, increased palatability and digestion by cattle, or for increased establishment on eroded soils (Donnelly, 1979; Donnelly and Anthony, 1983). This perennial plant is not to be confused with the annual varieties of lespedeza or our native perennial lespedezas.

Review

Climate/Region of Adaptation

Lespedeza cuneata occurs from the Atlantic states westward to Texas, Oklahoma, and Kansas, and as far north as the southern half of Illinois, Indiana, and Ohio. It has recently been discovered in extreme western Kansas counties on CRP land and in the southeastern corner of Nebraska (Scott, 1995; 1998; and personal communication, 2000). (See Figure 1.) Rainfall amounts generally must be 30 to 35 inches annually and be interspersed throughout the year (Guernsey, 1970). This species dies back to the caudex upon the first heavy frost and is dormant for the winter. Young seedlings are cold-hardy and can withstand heavy freezes in the two-leaf stage that would wilt the tender shoots emerging from an adult plant (Guernsey, 1970). *Lespedeza cuneata* is able to withstand periods of drought; the water potential can drop to half that of alfalfa when the plants are subjected to the same treatment (Brown and Radcliffe, 1986). In order to understand the capability of lespedeza to withstand seasonal drought, this author subjected *Lespedeza cuneata* and three prairie grasses (*Andropogon gerardi*, *Andropogon scoparius*, and *Sorghastrum nutans*) to a drought treatment. (Refer to the Appendix; Preliminary Investigations.)

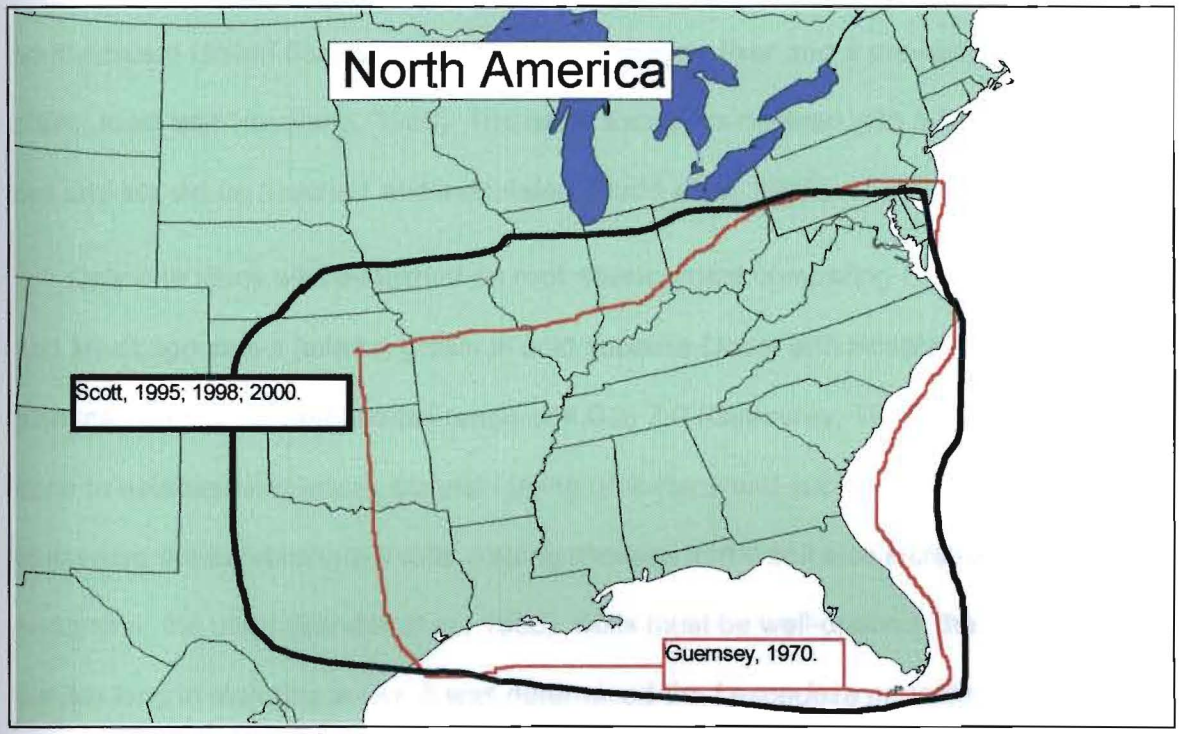

Figure 1. *Lespedeza cuneata* range of adaptation according to Guernsey, 1970, and 25-30 years later by Scott, 1995, 1998, and 2000.

Soils/Root Development

Lespedeza cuneata has been used extensively for reclamation of mine spoils, eroded soils, and poor soils. It is tolerant of the leached, high-acid/aluminum soils of the southeastern United States and is used as a nitrogen fixer and a pre-climax conditioner plant (Joost and Hoveland, 1986). The seed should be covered with a light amount of soil and should be mulched and inoculated (Dodd *et al.*, 1948).

Only one study was published on root development comparing *Lespedeza cuneata* and *Medicago sativa* (alfalfa) grown in acid subsoils (Joost and Hoveland, 1986). The plant can be established in a pH range of 4.0 to 7.0 (Guernsey, 1970). This testing was done to establish lespedeza stands. Liming of surface and sub-surface soils was done to improve the establishment rate. Adding nitrogen to the soil also increases the success of the plant (Bender *et al.*, 1985). Soils must be well-drained; the plant can not survive long in standing water. It was determined the *Lespedeza cuneata* root system developed sooner and was more tolerant of unlimed soils than was alfalfa. Roots of *Lespedeza cuneata* can penetrate up to 120 cm (Joost and Hoveland, 1986); however, grass roots have also been found to occupy the same zone (Anderson, 1965). More root biomass than crown biomass is developed during the first year of growth in lespedeza, but little is known about initial root growth of the lespedeza and the prairie grasses regarding initial competition for resources. Root development studies were attempted by this author to determine if some correlation existed between the root systems of *Lespedeza cuneata* and three prairie grasses. (Refer to the Appendix; Preliminary Investigations.)

Lespedeza cuneata produces up to two tons of leaf litter per acre per year (Dodd *et al.*, 1948; Guerney, 1970). The litter prevents soil runoff from rain and makes the soil

more porous through its deep tap roots. The plant is often recommended as a field border to reduce soil erosion (Guerney, 1970). The border should be mowed three to five weeks before the main crop is harvested to allow regrowth for winter survival. The seed can be planted at any time of the year for roadsides or for soil reclamation. The area should be fertilized, limed, and mulched. Mowing should only be performed in the fall after the seed reaches maturity (Guerney, 1970).

Seedling Emergence

To develop improved *Lespedeza cuneata* varieties that emerge and establish sooner before seasonal droughts, seedling emergence at different photoperiods and temperatures was tested by Mosjidis (1990) and Qiu *et al.* (1995) using mechanically-scarified seeds of previously-developed varieties of *Lespedeza cuneata*. Temperature exhibited greater control over germination than photoperiod. Interestingly, Mosjidis' (1990) germination percentages at low temperatures were approximately 42% at 13°C and increased to approximately 78% at 19°C. Qiu *et al.* (1995) found highest germinations of 90% at 25-30°C. Germination trials in this thesis' research, with unscarified seed, in no way produced the high germination rates reported by Mosjidis (1990) and Qui *et al.* (1995); however, the trend of lower germination at lower temperatures was confirmed. *Lespedeza cuneata* seedlings grow more rapidly (height) at warmer temperatures (Mosjidis, 1990) as long as moisture is adequate. Height growth also increases with increased photoperiods up to 14 hours, but the rate of growth decreases at a 15-hour photoperiod.

The plant emerges in late April, is tender until it reaches about 15 inches tall, and then becomes increasingly fibrous. Well-pulverized soil is required for establishment (Guernsey, 1970). Prior use of an herbicide is desirable to avoid competition from other

weedy species. It is not necessary to cover the seed unless the soils are sandy or prone to severe drying, indicating that the seed germinates well without a soil cover. An inoculant is also desirable (Guernsey, 1970; Joost and Hoveland, 1986). Heavy seeding rates produce a thick stand that can be used the second year after planting. Dense seedling stands can also result from the seeds dropped from established plants. Seedling growth ranges from a few inches to three feet the first year, depending upon the conditions (Guernsey, 1970).

To test the effect of inoculant on the establishment of *Lespedeza cuneata*, the lespedeza was planted, in conjunction with *Fesuca arundinacea*, in mine spoils with a top surfacing of forest topsoil (in order to obtain an established seedbank) (Wade, 1989). In one treatment, the forest topsoil was fumigated to remove the effects of microflora. The lespedeza was seeded at one-half the recommended rate in topsoil that held microflora and was successfully established, but failed to be significantly established in plots seeded at twice the rate in soil in which the microflora had been destroyed by fumigation. The author concluded that the native microflora inoculum was a necessary component for establishment.

Lespedeza as Forage

All lespedezas, whether annuals or perennials, are considered inferior forage (lower in protein) to cool-season grasses, warm-season grasses, alfalfa, and clovers. As noted before, the lespedezas do excel in pastures that are low in fertility or eroded; however, liming and fertilizing are highly recommended for establishment. If adequate lime and fertilizer are used, the need for planting lespedeza is reduced and clovers or alfalfa should be planted instead (Dodd *et al.*, 1948). The recommended seeding rate is 15 pounds per acre with grass or 20-30 pounds per acre alone, and the seed should be

inoculated with a nitrogen-fixing bacteria suitable for lespedeza. The plant's large root system is capable of taking in large amounts of nutrients which become available to other plants only upon the death of the lespedeza. If limed and fertilized, cropping can be done earlier, and the plant can withstand competition from *Andropogon virginicus* (broomsedge bluestem) and other undesirable plants (Guernsey, 1970). Crabgrass can grow thick enough to choke out *Lespedeza cuneata*. Again the use of pre-emergence herbicides is recommended.

Dodd *et al.* (1948) stated *Lespedeza cuneata* can produce two to two and one-half tons of hay per acre when mowed only once; however, 20 years later, Guernsey (1970) indicated four tons of hay per acre can be acquired when the acreage is mowed several times, depending upon the stand. This suggests increasing knowledge about the plant and use of improved varieties. The plant should be hayed when 12 to 15 inches in height for best livestock palatability, protein content, and lower tannin content. Tannins increase as the plant approaches maturity. The plant should be mowed to a height of over three inches; mowing too short can severely damage the stand, which suggests how it might be controlled. Also, if the stand is mowed too late in the fall for the plant to conserve nutrients, damage can occur. On poor soils, one hay cutting per year is all that can be supported or tolerated. The hay cures very rapidly and can usually be baled after six hours if drying conditions are right. Care must be taken to bale the hay before total moisture is gone or the leaves will shatter. If a mixture of grass and lespedeza is being hayed, this mixture will be a problem, with the grass hay drying too slowly and the lespedeza hay leaves shattering.

Pastures

Lespedeza cuneata was first used in the southeastern states for pasture in the 1940s. Prior to this time, farmers did not think that livestock would graze the green plants and it was necessary to fence the cattle to force grazing. Grazing is now being promoted because the plant has deep roots and can withstand periods of drought. It is recommended to graze the plants early and to let the plant grow faster than it is grazed in order to have the root reserves replenished (Guernsey, 1970). Grazing can start when the plant is six inches tall, but livestock must be removed when there is danger of grazing closer than three inches. If the plants grow too tall, the pasture should be mowed to promote new stems. If a pasture mixture is desired, lespedeza should be planted with a cool-season grass, such as tall fescue (*Festuca arundinacea*). Thus, the grass can be grazed initially and the lespedeza later as the climate warms and the grass goes dormant. Either the grass or the lespedeza can be established first and the other overseeded later into the stand. This suggests that established fescue provides a niche for the establishment of the lespedeza seedlings. Brome (*Bromus inermis*) is likely to respond in a similar manner. It is recommended that lespedeza seed be hulled and scarified. This suggests that the lespedeza is hardy enough to withstand competition from the fescue, although a warning is given by Guernsey (1970) to watch for overcrowding of the lespedeza by the fescue. It is suggested not to let the fescue set seed to avoid crowding the lespedeza and to not graze during the first year of establishment. Periodic liming and fertilizing of established pastures is again recommended.

Stitt and Clarke (1941, as cited in Guernsey, 1970) found the tannin content to increase in unmowed lespedeza up to July, as compared to grazed or mowed

lespedeza. Donnelly and Anthony (1983) indicated the tannin content of the plant increased with maturity without regard to clipping or mowing. Tannin content rises in summer [August (155 g kg^{-1})] but starts to fall in autumn [October (60 g kg^{-1})] as the leaves mature (Windham *et al.*, 1988). Digestion of other proteins, such as those in grasses, is diminished when fresh lespedeza is eaten by some classes of livestock as the proteins bind with the tannins (Lyford *et al.*, 1967 as cited by Fales, 1984; Peterson and Hill, 1991; Peterson *et al.*, 1991; Terrill *et al.*, 1989). The tannins affect the enzymes that break down cellulose. To avoid affecting the rumen microflora and to increase digestibility of lespedeza cellulose, it is again suggested that nitrogen-containing supplements that have an affinity for the tannins be fed to the livestock to restore the digestive activity for improved animal performance.

Nutrition

Common *Lespedeza cuneata* and most developed varieties have high quantities of tannins. A dominant allele at one locus is primarily responsible for the tannins, and the effect of this allele has been diminished in some of the varieties (Donnelly and Anthony, 1983). Tannin levels increase throughout the growing season and are concentrated both in the leaves and the stems, with the higher quantities in the leaves (Mosjidis *et al.*, 1990). The stems are mostly indigestible fiber. Both of these qualities can make lespedeza unpalatable to cattle and other grazing animals (Fales, 1984). Varieties have been developed for increased digestible dry matter. It is also suggested to add other proteins to act as a dietary supplement to the lespedeza forage to aid in animal performance. When lespedeza is field dried, tannin levels decrease, thus increasing the palatability and digestion, but indigestible high fiber still plays a role

because animals selectively seek out the leaves of the plants as opposed to the stems, even as hay.

Feeding trials on 99 steers at the North Carolina Agricultural Experiment Station (Guernsey, 1970) compared a ration of crushed corn and cottonseed meal (normal meal) with a ration of alfalfa meal or *Lespedeza cuneata* meal. The daily weight gain for a trial of seventy days was greatest for the normal ration, followed next by the lespedeza group, and lastly the alfalfa group. Carcass grade was highest for the alfalfa group, followed by the lespedeza group, and finally by the normal ration group; however, it was noted that little difference existed between the groups.

Researchers at the Sandhill Experiment Station in South Carolina used dairy heifers and grazed them on lespedeza pastures. The heifers were turned out when the lespedeza was nine inches tall and the trial lasted five months; the average daily gain was 1.19 pounds and the total gain per acre was 357 pounds (Guernsey, 1970). There was no control trial nor did the study suggest that this was above or below the norm.

Residues

As *Lespedeza cuneata* produces up to two tons of leaf litter per acre per year (Guernsey, 1970), the residues from the tannins become a concern. Nitrogen released from the plants to the soil benefits crops grown following the destruction of a field of lespedeza. The nitrogen produced by the lespedeza is used by soil micro-organisms that change the vegetative material to soil organic material. *Lespedeza cuneata* was planted in a previous corn field at the West Tennessee Soil Conservation Station and allowed to stand for hay for three years. In the fourth year, corn was planted and the production increased fifty percent and finally dropped to the original rate nine years later. Authors of this study did not state if the lespedeza stand was established with the

help of an inoculant or lime and fertilizer for the purpose of a strong hay field. As this field was hayed, it is assumed that most leaf and stem litter would have been removed from the site so the effects of accumulated tannins would have been minimal, and increased corn production would have resulted from stored nitrogen in the lespedeza root system.

Lespedeza cuneata residues have been shown to initially inhibit height growth of corn (*Zea mays*) planted in minimum tillage plots. The lespedeza leaves only decreased corn germination if the corn was planted immediately in soil with fresh leaf residues. After several weeks at 25-30°C, the leaves decompose and nitrogen is released. It was determined that the stems cause the most stunted effects. However, partially decomposed leaves were shown to promote the growth of corn, probably because of the accumulated nitrogen in the leaves (Langdale and Giddens, 1967), which more than compensated for the effects of the stem residues. Langdale and Giddens' (1967) research indicated lespedeza stems have higher concentrations of the phytoxic compounds although Mosjidis *et al.* (1990) indicated that tannin polyphenols were located in both stems and leaves.

Three published papers were found examining the effects of *Lespedeza cuneata* residues on both cool- and warm-season grasses (Kalburtji and Mosjidis, 1992; 1993a; 1993b). The grasses tested were: warm-season -- bermudagrass (*Cynodon dactylon*) and bahiagrass (*Paspalum notatum*); cool-season -- tall fescue (*Festuca arundinacea*), rye (*Secale cereale*), and ryegrass (*Lolium multiflorum*). Germination of the grass seed was not affected but root development was reduced.

There was a significant reduction in grass radicle (embryonic root of a germinating seed) length and total biomass in the above treatments. Soil extracts taken from

locations where *Lespedeza cuneata* was found four years prior were shown to still contain plant growth inhibitors. Nitrogen fertilization was recommended to offset the stunting effects of the lespedeza residues. This study seems to negate the nitrogen-fixation qualities of the plant when in a predominately grass community.

Germination studies were attempted by this author to determine the effects of *Lespedeza cuneata* residues on the germination of native prairie grass seeds. Fresh *Lespedeza cuneata* leaves were slurried and used as an imbibing agent for seeds of the lespedeza and the three studied prairie grasses. (Refer to the Materials and Methods section.)

Seed Production

Although very low, seed production can occur even after two hay cuttings. The production of seed is governed by the amount of moisture received during the growing season of the plant. Seed yields are better on fertilized lespedeza than unfertilized plantings. In some yearly conditions, the seed remains on the plant until frost; other conditions cause the seed to dehisce as soon as the seed is mature. Between 300 and 600 pounds of hulled seed can be produced per acre. Each pound has approximately 350,000 seeds (Guernsey, 1970). *Lespedeza cuneata* seed retains its ability to germinate for three years under controlled climate conditions (Mosjidis, 1990).

Weeds/Pests/Diseases

Lespedeza cuneata has very few problems with weeds or pests. It is noted to watch for overcrowding when tall fescue is planted in conjunction with the plant, indicating that dense weedy species could be a problem. Weedy species that should be controlled are *Andropogon virginicus* (broomsedge bluestem), *Cynodon dactlon*

bermuda grass), *Sorghum halepense* (Johnson grass), *Agropyron triticeum* (quackgrass), and *Cuscuta coryli* (dodder). Herbicides are the recommended controls. The plant has very few insect problems. The plant is also resistant to diseases except cotton root rot and should not be planted where this disease has been prevalent (Guernsey, 1970). Recently, a webworm (*Tetralopha scorealis*) has shown promise as a biological control (Scott, 1995; Eddy, personal communication, 2000).

Control

Herbicides. Control of established *Lespedeza cuneata* plants in perennial pastures is difficult and the most common method is the use of herbicides postemergence or prior to flowering. There is little published research on this subject. In one study by Altom *et al.* (1992) in Oklahoma, three pastures were selected for treatment; all were unfertilized, two were grazed, and all had greater than 250 ramets per square meter. The plants were spot-sprayed to obtain a thorough coverage. Spraying was done in mid-May/early June when the plants were actively growing. Stem heights and densities were recorded both prior to spraying and one year later. A nonionic surfactant was used only on two spray mixtures, undoubtedly per the manufacturers' recommendations, but the researchers noted the surfactant made no difference in the amount of control. Stem counts were reduced by Triclopyr (Remedy) 94%, Triclopyr plus picloram (Tordon) 99%, and Fluroxypyr (Starance) 99%, one year after treatment. Picloram and also Metsulfuron (Ally/Escort) stem reduction rates were significant but still with an average of 190 stems/m^2. In a Kansas study by Fick (1990), plants were sprayed in June and during early flowering using similar herbicides as listed in the Altom study. The time of spraying was not significant and the herbicide with the most control was again Triclopyr. Picloram and 2,4-D did not offer effective control.

Metsulfuron appears to have had mixed results. In the Oklahoma study, 1988 stem counts were reduced only 46% using a light (0.018 kg/ha) spray rate and 67% using a heavy (0.035 kg/ha) spray rate. However, in 1989, stem counts were reduced by 82% using the light spray rate and 97% using the heavy spray rate. It was concluded by the authors of the Oklahoma study that variation in results from the spray rate to the specific location required more research. The Kansas study by Fick (1990) exhibited 90% control one year later using Metsulfuron at the same heavier spray rate as in the Oklahoma study. In a follow-up study of Metsulfuron in 1996 by Dudley and Fick (1996), a spray rate of 0.014 kg/ha offered little control the same year of application.

The 2,4-D treatment results were not significantly different than the control results. Treatments with 2,4-D or 2,2-D to eliminate weed competition with lespedeza seedlings are routinely used in lespedeza crop establishments in the south (Hoveland *et al.*, 1971; Wehtje *et al.*, 1999). Also 2,2-D does not reduce the seedling stands and is an effective weed control. Use of 2,4-D reduces stem count and seed production, and imposes some injury to the seedlings (first and second year plants), but is within acceptable limits when compared to the amount of weed control exhibited.

Mowing. Mowing, in conjunction with postemergence, pre-flowering, or during flowering herbicide application, has met with some success. Two Kansas studies by Dudley and Fick (1996) indicated early season mowing plus an application of Triclopyr seven weeks later resulted in a 72% reduction of stem counts one year after treatment. Mowing alone late in the season reduced stem counts by 50%.

Mowing for three years in May and September on planted fescue/lespedeza pastures in Georgia had no negative or positive impact on the lespedeza density but favored the fescue and prevented secondary succession weedy species (Brock, 1975).

These pastures were limed, fertilized, and grazed prior to mowing. In some plots, the lespedeza had disappeared; in the other plots, lespedeza flourished with no correlation to soil treatment. No mention was made regarding the type of mowing or the stubble height in any of these studies.

Clipping and Forage Production. Stands of 'Serala' *Lespedeza cuneata* (a fine-stemmed, high-tannin variety) are planted in the Southeastern United States for forage and thus are frequently grazed or hayed. To determine the greatest amount of forage that could be produced from a stand, a three-year study on the effects of the time and amount of clipping for a particular treatment was conducted. Clipping to various stubble heights and varying the timing of the clipping reduces forage and seed production (Hoveland and Anthony, 1974). All plots were previously limed and fertilized. Cuttings were done at three, six, or nine-week intervals beginning in late April with the total harvest terminating in June, August, or October; the amount of forage produced was tabulated at that time. Stubble heights were 4 or 10 cm. Initial stem counts were taken each year in April and the amount of seed production calculated at year end. More forage was obtained when cutting at nine-week intervals until August or October, indicating *Lespedeza cuneata* responded to haying by producing more shoots. Forage was reduced when cutting every three or six weeks until August or October. Results of clipping to the 4 cm height were not significantly different than clipping to the 10 cm height when clipped every nine weeks; however, forage was significantly reduced when clipped to 4 cm every three to six weeks. Initial shoot growth was more evident in the plant when it was cut frequently, but final recovery of the plant's biomass was increased when less frequent cuttings were done. The authors concluded that *Lespedeza cuneata* should be managed similar to alfalfa with cuttings at the 10 cm

ight and only twice in a season. Grazing should be rotational with care to maintain at ast a 10 cm height.

Clipping and Carbohydrate Reserves. After harvest had terminated in Hoveland nd Anthony's study (1974), plants in the particular study plot were dug up, with the oot ball and surrounding soil intact, and grown in the laboratory in darkness to etermine the amount of root reserves remaining to produce shoot regrowth. Cutting rminated in October resulted in less root reserves than harvest terminating in June. evere and frequent clipping also reduced the plants' vigor.

Clipping and Seed Production. Irrigation and clipping on lespedeza plots in the outheast was studied to determine the effect of clipping on seed production with the esire to increase chasmogamous (open-pollinated) seed (Donnelly and Patterson, 969). Plants from chasmogamous seed reportedly produce more forage. Eighteen arieties of *Lespedeza cuneata* were used in the study but were not named, so it could ot be determined whether the native Asian (common) Lespedeza was included. The lipping treatments were to a height of 7.76 cm once in early June and also after the lants attained an average height of 51 cm; both clipping treatments reduced seed roduction. Clipping in irrigated plots also reduced seed production because the plants emained in a vegetative state longer. Clipping at 4 cm or 10 cm every three, six, or ine weeks with the harvest terminating in June, August, or October in Hoveland and Anthony's research (1974) resulted in lowest seed production at the 4 cm stubble eight and cutting at three-week intervals.

Clipping and Ramet Counts. Ramet counts were not reduced when clipping to only 10 cm for three years but the count began to drop by the third year when clipped to 4 cm at six-week intervals. Counts were significantly reduced in the second year when

clipped to 4 cm at three-week intervals. The terminating harvest date had no effect on ramet counts. This would indicate that to reduce the stand's vigor, one could severely clip to the 4 cm level and at three-week intervals at any time during the active growing period of the plant as long as at least two total clippings were conducted.

Lespedeza cuneata does not respond well to frequent and drastic cutting; biomass, seed, number of ramets, and root reserves were reduced. Although the authors concluded this would not eliminate the plants, it might reduce the vigor of the stand to allow invasion of secondary weedy species. To follow up on this research, part of this thesis study was designed to determine if the plant could be severely reduced by drastic clipping every 30 days through the growing year until the control plants began to go dormant.

Burning. Burning, as a control method, was only briefly mentioned by Dudley and Fick (1996). Their study indicated no significant reduction in the lespedeza but did not indicate the time of the burn, leaving the reader to speculate that the burn was conducted during the traditional spring pasture burning season. To follow up on this aspect, another part of my study was designed to determine if the plant could be severely reduced by burning either once or twice during the growing year.

Timing of pasture burning seems highly important in terms of the overall health of Flinthills pastures and its tall-grass species. Anderson's (1965) research on the soil moisture in the upper five feet of soil throughout the year indicated range plants actively take up soil moisture during periods of heaviest rainfall in the spring, and overall soil moisture is depleted during the same period. Soil moisture levels are replenished during fall and winter months when rainfall amounts are lower. Anderson's study (1968) on the Flinthills region near Manhattan, Kansas, where the average

annual precipitation is 32 inches, involved burning in winter, early-spring, mid-spring, and in late-spring. In areas where much mulch has accumulated, burning once can increase the production of grasses (Hulbert, 1969; Rice and Parenti, 1978) by removing deep litter. Removal of small amounts of accumulated litter has little or no effect. Repeated burning with no grazing over a thirty-year period (Anderson, 1965) significantly reduced forage without regard to the time of the burn, but burning in late spring produced more forage because winter burning reduced soil moisture levels the greatest. Burning pastures increased beef yield but did not reduce the quality of the forage (weedy species do not invade). However, the amount of forage or stems per meter was reduced over time in this area of Kansas. Wetter or drier regions have produced either more or significantly less yearly forage after repeated burnings.

During dry years, the soil moisture levels still drop because of the requirements of the plants; thus, the forage should be grazed accordingly, and if burned, should be burned in late spring because burning increases soil temperature by three to seven degrees Fahrenheit (Anderson, 1965; Hulbert, 1969; Rice and Parenti, 1978; Young, 1993, undergraduate research). Increased soil temperatures promote plant growth and, at that time, start the depletion of soil moisture even up to depths at five feet. Burning early in spring stimulates plant growth, causing it to take up moisture. In seasons of low precipitation, the plants might experience drought later in the same season when rainfall is lessened. Burning reduces the soil moisture in the upper layers of soil even if the range is not grazed (Anderson, 1965; Hulbert, 1969; Rice and Parenti, 1978). The mulch remaining from not burning prevents runoff and reduces evaporation even when adequate forage is present. One cannot predict an upcoming dry year; however, in the year following an unusually dry year, the pasture can be protected from further water stress and perhaps be replenished by not burning.

Research

There is no recommended control of *Lespedeza cuneata,* other than herbicide spraying, and the best treatment has not yet been determined. The research objectives of this thesis were:

1. To evaluate selected (suggested) plant control methods.
2. To determine the optimum germination conditions as well as the worst germination conditions for *Lespedeza cuneata* native seed (seed collected locally) when compared to : *Andropogon gerardi* (Big Bluestem), *Andropogon scoparius* (Little Bluestem), and *Sorghastrum nutans* (Indiangrass).
3. To determine the root depth and volume, and the drought tolerance when compared to the three dominant native grass species in the tall-grass prairie: *Andropogon gerardi* (Big Bluestem), *Andropogon scoparius* (Little Bluestem), and *Sorghastrum nutans* (Indiangrass). (Refer to the Appendix; Preliminary Investigations.)

CHAPTER 2 -- MATERIALS AND METHODS

Introduction -- Plant Control Methods

Several methods of plant control have been researched, as described in the Introduction of this thesis, to perhaps reduce the vigor of *Lespedeza cuneata* (number of ramets per plant or the amount of biomass produced in a season). This phase of my research used some of these methods to determine the response of *Lespedeza cuneata* to practices already performed by ranchers, often on a yearly basis.

Previous researchers, mentioned in the Introduction, only noted 'stem counts', which may or may not have included secondary branching at a noted height. The term 'ramet' will be used throughout this phase of my research because only the primary stems emerging from the root crown, and not secondary or branching stems, were counted.

Plant Control Treatments

Lespedeza cuneata, in permanent plots, was subjected to five different plant control treatments as listed in Table 1. Figure 2 is a grid view of the plots and treatments. Fifty one-meter-square plots were laid out, and ten each were randomly assigned to one of the five treatments. The plots were permanently staked using steel posts and the boundaries of each plot marked by twine to monitor each grouping because the treatments would only be conducted for one year.

The treatment areas were in a pasture in south Lyon County (the W ½ SE ¼ of Section 26, Township 21, Range 12 East of the 6th P.M.). The soil type at the study sites is Martin silty clay loam (U.S. Depart. of Agriculture, 1981). After randomly

Table 1. Plant Control Treatments

1. Control -- no treatment.
2. Burn 1X -- burned once (March 30, 1997).
3. Burn 2X -- burned March 30, 1997; burned August 20, 1997.
4. Clip Jun/Jly – Clip in mid-June and mid-July (normal hay harvest) to a height of 5 cm.
5. Clip Every 30D, Jun-Sept – Clip in mid-June and every 30 days thereafter to a height of 5 cm until Control treatment leaf abscission.

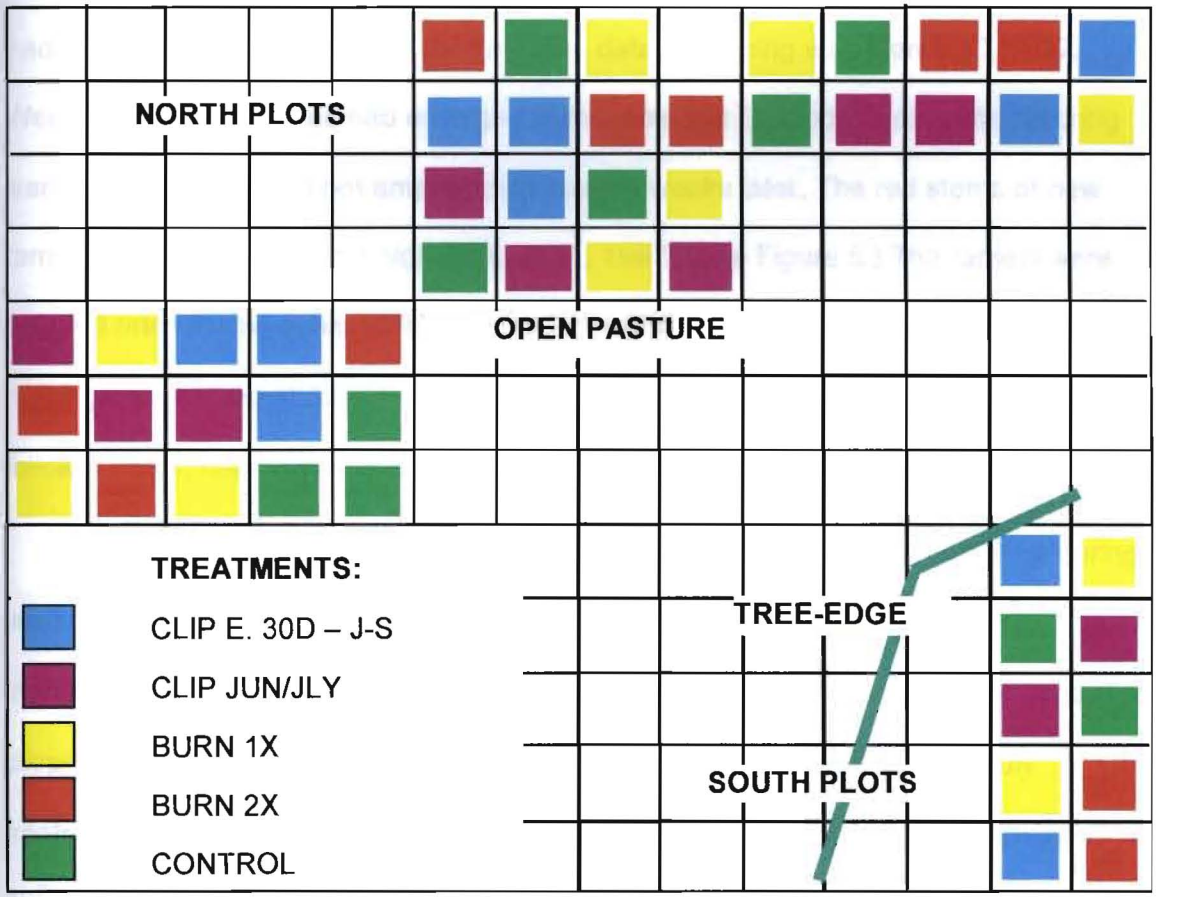

Figure 2. Map view of permanent plots for plant control treatments. Plots were laid out in a grid and randomly assigned a treatment.

choosing four major plot areas where large populations of *Lespedeza cuneata* existed (one area being under an tree edge effect and the other three areas located in open pasture). (See Figures 3 and 4 for views of the plots.) Other species within the plant control treatment plots were identified and listed in Table 2. A timeline of treatment procedures is listed in Table 3.

Control. Ramet counts were taken in mid-June. The ramets were clipped in the fall, just prior to leaf abcission, and the clippings were dried at 32°C for 10 days and weighed.

Burn 1X Treatment. The Burn 1X (burn one time) treatment consisted of the traditional spring burning of the pasture. The date of burning was March 30, 1997. Weedy broadleaf species had emerged at that time but *Lespedeza cuneata*, favoring warm temperatures, did not emerge until several weeks later. The red stems of new ramets were 2.5 cm to 5 cm high on April 21, 1997. (See Figure 5.) The ramets were counted once in mid-June, 1997 and clipped and weighed in October, 1997. The clippings were dried at 32°C for 10 days and weighed. Comparison data were taken the following year; counts in mid-June and weights in the fall.

Clipping Treatments. All ramets in all plot treatments were counted once during June 7th through June 19th, 1997. If the particular plot was assigned a clipping treatment, the ramets were counted and clipped to a 5-cm height at the same time. The clippings were then dried at 32°C for 10 days and weighed. The Clip June/July treatment consisted of clipping the ramets to a 5 cm height in June 7th through June 19th and thirty days later in mid-July at the time of the traditional haying date for this area (July 19th through July 26th, 1997). The Clip Every 30D June–Sept. treatment started from June 7th through June 19th and continued once every 30 days until the

Table 2. Plant control treatments -- species found in treatment plots.

Species	Common Name
Andropogon gerardi	Big Bluestem
Andropogon scoparius	Little Bluestem
Sorghastrum nutans	Indiangrass
Panicum capillare	Witch Grass
Panicum scribneriánum	Scribner's Panicum
Bromus inermis	Brome
Tridens flávus	Purple Top
Sporobolus heterolepis	Drop Seed
Chloris verticillata	Windmill Grass
Potentilla	Cinquefoil
Oxalis	Wood Sorrel
Solanum carolinense	Horse Nettle
Ambrosia artemislifolia	Common Ragweed
Thlaspi	Pennycress
Symphoricarpos orbiculatus	Buckbrush
Cornus drummondii	Rough-leaved Dogwood
Lespedeza violacea	Violet Bush Clover

Table 3. Timeline for Plant Control Treatments.

March 30, 1997	Burn 1X.
April 21, 1997	Ramets emerged; 2.5-5 cm high.
June 7-19, 1997	Count ramets in all plots. Clip ramets in Clip Jun/Jly and Clip Every 30D, Jun-Sept treatments. Weigh biomass after drying.
July 19-26, 1997	Last clip on Clip Jun/Jly treatment and second clip on Clip Every 30D, Jun-Sept treatment.
August 23-24,1997	Burn 2X.
August – Sept.	Continue Clip Every 30D, Jun-Sept treatment.
October 18-19,1997	Plants dormant. Clip Control, Burn 1X, and Burn 2X treatments. Weigh Control and Burn 1X biomass after drying.
June, 1998	Count ramets in all plots. Clip ramets in Clip Jun/Jly and Clip Every 30D, Jun-Sept treatments. Weigh biomass after drying.
Fall, 1998	Clip Control and Burn 1X. Weigh biomass after drying.

Figure 3. Plant control treatments -- location of south plots in a tree edge effect.

Figure 4. Plant control treatments -- location of all north plots in open pasture.

plants began to go dormant under cooler temperatures and a decreasing photoperiod in the fall. The last clipping on this treatment was done on September 14th, 1997 because thirty days later in October, there was little regrowth to clip. (See Figures 6, 7, and 8 for views of the clipping treatments.) Comparison counts and weights were taken the following year in mid-June.

Burn 2X Treatment. The Burn 2X (burn two times) treatment consisted of the spring pasture burn as before on the Burn 1X treatment. The ramets were counted once in mid-June, 1997. A second burn was conducted on August 23rd and 24th, 1997. The plots were burned using a burn box, one meter square by 0.9 m high and of 16-gauge metal. The metal box could be easily moved and aligned on all four edges of the permanent plot assigned the burning treatment. (See Figures 9, 10, and 11 for views of the burning treatment.) A propane torch was used to burn any areas within the plot that appeared not significantly burned but, because of high summer temperatures, one match was adequate for an intense blaze. Several hand sprayers filled with water were kept on hand to prevent the blaze from creeping under the bottom of the box and for safety reasons. No weight data could be taken on these plots as the main biomass was consumed during the second burn. Comparison counts were taken the following year in mid-June.

The remaining 30 quadrants that were either a control or a burn treatment were clipped on October 18th and 19th, 1997 in order to prevent seed dehiscence. The plants had lost leaves at that time, with the exception of the quadrants in the tree-edge effect, but seeds were still present.

Ramet Growth -- Plant Control Treatments

Lespedeza cuneata emerged vegetatively in April and the red stalks were observed to be 2.5 to 5 cm high on April 21, 1997. (See Figure 5.) On June 12, 1997, the plant was 15 to 36 cm high. (See Figure 12.) From June 6th through 19th, I began the clipping treatments in order to fall one month earlier than the traditional haying dates of mid-July in this area. Height measurements were taken at the first clipping in June, 1997 to determine the amount of growth of the plant at the time of clip. (See Figure 13.) Of the plots randomly chosen for treatment, the closest neighboring Control plot or Burn 1X plot was also chosen for the fall analysis of height. A Burn 1X plot could be used because the spring pasture burn (burn one time treatment) was done on March 30, 1997 and the plants did not emerge until later on April 21, 1997. Six plots, comprising three pairs, were chosen for the height paired plot analysis.

Figure 5. Emerging ramets (2.5 to 5 cm high) on 04-21-97 -- study for plant control treatments.

Figure 6. Plant control treatments -- south plots staked and clipped.

Figure 7. Plant control treatments -- north-middle plots staked and twine strung for plot boundaries.

Figure 8. Plant control treatments -- north-middle plots being counted and clipped.

Figure 9. Plant control treatments -- readying for Burn 2X plot treatments in mid-August.

Figure 10. Plant control treatments -- burn box for Burn 2X treatments. One-square-meter box positioned over assigned plot for treatment.

Figure 11. Plant control treatments -- Burn 2X treatment. Grasses and *Lespedeza cuneata* consumed during August burn.

Figure 12. Ramets 15 to 36 cm high on 05-12-97 -- study for plant control treatments.

Figure 13. Ramets sorted to height for each plot -- plant clipping treatments.

Germination Treatments

The germination requirements for crop or forage *Lespedeza cuneata* has been determined to be late spring temperatures to warm the soil, and adequate moisture for the seed to fully imbibe. Mosjidis (1990) and Qui *et al.* (1995) used maximum germination temperatures of 30°C; however, all tests were conducted using mechanically-scarified seed. The germination requirements of area lespedeza seed are unknown.

The germination tests of Table 4 were conducted following the recommendations of the AOSA (Association of Official Seed Analysts) 1996 rules (unless otherwise noted) and Young and Young (1986). Seeds of *Lespedeza cuneata* [with an approved abbreviation of LESCU (Altom *et al.*, 1992)] and the three species of grasses: *Andropogon gerardi* (ANGE), *Andropogon scoparium* (ANSC), and *Sorghastrum nutans* (SONU) were tested. This allowed a comparison of the requirements for the four species under identical conditions in the laboratory. The grass seeds were ordered from Sharp Brothers Seed Company in 1997. The lespedeza seeds were field collected, near the site of the plant control treatment studies, in the fall of 1996 (in order to eliminate after-ripening requirements, if any). The lespedeza seeds were stored at 16°C in sealed glass containers to prevent moisture uptake.

Seeds were placed into quartered germination trays to allow testing of all species in an identical environment. Each tray held seeds of the three species of grasses in their respective quadrants and a fourth quadrant with *Lespedeza cuneata*. (See Figure 14.) Each species was randomly assigned to a tray quadrant. The germination substrate was Stayfree Classic Mini feminine protection pads cut to the dimensions of each quadrant in the trays. Other pads were tried but some apparently had some sort

Table 4. Germination treatments of *Lespedeza cuneata* and three species of grasses: Andropogon gerardi, Andropogon scoparius, and Sorghastrum nutans.

1. 5°C Prechill with Inbibition
2. 25°C
3. 30°C
4. 40°C
5. Light 25°C
6. Freeze/Thaw at 30°C
7. Mannitol –2.03 MPa
8. Mannitol –1.01 MPa
9. Escort® 30°C
10. Remedy™ 30°C
11. Lespedeza Filtrate 30°C
12. Wet Heat 100°C
13. Burn 400°C
14. Burn 200°C
15. Burn 100°C
16. Conc. H_2SO_4 1996 seed at 30°C
17. Conc. H_2SO_4 1997 seed at 30°C

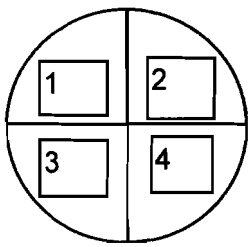

Figure 14. Germination trays -- partitioned for trials on *Lespedeza cuneata* and three species of grasses.

f inhibitor to seed germination. Seeds were placed in germination trays and supplied ith adequate moisture throughout the germination period. The germination trays were quipped with a cover but provided adequate air circulation. The wetting media was istilled water mixed with Daconil® fungicide unless otherwise noted.

Treatments consisted of four trials of 250 seeds, 1000 seeds total of each species; 000 seeds total for the treatment unless otherwise noted. All seeds were imbibed, nless otherwise noted, at a prechill temperature of 5°C for a period of two weeks and hen placed in the particular treatment temperature. Incubation was in a Precision cientific Incubator Model 805. The number of germinated seeds was recorded every hree to seven days.

Germination Treatments -- 5°C Prechill and Inbibition

The AOSA (Association of Seed Analysts) recommends a prechill at 5°C for two eeks for the three grasses. Because the *Lespedeza cuneata* is a hard-coated seed, nbibition would benefit this species, although the AOSA recommended no prechill. To etermine that no germination of the four species occurred in the 5°C prechill with oisture condition, four trays with 80 seeds (20 in each quadrant) of each species were cubated in a normal household refrigerator. This prechill with imbibition of lespedeza eeds was started in July of 1997. The grasses were started in November of 1997. This eatment was terminated for all species in June of 1999. The wetting media was istilled water until January of 1999 when distilled water with Daconil® fungicide was dded, although the seeds had no signs of fungus. The fungicide was added later ecause seeds on other treatments, especially at higher temperatures, developed ungus. To make sure Daconil® would not inhibit or promote germination, the fungicide

was added to the prechill treatment as a check. The chambers were checked for adequate moisture throughout the prechill period.

Germination Treatments -- 25°C

After imbibing at 5°C (41°F) for two weeks, the seeds were placed in the 25°C (77°F) treatment. The treatment was conducted for two months.

Germination Treatments -- 30°C

After imbibing at 5°C (41°F) for two weeks, the seeds were placed in the 30°C (86°F) treatment. The treatment was conducted for two months.

Germination Treatments -- 40°C

After imbibing at 5°C (41°F) for two weeks, the seeds were placed in the 40°C (104°F) treatment. The treatment was conducted for one month because germinations for the second month on the 25°C and 30°C were negligible.

Germination Treatments -- Light/25°C

The germination trays were, for this treatment, fitted with clear transparent covers. The trays were wrapped in aluminum foil during the imbibition at 5°C for two weeks to prevent any light reaching the seeds. After imbibing, the treatment trays were placed in 25°C (77°F) under two plant light fluorescent bulbs of 40 watts each and a fifteen-hour photoperiod.

Germination Treatments -- Freeze/Thaw 30°C

Seeds were imbibed at 5°C (41°F) for several days, frozen one to two days at 0°C (32°F), placed at room temperature until the substrate was thawed after several hours, then placed back at the 5°C. This treatment continued for three freezes and three thaws during the two-week period of imbibition. After the treatment of freeze/thaw, the trays were placed in the 30°C (86°F) incubation.

Germination Treatments -- Mannitol –2.03 MPa/25°C

The germination substrate was wetted with the Mannitol mixed for a negative osmotic potential of –2.03 MPa (–20 atm) (140 grams of Mannitol to 1000 grams of distilled water with Daconil® fungicide). Seeds were imbibed at 5°C (41°F) for two weeks then placed in the 25°C (77°F) treatment.

Germination Treatments -- Mannitol –1.01 MPa/25°C

The germination substrate was wetted with the Mannitol mixed for a negative osmotic potential of –1.01 MPa (–10 atm) (70 grams of Mannitol to 1000 grams of distilled water with Daconil® fungicide). Seeds were imbibed at 5°C (41°F) for two weeks then placed in the 25°C (77°F) treatment.

Germination Treatments -- Escort® 30°C

The germination substrate was wetted with Escort® (Metsulfuron methyl) mixed with distilled water and Daconil® fungicide. The mixture was 0.28 grams Escort® to one gallon water. Seeds were imbibed at 5°C (41°F) for two weeks then placed in the 30°C

(86°F) treatment. After each seed germinated, the seedling was placed in the opposite quadrant of the germinating tray in order to keep the seedling on the Escort® soaked substrate because this chemical uptake is by contact. This was to determine if the seedling could remain visibly healthy and continue to produce normal seedling structures.

Germination Treatments -- Remedy™ 30°C

The germination substrate was wetted with Remedy™ (Triclopyr) mixed with distilled water with Daconil® fungicide. The mixture was 0.5 ounce Remedy™ to 40 ounces water. Seeds were imbibed at 5°C (41°F) for two weeks then placed in the 30°C (86°F) treatment. As in the Escort study, after each seed germinated, the seedling was placed in the opposite quadrant of the germinating tray in order to keep the seedling on the Remedy™-soaked substrate. This was to determine if the seedling remained visibly healthy and continued to produce normal seedling structures.

Germination Treatments -- *Lespedeza cuneata* Leachate 30°C

Fresh lespedeza was collected in mid-summer when tannin levels were high. The leaves were stripped off stems and liquefied in a blender in the ratio of eight ounces of packed leaves with four ounces of distilled water and Daconil® fungicide. After blending, the mixture was filtered and the filtrate was poured over the seeds and the germination substrate until both were thoroughly wetted. (See Figure 15.) Seeds were imbibed at 5°C (41°F) for two weeks then placed in the 30°C (86°F) treatment. The treatment was conducted for two months.

Germination Treatments -- Wet Heat at 100°C

The treatment was of one trial of 250 seeds of each species, equaling 1000 seeds total. Twenty-five seeds of each species were placed in a packet made of paper toweling. A copper-constantan thermocouple, connected to an Omego CL6053 Precision Calibrator digital thermometer, was placed in one of the *Lespedeza cuneata* packets. All packets were wetted with distilled water and positioned, with no overlap, into a larger packet of aluminum foil that was placed in an oven set at 100°C (212°F). (See Figure 16.) When the digital thermometer registered 100°C in the lespedeza packet, timing started and continued for six minutes; this was the optimum treatment temperature and time reported for prairie-collected seed in Oklahoma (Segelquist, 1971). The foil package was then immediately removed from the heat source. The lespedeza seeds were visually imbibed from the heat treatment. The seeds were then placed into ten germination trays with 25 seeds of each species placed into each quadrant. The substrate was moistened with distilled water and Daconil® fungicide. The trays were placed immediately in 30°C (86°F).

Germination Treatments -- 400°C Burn

The treatment was of one trial of 250 seeds of each species, equaling 1000 seeds total. A handful of seeds of one species was placed in a metal screen packet. The copper-constantan thermocouple was positioned in the center of the packet and then the packet was stapled shut to prevent movement of the thermometer. The packet was then passed back and forth through the flame of a bunsen burner until the digital thermometer registered 400°C (752°F). This procedure was repeated for all four species. After the treatment, 250 seeds were picked from the center of the packet

Figure 15. Germination treatments -- *Lespedeza cuneata* Leachate 30°C. Germination tray with all four tested species soaked with *Lespedeza cuneata* leachate.

Figure 16. Germination treatment -- Wet Heat at 100°C (212°F). Seeds in paper toweling wetted with distilled water prior to treatment.

(burnt seeds that were overexposed on the edges of the screen were avoided) and placed in the germinating trays. The seeds were imbibed at 5°C and incubated at 30°C (86°F).

Germination Treatments -- 200°C Burn

The treatment was of one trial of 250 seeds of each species, equaling 1000 seeds total. The testing procedure was the same as the 400°C treatment, except the packet was passed back and forth through the flame of a bunsen burner until the digital thermometer registered 200°C (392°F). Seeds were picked from the center of the packet and placed in the germinating trays. The seeds were imbibed at 5°C and incubated at 30°C (86°F).

Germination Treatments -- 100°C Burn

The treatment was of one trial of 250 seeds of each species, equaling 1000 seeds total. The testing procedure was the same as the 200°C treatment, except the packet was placed on top of an asbestos screen deflector. The flame of a bunsen burner was placed below the asbestos and seed packet until the digital thermometer registered 100°C (212°F). Seeds were picked from the center of the packet and placed in the germinating trays. The seeds were imbibed at 5°C and incubated at 30°C (86°F).

Germination Treatments -- H_2SO_4 1996 *Lespedeza cuneata* Seed at 30°C

This treatment was applied only to the *Lespedeza cuneata* seeds to test the relative hardness of the seed coat. These seeds were collected in 1996 near the site of the plant control treatments. The scarification treatment using concentrated sulfuric acid was done in four trials of 250 seeds for each immersion treatment, 1000 seeds for each

rial, 4000 seeds total. The germination substrate was wetted with distilled water with Daconil® fungicide. Seeds were not imbibed for two weeks but placed immediately into the 30°C (86°F) incubation after scarification. The acid treatments were: control, three-minute immersion, 10-minute immersion, and 20-minute immersion. A thorough rinse with tap water was done after H_2SO_4 immersion. The control was only rinsed with tap water. All H_2SO_4 immersions were agitated. The seeds were placed in germination trays with one quadrant of each tray devoted to a treatment, and the trays were placed immediately in the 30°C (86°F) incubation for a total of two months.

Germination Treatments -- H_2SO_4 1997 *Lespedeza cuneata* Seed at 30°C

This treatment was applied to the *Lespedeza cuneata* seeds collected in 1997 (also from near the site of the plant control treatments) to determine if germination percentages were significantly different from one year to the next. This treatment was conducted exactly as the 1996 test.

Germination Treatments -- 1996 Seed Viability

In order to determine the percentage of viable seeds used in the germination tests, and also to determine the percentage of viable seeds produced within a given year, a tetrazolium chloride test was conducted. After the H_2SO_4 treatment and the two month-incubation period, the 1996 seeds were placed back into 5°C (41°F) condition until a tetrazolium chloride viability test could be conducted on the remaining seeds. The tetrazolium chloride test involved slicing in half the seeds that had not previously germinated. The seed half was immersed in the solution for approximately one hour or until the seed stained red, indicating viable tissues. (See Figure 17.)

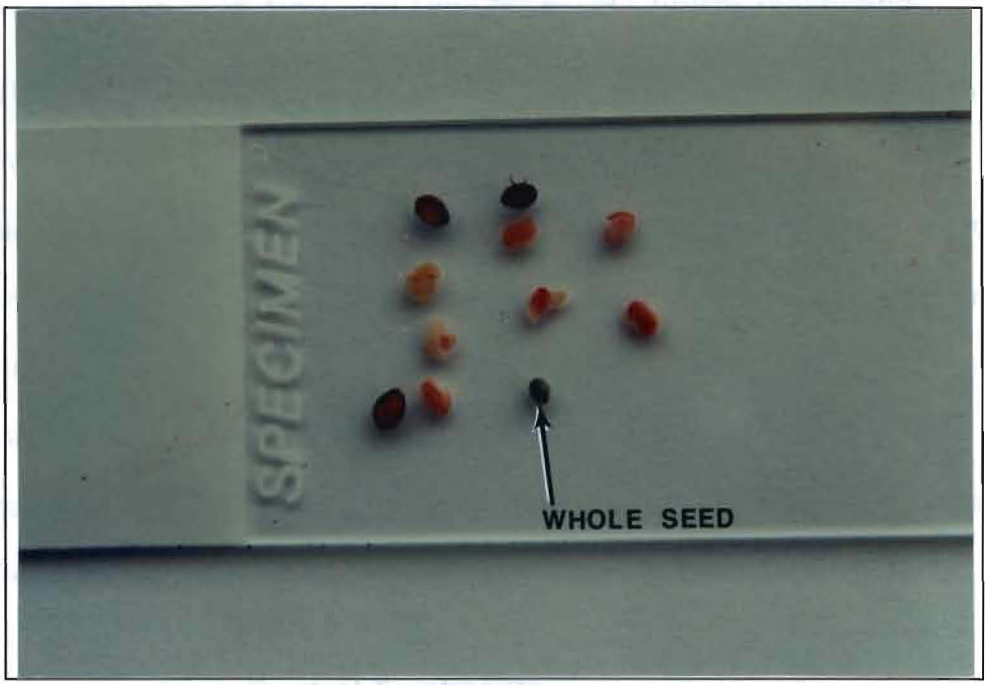

Figure 17. Tetrazolium chloride test of *Lespedeza cuneata* seeds. Stained seed halves indicating tissue respiration.

CHAPTER 3 -- RESULTS

Weather Analyses from 1997 and 1998 for Plant Control Treatments

The Plant Control treatment studies were field studies, so the climatological conditions in 1997 (the year that plant control treatments were conducted) were compared with those from 1998 (the year of post-treatment data collection) to look for large variations, if any. Weather data was provided from the local KVOE Radio Station. (See Figure 18.) An ANOVA was used to compare both years for weather conditions and found no statistical differences ($P > 0.25$) between average annual high temperatures, low temperatures, or precipitation. (Refer to Appendix, Table A-1 through Table A-4.)

Ramet Growth -- Plant Control Treatments

The initial growth for *Lespedeza cuneata* was analyzed to determine what percentage of growth had been attained at the time of the first clipping treatments in June. Table 5 lists the ramet means for the height analysis, the population mean, and the significance. (See Figure 19 and refer also to Table A-5, Ramet Height Data.) The hypothesis was rejected ($0.01 > P > 0.005$; refer to Table A-6) for the attainment of full growth in the June clipping treatment (ramet height), so the percentage of growth was analyzed. Seventy percent of the plant's growth had been attained by mid-June. The growing period appears to be from mid-April to late July (depending upon the year and the location). The plant requires warmer temperatures and longer daylengths to attain most of its height (Dodd *et al.*, 1948; Mosjidis, 1990).

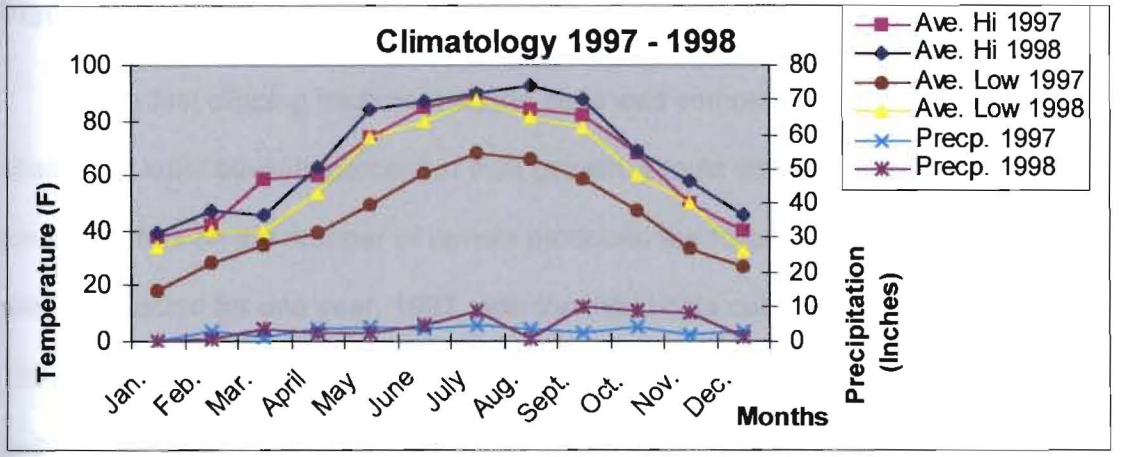

Figure 18. Climatological data chart for plant control treatments comparing years 1997 to 1998.

Table 5. Ramet height means and population means (at time clipped) of six paired plots for first clipping treatment (mid-June) compared to total ramet height of Control and Burn 1X treatments in fall.

June '97		Fall '97	
Plot Treatment	Clip Means (Inches)	Control/ Burn 1X Means (Inches)	Plot Treatment
CLIP E.30D J-S	16	21	CONTROL
CLIP JUN/JLY	16	24	CONTROL
CLIP JUN/JLY	15	22	BURN 1X
	μ = 15.66	μ=22.33[a]	

[a] Significant at 0.05 level or better.

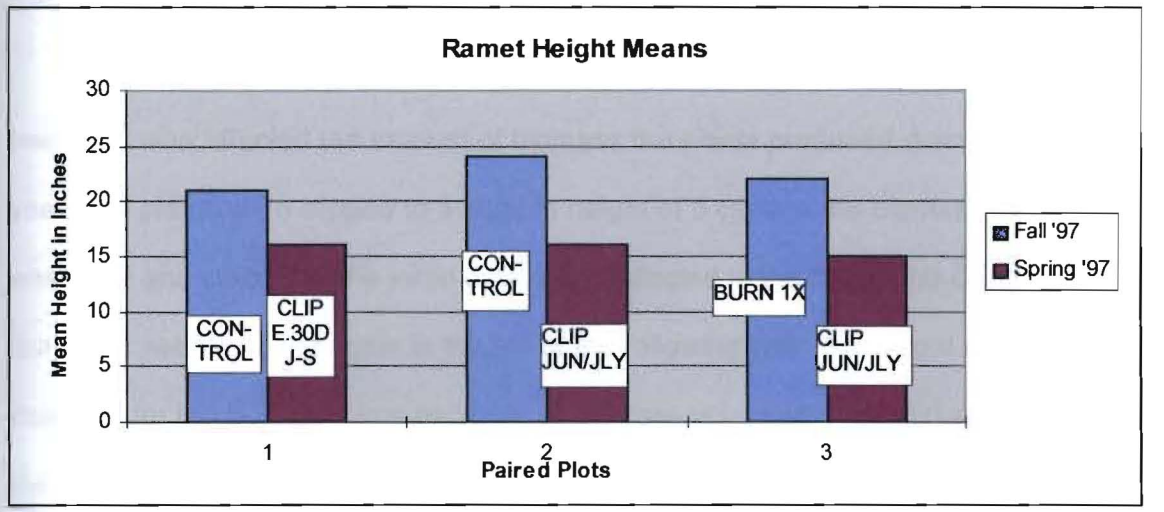

Figure 19. Ramet Height – means comparison of first clip height to full fall growth.

ant Control Treatments - Effect on Ramet Count

The first clipping treatment on the plots was completed when the plants had ained at least seventy percent of their growth. Would either severe clipping or fire ve an effect on the number of ramets produced the following year? The treatments re conducted for one year, 1997, with the initial data collected during the spring of 97 and the comparison data collected in the spring of 1998. The variables were alyzed using the paired plot method. Ramet count means for each treatment are mmarized in Table 6 and Figure 20 depicts the percentage of increase/decrease.

There was a significant increase of ramets in the Burn 1X treatments from the ring of 1997 to the spring of 1998 (281.3 $\pm$ 143.2 SD and 376.9 $\pm$ 183.7 SD, spectively; $P < 0.0005$). The rest of the treatments (Control, Burn 2X, Clip June/July, lip Every 30 Days June-Sept.) resulted in no statistically significant increase or crease in the number of ramets. (Refer to Table A-7 through A-12 for the treatment met count statistics.) All other treatments, except for the Control, had a decrease in mets.

lant Control Treatments – Effect on Ramet Weight

After analyzing the treatment effect on ramet count, I wanted to know if the reatment also affected the amount of biomass the plants produced during the following ear. The plants were clipped to a stubble height of 5 cm and the biomass for each plot was dried and weighed. The initial data were collected in the fall for the Control and the Burn 1X treatments and again in the fall of the following year. No weight data could be collected for the Burn 2X plots because all biomass was destroyed during the second burn. The weight data for the clipping treatments were collected during the first clipping in June of 1997 and the comparison data were collected in June of 1998.

These results were analyzed using the paired plot method. The means for each treatment are listed in Table 7. (See also Figure 21 for the percent of increase/ decrease.) There was a significant increase of the amount of ramet biomass in the Control treatment from the fall of 1997 to the fall of 1998 (121.9 $\pm$ 73.1 SD and 263.3 $\pm$ 96.3 SD, respectively; $0.0005 < P < 0.001$). The Burn 1X treatment resulted in an increase in the amount of ramet biomass but was not significant. Both of the clipping treatments, Clip mid-June/mid-July and Clip Every 30 Days mid-June-Sept., resulted in a significant decrease in ramet biomass. The Clip mid-June/mid-July treatment was significantly reduced from the spring of 1997 to the spring of 1998 (129.6 $\pm$ 19.6 SD and 39.8 $\pm$ 11.6 SD, respectively; $P < 0.0005$). The Clip Every 30 Days mid-June-Sept. treatment was significantly reduced from the spring of 1997 to the spring of 1998 (124.7 $\pm$ 95.3 SD and 34.9 $\pm$ 23.2 SD, respectively; $0.0025 < P < 0.005$). (Refer to Table A-13 through A-16 for the treatment ramet weight statistics.)

Seed Production -- Plant Control Treatments

In the Fall of 1997, both clipping treatments and the Burn 2X treatment produced no seed. The Burn 1X and Control treatments did produce seed. In the Fall of 1998, no seeds were produced in any of the treatments in the North plots. This included the Burn 1X and Control treatments although ramet count (see Figure 20) and ramet biomass (weight in grams per plot, see Figure 21) increased from the previous year. The south plots, located on the tree edge, did not produce seeds on either of the clipping treatments, even though no clipping was done in 1998. The Burn 1X and Control plots did produce seed.

Table 6. Ramet count -- plant control treatment means. The effect of treatment on ramet density noting the mean number of ramets per square-meter.

Spring '97	Control	Burn 1X Spring	Burn 2X Spring/Fall	Clip Mid-June/Mid-July	Clip Every 30 Days June-Sept.
Mean (X)	247.8	281.3	275.6	352.8	300.3
Std. Dev. (s)	129.41	143.18	162.75	154.99	137.46
Var. (s^2)	16747.511	16236.25	19568.028	22054.194	20832.778
n = 10	n = 10	n = 10	n = 10	n = 10	n = 10
Spring '98	**Control**	**Burn 1X Spring**	**Burn 2X Spring/Fall**	**Clip Mid-June/Mid-July**	**Clip Every 30 Days June-Sept.**
Mean (X)	260.6	376.9 [a]	255.6	293.6	277.1
Std. Dev. (s)	157.11	183.70	185.56	146.64	118.23
Var. (s^2)	24684.489	28568.25	16246.361	16947.194	15656.528
n = 10	n = 10	n = 10	n = 10	n = 10	n = 10
		P < 0.0005			

[a] Significantly more ramets from pre-treatment at 0.05 level or better.

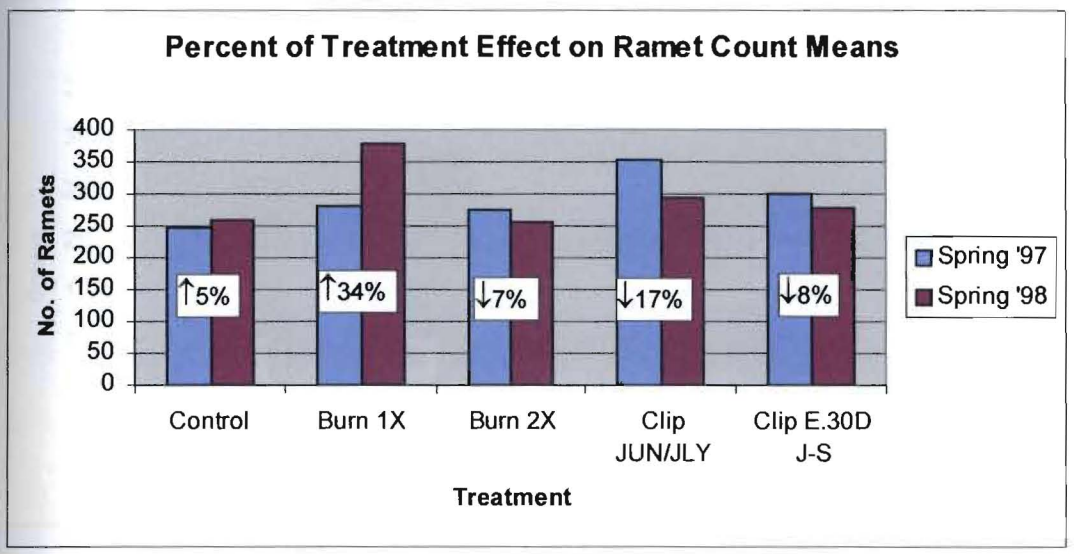

Figure 20. Ramet count -- plant control treatment means showing the percent effect of treatment on the vigor of *Lespedeza cuneata*.

Table 7. Ramet weight means (grams) -- plant control treatments. The effect of treatment on ramet biomass noting the mean grams of biomass per square-meter.

Fall '97	Control	Burn 1X Spring	June '97	Clip Mid-June/Mid-July	Clip Every 30 Days June-Sept..
Mean (X)	121.9	216.4		129.62	124.71
Std. Dev. (s)	73.10	102.31		19.56	95.27
Var. (s^2)	5344.6	10467.5		382.776	9075.61
n=	4	3		10	10
Fall '98	**Control**	**Burn 1X Spring**	**June '98**	**Clip Mid-June/Mid-July**	**Clip Every 30 Days June-Sept.**
Mean (X)	263.3[a]	290.6		39.78 [a]	34.92 [a]
Std. Dev. (s)	96.3328	144.595		11.6119	23.2431
Var. (s^2)	9280.01	20907.8		134.837	571.234
n=	4	3		10	10
	0.0005 < P < 0.001			P < 0.0005	0.0025 < P < 0.005

[a] Significantly different from pre-treatment at 0.05 level or better.

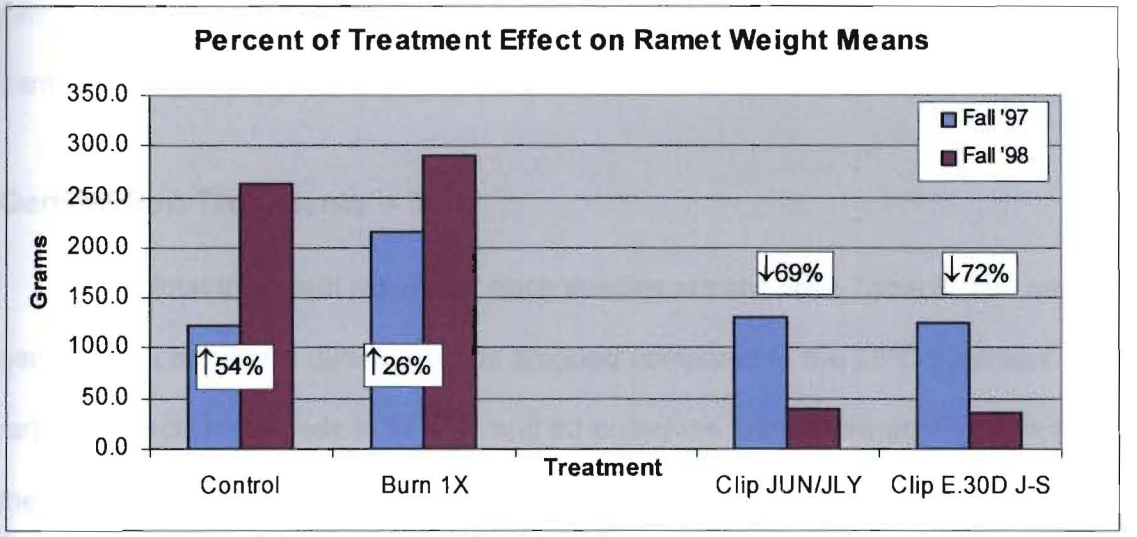

Figure 21. Ramet weight means -- plant control treatments. The percent effect of pre- and post-treatment on the vigor of *Lespedeza cuneata* showing the mean grams of biomass per square-meter.

Germination Treatments -- 5°C Prechill and Inbibition

No germination occurred in any species during the 5°C Prechill with Inbibition treatment period. (Refer to Table 8.) The seeds remained visibly intact. After treatment, the seeds were then placed at 25°C during which the seeds of all species initiated germination.

Germination Treatments -- 25°C

Total germination results for the total treatment for each species are shown in Table 8. The initial and continued germinations of the species are shown in Figure 22. *Andropogon gerardi* germinated beginning on day two and highest on day four, followed closely by the other grass species and the *Lespedeza cuneata*. The highest germinations of *Lespedeza cuneata* were on day eight. The majority of lespedeza germinated by day eighteen for this treatment.

Germination Treatments -- 30°C

The total treatment results for each species are shown in Table 8. The total germinated *Lespedeza cuneata* seeds dropped compared to the 25°C treatment. The random selection of seeds in Trial #1 and #3 pulled the total germinations down from the cooler 25°C treatment. The initial and continued germinations of the species are shown in Figure 23. *Andropogon gerardi* first germinated and was highest on day four and day ten. The other grasses also peaked similarly. *Lespedeza cuneata* germinations were constant through day 60.

Table 8. Germination treatment results[1] of the four tested species (with the exception of H_2SO_4 and Heat/Fire treatments).

	Treatment										
	5°C	25°C	30°C	40°C	Light/ 25°C	Freeze/ Thaw 30°C	Mannitol -1.01 MPa/ 25°C	Mannitol -2.03 MPa/ 25°C	Escort/ 30°C	Remedy/30 °C	Leachate/ 30°C
Species	Means										
LESCU	0	46 abc	32 abc	73.75 cd	63.75 bcd	98.25 d	13.5 ab	0.75 a	30.25 abc	0.5 a	53.5 bcd
ANGE	0	179 d	166.5 cd	152.75 cd	171.5 d	3 a	136.5 bc	76.5 b	164.5 cd	28.25 a	151.5 cd
ANSC	0	78.5 bcd	73 de	48.75 bc	79.25 e	1.25 a	60.25 cd	3 a	88 e	3.25 a	72.75 de
SONU	0	64 b	68.5 b	59.25 b	101.75 c	0.5 a	9.5 a	0.25 a	71 b	2.5 a	71 b
	SD (s)										
LESCU	-	8.83	15.43	17.31	41.18	30.55	0.58	5.92	22.71	1.00	31.61
ANGE	-	2.94	7.68	15.00	11.09	2.45	5.56	25.83	1.73	19.38	27.74
ANSC	-	16.36	16.35	2.50	10.08	1.26	1.50	9.78	2.00	3.59	11.03
SONU	-	7.39	6.66	10.72	9.59	0.58	0.50	2.50	11.46	2.08	19.77
	Var. (s^2)										
LESCU	-	78.00	238.00	299.58	1695.58	933.58	0.33	35.00	515.58	1.00	999.00
ANGE	-	8.67	59.00	224.92	122.92	6.00	30.92	667.00	3.00	375.58	769.67
ANSC	-	267.67	267.33	6.25	101.67	1.58	2.25	95.58	4.00	12.92	121.58
SONU	-	54.67	44.33	114.92	92.00	0.33	0.25	6.25	131.33	4.33	390.67
	SEM										
LESCU	-	4.42	7.71	8.65	20.59	15.28	0.29	2.96	11.35	0.50	15.80
ANGE	-	1.47	3.84	7.50	5.54	1.22	2.78	12.91	0.87	9.69	13.87
ANSC	-	8.18	8.18	1.25	5.04	0.63	0.75	4.89	1.00	1.80	5.51
SONU	-	3.70	3.33	5.36	4.80	0.29	0.25	1.25	5.73	1.04	9.88

[1] Within a row, means followed by the same letter are not significantly different at 0.05 level or better. Tukey multiple comparison population means, from smallest (a) to largest (e).

LESCU – *Lespedeza cuneata*; ANGE - *Andropogon gerardi*; ANSC - *Andropogon scoparius*; SONU - *Sorghastrum nutans*.

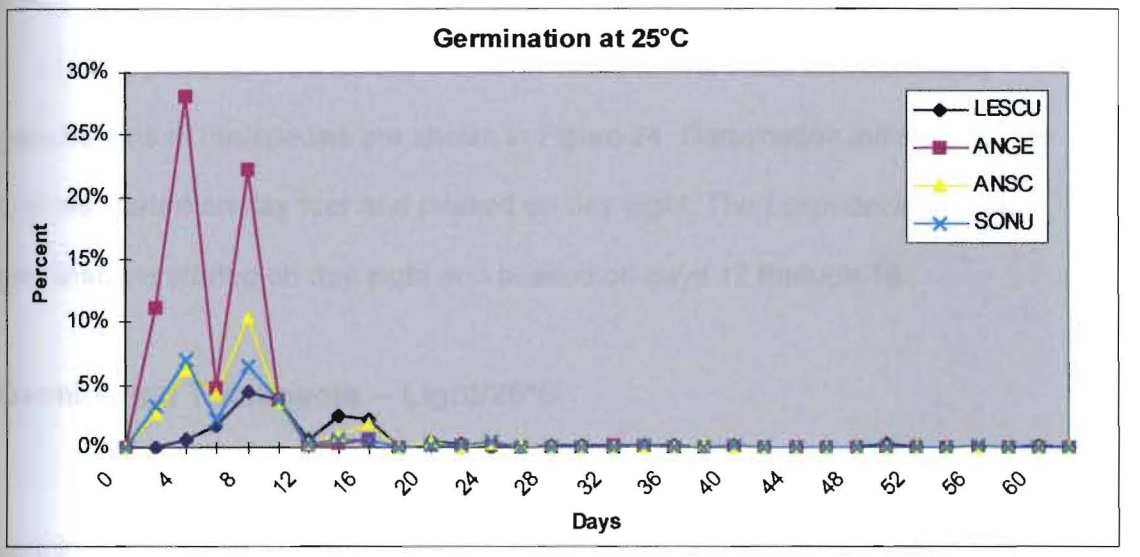

Figure 22. Germination time chart for 25°C (77°F) treatment; prechill of 5°C (41°F). Seedling emergence of the four tested species over a 60-day period.

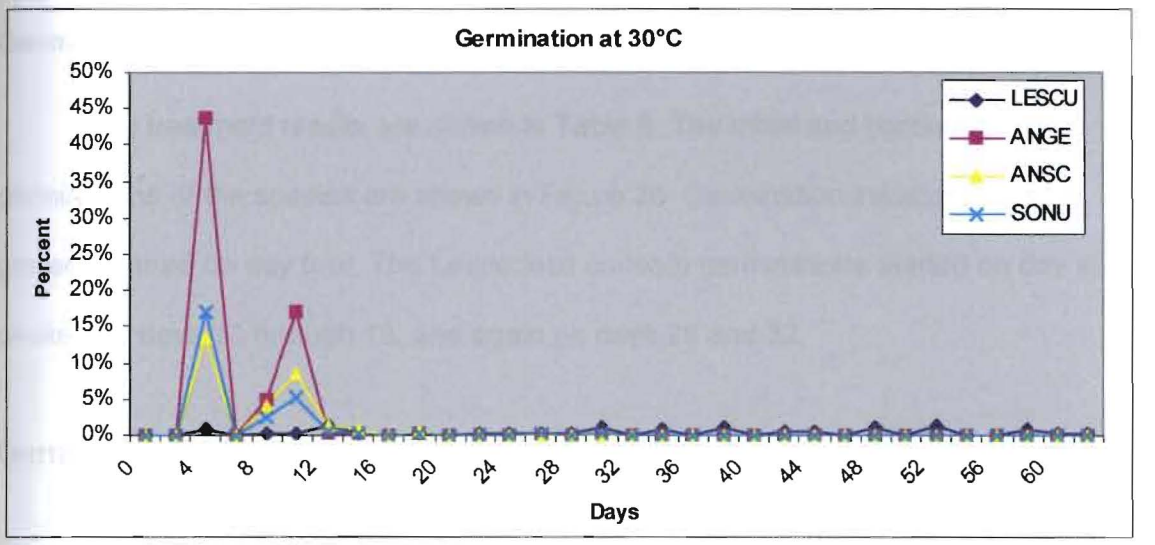

Figure 23. Germination time chart for 30°C (86°F) treatment; prechill of 5°C (41°F). Seedling emergence of the four tested species over a 60-day period.

rmination Treatments -- 40°C

The treatment results are shown in Table 8. The initial and continued erminations of the species are shown in Figure 24. Germination initiation for the grasses started on day four and peaked on day eight. The *Lespedeza cuneata* germinations started on day eight and peaked on days 12 through 16.

Germination Treatments -- Light/25°C

The treatment results are shown in Table 8. The initial and continued germinations of the species are shown in Figure 25. Germination initiation for the grasses started on day two and peaked on day six. The *Lespedeza cuneata* germinations started on day six and peaked on day 12.

Germination Treatments -- Freeze/Thaw 30°C

The treatment results are shown in Table 8. The initial and continued germinations of the species are shown in Figure 26. Germination initiation for the grasses started on day four. The *Lespedeza cuneata* germinations started on day six, peaked on days 10 through 18, and again on days 28 and 32.

Germination Treatments -- Mannitol –2.03 MPa/25°C

The treatment results are shown in Table 8. The initial and continued germinations of the species are shown in Figure 27. *Andropogon gerardi* germinations were delayed to day six and peaks were spread out from days 12 through 18. The other grasses did not initiate germination until day 12. Grass germinations were greatly reduced. There were no germinations of *Lespedeza cuneata* as seen in Table 8.

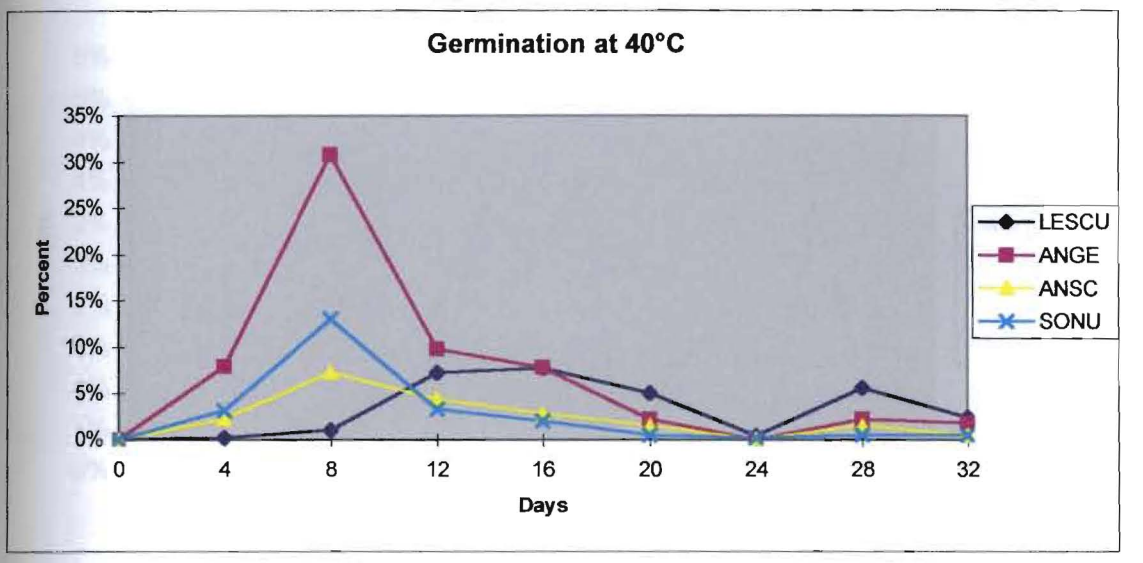

Figure 24. Germination time chart for 40°C (104°F) treatment; prechill of 5°C (41°F). Seedling emergence of the four tested species over a 30-day period.

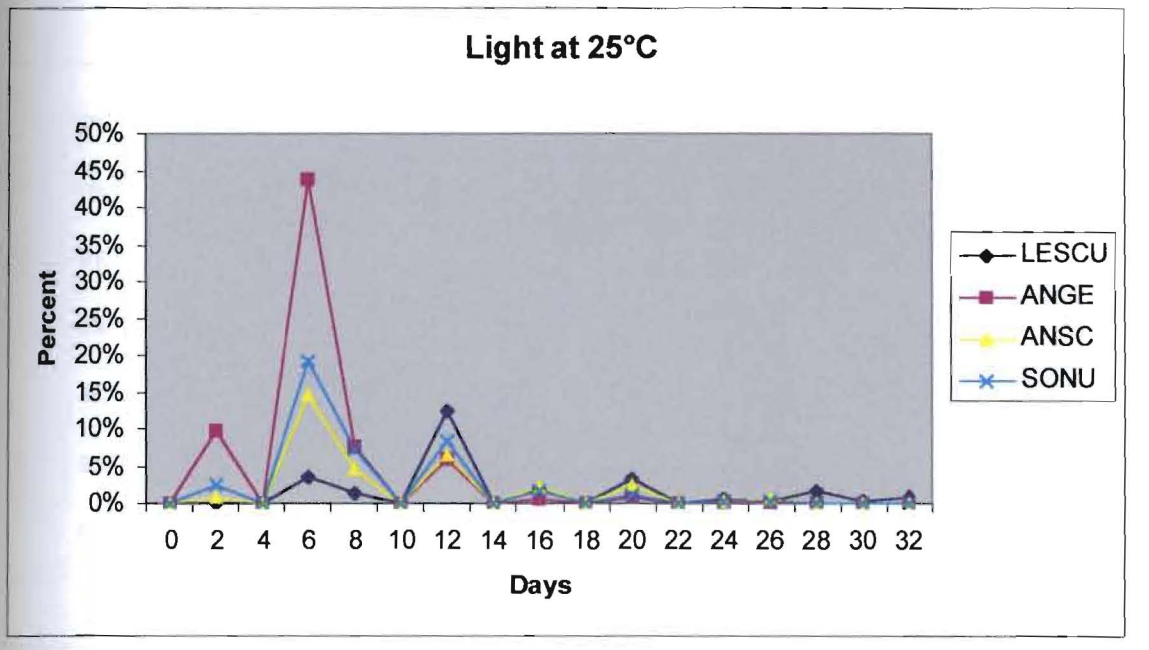

Figure 25. Germination time chart for Light/25°C (77°F) treatment; prechill of 5°C (41°F). Seedling emergence of the four tested species over a 30-day period.

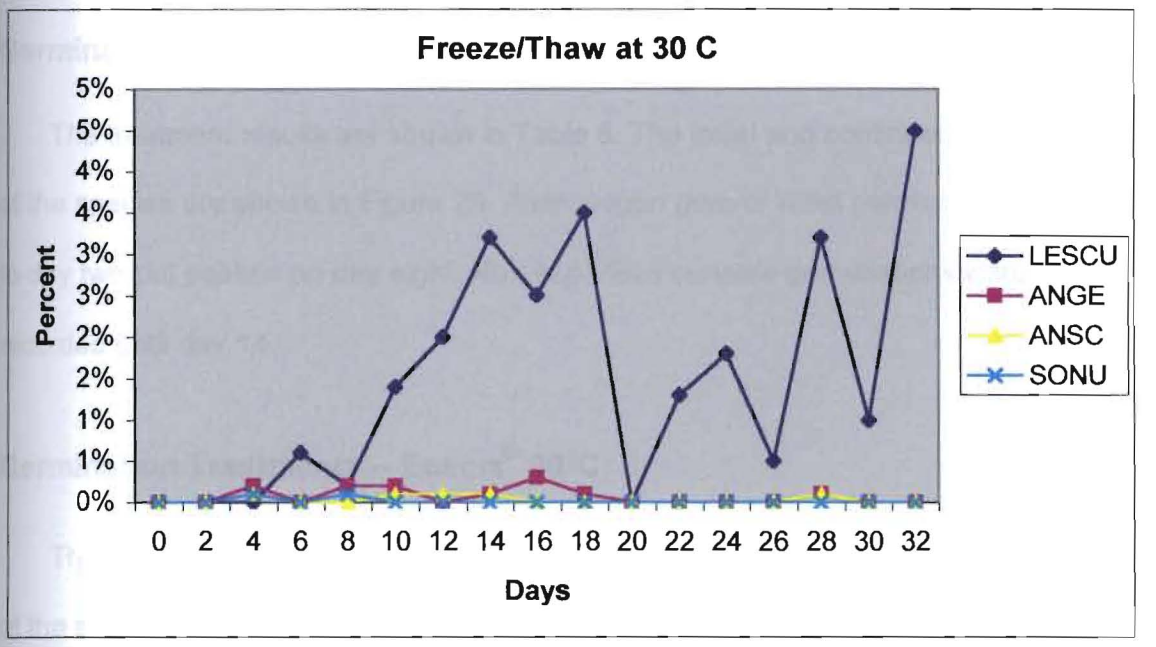

Figure 26. Germination time chart for Freeze/Thaw/30°C (86°F) treatment; prechill of 5°C (41°F). Seedling emergence of the four tested species over a 30-day period.

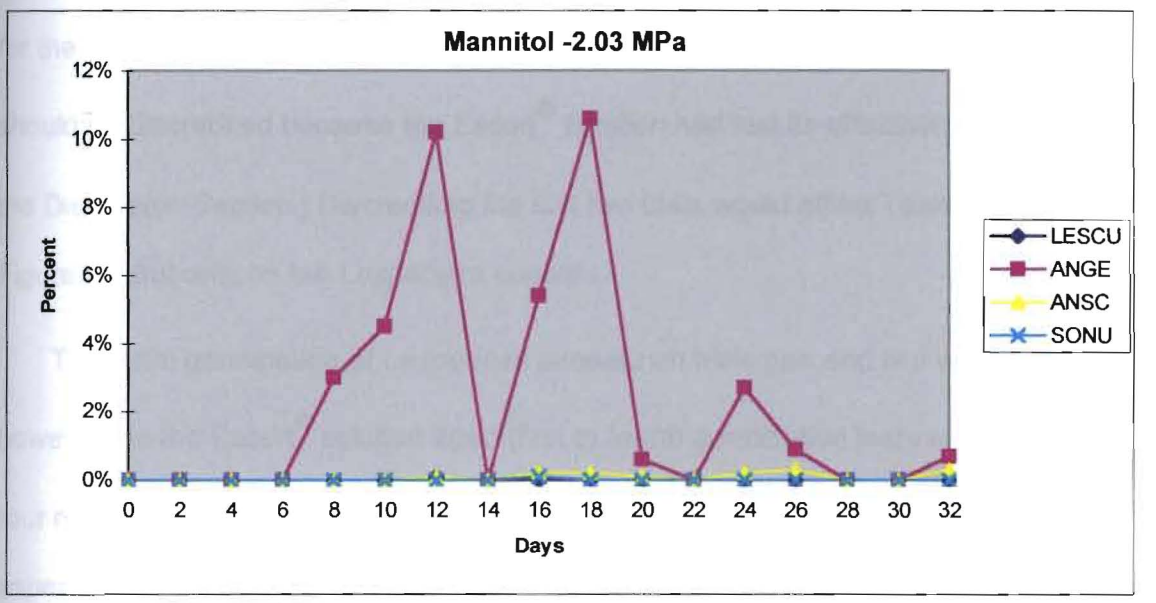

Figure 27. Germination time chart for Mannitol –2.03 MPa/25°C (77°F) treatment; prechill of 5°C (41°F). Seedling emergence of the four tested species over a 30-day period.

Germination Treatments -- Mannitol –1.01 MPa/25°C

The treatment results are shown in Table 8. The initial and continued germinations of the species are shown in Figure 28. *Andropogon gerardi* initial germinations returned to day two but peaked on day eight. No *Lespedeza cuneata* germinations were recorded until day 14.

Germination Treatments -- Escort® 30°C

The treatment results are shown in Table 8. The initial and continued germinations of the species are shown in Figure 29. Initial germinations for the grasses started at day two and were heightened from day four through ten. The *Lespedeza cuneata* initiated germination on day four and peaked on day ten. The treatment results for each trial are shown in Table 9. When referring to Table 9, note the trials one and two were similar for the *Lespedeza cuneata*, however, trials three and four were greatly inflated and should be discredited because the Escort® solution had lost its effectiveness. (Refer to the Discussion Section.) Discrediting the last two trials would affect Table 8 results and Figure 29, but only on the *Lespedeza cuneata*.

The initial germination of *Lespedeza cuneata* on trials one and two were negligible; however, as the Escort® solution aged (first to fourth germination tests were conducted four months after the solution was first mixed), the germination rate started to rise, especially on the fourth test. Apparently the mixed chemical's effectiveness is short-lived, and the third and fourth trial results should be considered invalid. Seedling structure on the third and fourth trials was generally normal; the seed appeared to develop the force needed to break the seed coat and the two cotyledons were

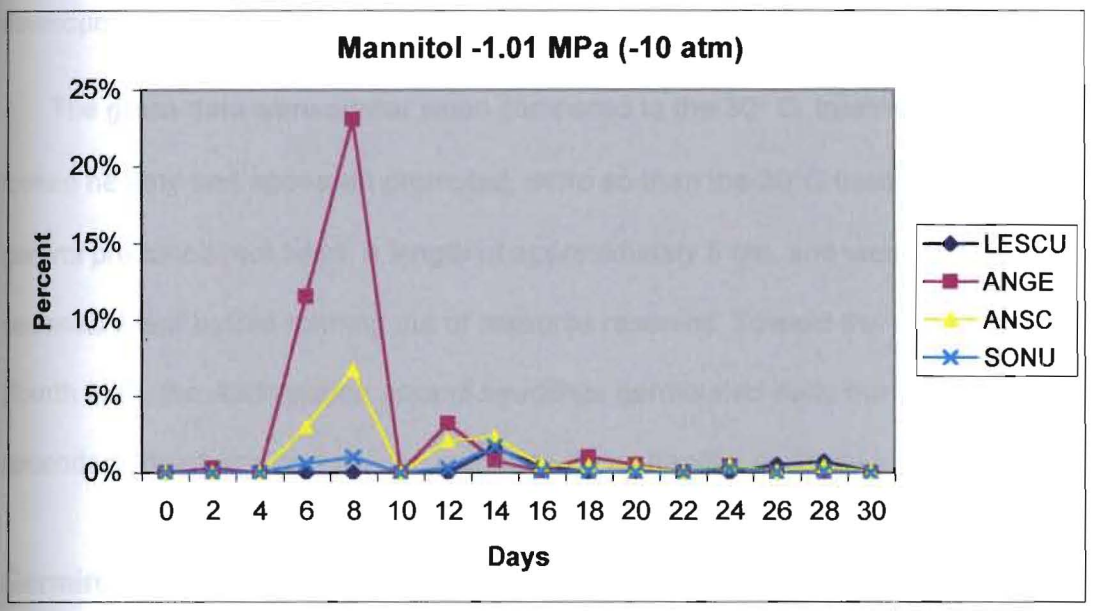

Figure 28. Germination time chart for Mannitol –1.01 MPa/25°C (77°F) treatment; prechill of 5°C (41°F). Seedling emergence of the four tested species over a 30-day period.

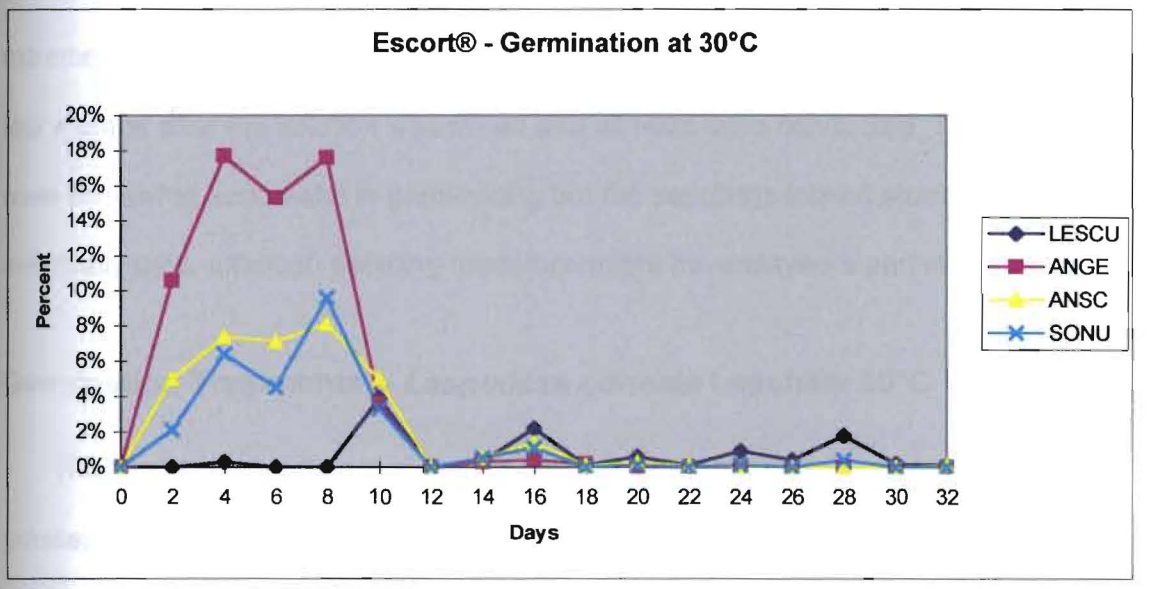

Figure 29. Germination time chart for Escort® 30°C (86°F) treatment; prechill of 5°C (41°F). Seedling emergence of the four tested species over a 30-day period.

apparent, but the radicle (primary root) and the cotyledons never continued development; the seed coat just appeared to be "popped." (See Figure 30.)

The grass data were similar when compared to the 30° C. treatment. The seedlings looked healthy and appeared promoted, more so than the 30°C treatment. *Andropogon gerardi* produced root hairs, a length of approximately 5 cm, and were on the secondary leaf before running out of resource reserves. Toward the end of the testing (fourth trial), the *Andropogon gerardi* seedlings germinated early but did not produce secondary structures and did not appear to be as healthy as those in the first trial.

Germination Treatments -- Remedy™ 30°C

The treatment results are shown in Table 8. The initial and continued germinations of the species are shown in Figure 31. Initial germinations of the grasses started at day two and peaked during days four through eight; however, the germination rate was extremely low. As shown in Table 8, the *Lespedeza cuneata* never germinated, even four months after the solution was mixed and all tests were conducted. The grasses were somewhat successful in germinating but the seedlings looked stunted and eventually died, although seedling resources might have played a part in this.

Germination Treatments -- *Lespedeza cuneata* Leachate 30°C

The treatment results are shown in Table 8. The germination percentages of the grasses were not reduced when comparing the leachate treatment against the 30°C treatment as a control. The germination for the lespedeza seed was not increased significantly. The initial and continued germinations of the species are shown in Figure 32. Initial germinations started of the grasses started at day two and peaked from days

Table 9. Germination totals for Escort® 30°C (86°F) treatment with a prechill at 5°C (41°F).

Escort® 30°C	LESCU	ANGE	ANSC	SONU
Total Trial #1	14	164	89	67
%Germination	6%	66%	36%	27%
Total Trial #2	9	167	89	66
%Germination	4%	67%	36%	26%
Total Trial #3	41	163	85	88
%Germination	16%	65%	34%	35%
Total Trial #4	57	164	89	63
%Germination	23%	66%	36%	25%
Total Germination	121	658	352	284
Total %	12%	66%	35%	28%

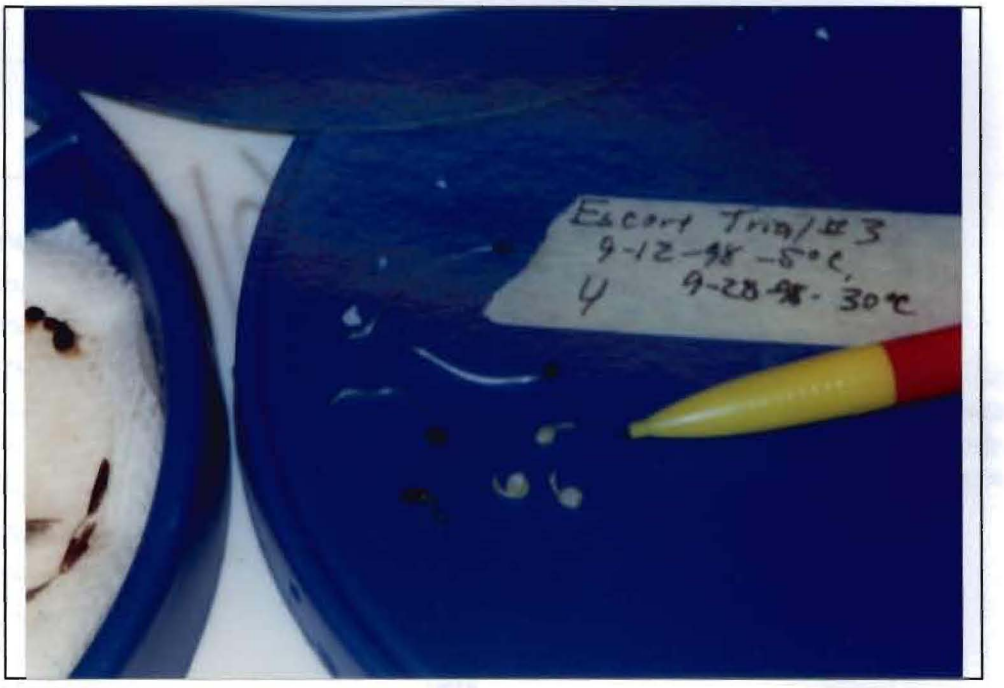

Figure 30. Germination treatment for Escort® -- Lespedeza seedlings in Escort® treatment. Trial three showing embryonic root elongation above and seed coat broken below. Escort® solution effectiveness failed on trial three and four.

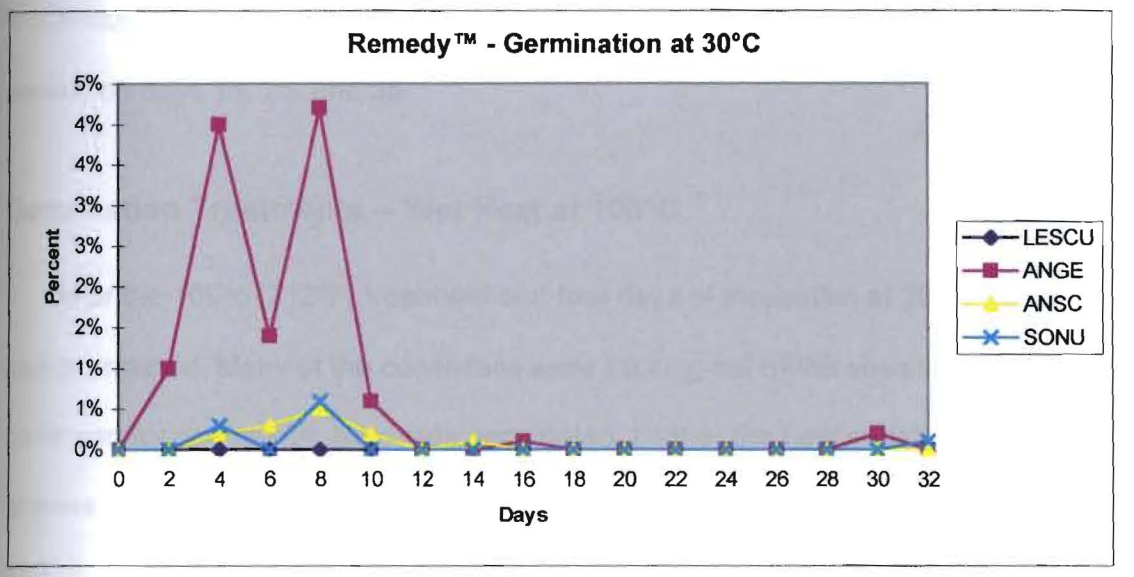

Figure 31. Germination time chart for Remedy™ 30°C (86°F) treatment; prechill of 5°C (41°F). Seedling emergence of the four tested species over a 30-day period.

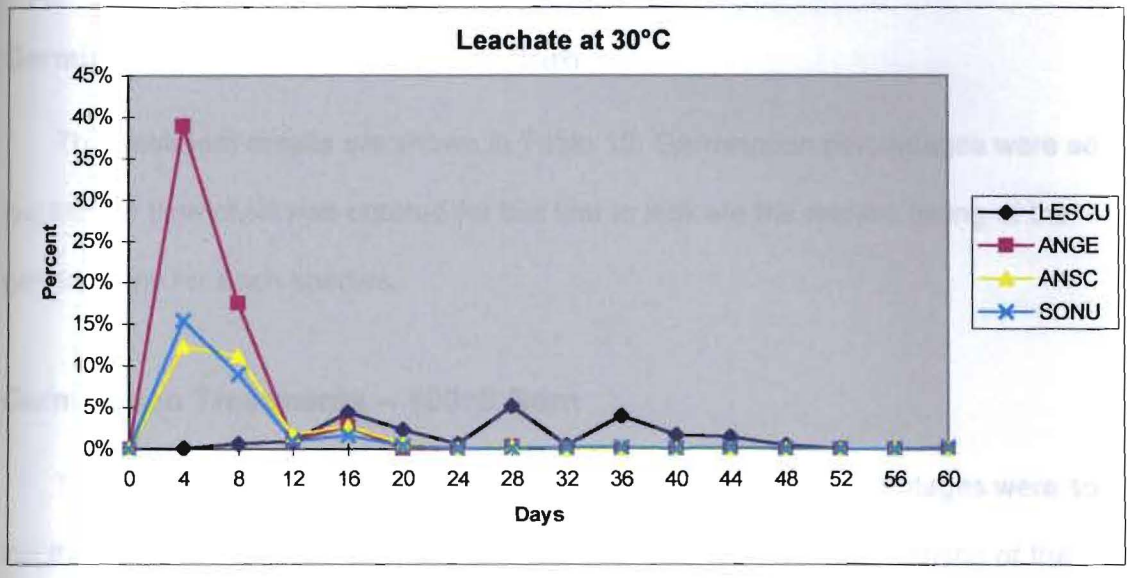

Figure 32. Germination time chart for *Lespedeza cuneata* Leachate 30°C (86°F) treatment; prechill of 5°C (41°F). Seedling emergence of the four tested species over a 60-day period.

r through eight. The initial *Lespedeza cuneata* germinations were on day four and aked on days 16, 28, and 36.

rmination Treatments -- Wet Heat at 100°C

After the 100°c (212°F) treatment and four days of incubation at 30°C, no seeds d germinated. Many of the cotyledons were sticking out of the seedcoats. Incubation ntinued for one month. No seeds germinated, neither the Lespedeza cuneata nor the asses. The seeds apparently were "cooked." (Refer to the treatment results in Table 0.)

ermination Treatments -- 400°C Burn

The treatment results are shown in Table 10. No seeds germinated with the exception of *Androgogon scoparius*.

Germination Treatments -- 200°C Burn

The treatment results are shown in Table 10. Germination percentages were so low that no time chart was created for this test to indicate the relative timing of the germinations for each species.

Germination Treatments -- 100°C Burn

The treatment results are shown in Table 10. Germination percentages were so low that no time chart was created for this test to indicate the relative timing of the germinations for each species.

Table 10. Germination totals for Heat/Fire treatments.

	Treatments							
	100°C (212°F) Wet Heat 6 Min; 30°C (86°F)		Burn 400°C; 30°C (86°F)		Burn 200°C (392°F)		Burn 100°C (212°F)	
Species	Total	Total %	Total	Total %	Total	Total %	Total	Total %
LESCU	0	0%	0	0%	7	3%	8	3%
ANGE	0	0%	0	0%	51	20%	64	26%
ANSC	0	0%	7	3%	0	0%	17	7%
SONU	0	0%	0	0%	0	0%	18	7%

Germination Statistics for Treatments (with the exception of the Heat/Fire Treatments)

The germination treatments were analyzed (with the exception of the Heat/Fire Treatments) and there was an effect of all treatments on each of the individual species. (Refer to Tables A-17 through A-20.) Figure 33 depicts the percent of treatment effects of all the treatments, including the Heat/Fire Treatments, on each particular species.

Tukey Multicomparison for Germination Treatments

Because there was an effect of treatment on the seed germination of *Lespedeza cuneata* and the grass species (refer to Tables A-17 through A-20 for each ANOVA), a Tukey multicomparison was performed to determine which treatments were similar. (Refer to Tables A-21 through A-24.) Results of the tukeys for each species are shown in Table 8.

Germination Statistics for Heat/Fire Treatments

Because the heat/fire germination treatments only had one trial each (although 250 seeds of each species were tested) these treatments were analyzed separately. It becomes apparent in Figure 33 that none of the heat trials correspond to any of the other treatments performed. (Refer also to Table A-25 for treatment statistics.) When analyzing the heat treatments, there was no positive effect of heat treatment on the germination.

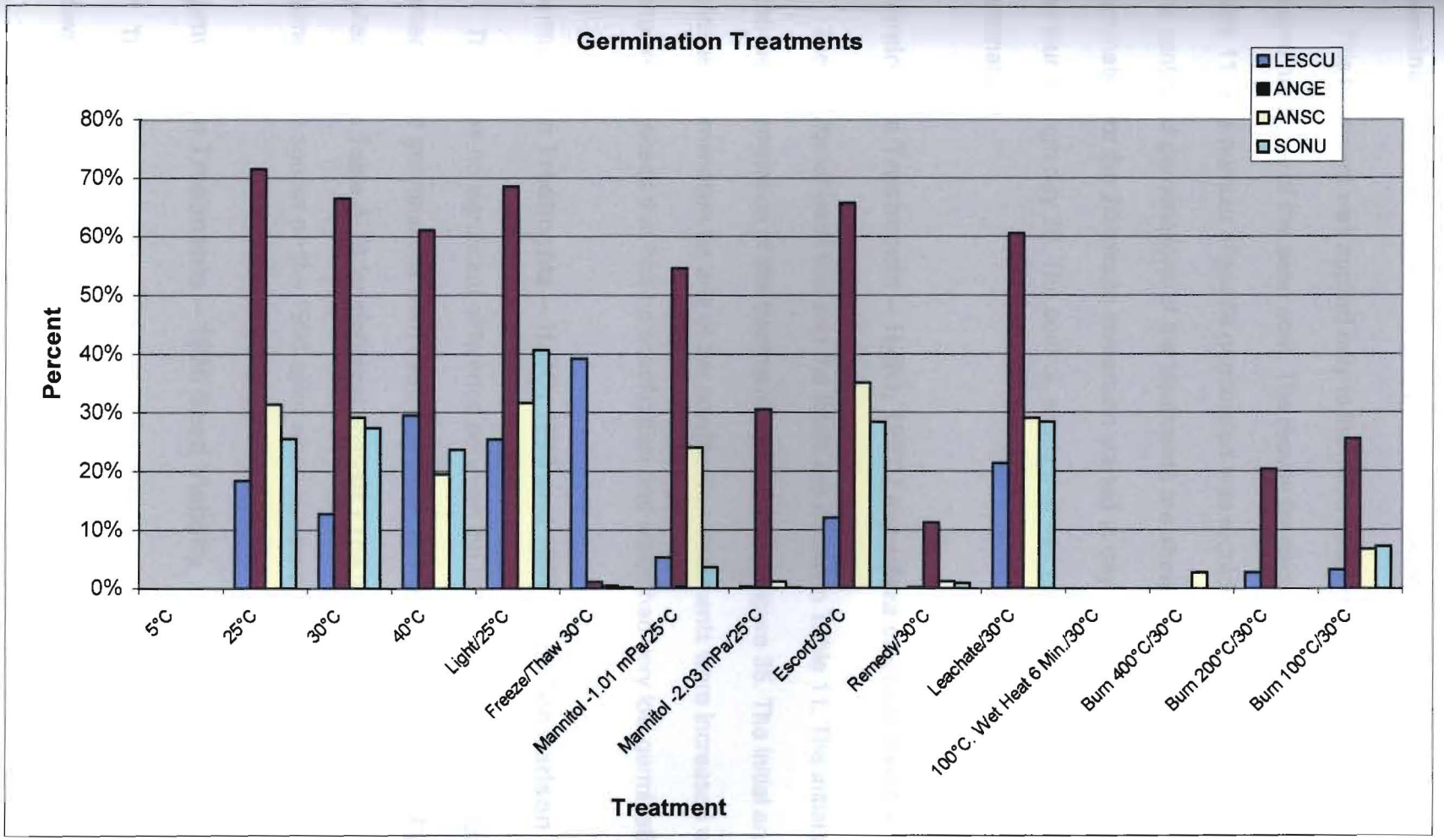

Figure 33. Germination treatments -- percentage of germination for the four tested species.

Germination Treatments -- H_2SO_4 1996 *Lespedeza cuneata* Seed at 30°C

This treatment was applied only to the 1996 *Lespedeza cuneata* seeds to test the relative hardness of the seed coat. The results for each trial and the totals are shown in Table 11. The number of seeds germinated was recorded every 3 to 7 days. The initial and continued germinations of the treatments are shown in Figure 34. Initial germination for the 20-minute immersion started at day two and were heightened from day four through day 28. The control, seeds that had no scarification, had very low germination.

Germination Treatments -- H_2SO_4 1997 *Lespedeza cuneata* Seed at 30°C

The results for each trial and the totals are shown in Table 11. The initial and continued germination of the treatments are shown in Figure 35. The initial and continued germination for any of the scarification treatments were increased when compared to seeds that had no scarification and which had very low germination.

Germination Treatments -- H_2SO_4 1996 and 1997 Seed Comparison

There was no significant difference between the hardness of the seed coat or the percentage of germinations from 1996 and 1997 as shown in Table 11 and Figure 36. (Refer also to Table A-26 for statistical analysis.) The timing of the germinations seemed to be sooner on the 1996 seed when compared to the 1997 seed.

Germination Treatments -- 1996 Seed Viability

The number of viable seeds determined by the tetrazolium test was recorded as shown in Table 12, then totaled with the number of germinated seed to obtain a total

ed viable percentage for the year 1996 (the year of seed production used for all other rmination tests). By combining the total germination of the H_2SO_4 1996 30°C eatment with the tetrazolium test, a total number of viable seeds out of 4000 seeds uld be approximated. (Refer to Table 12.) The total percentage of viable seed in 996 was approximately 59%. Some variation can be seen between treatments from e Control to the 20-minute treatment because some Control seed had possibly xpired whereas the 20-minute treatment seeds were allowed germinate immediately.

Table 11. Germination totals for H_2SO_4 1996 and 1997 *Lespedeza cuneata* seed at 30°C (86°F). Treatments were Control, 3-minute, 10-minute, and 20-minute immersion.

H_2SO_4 Treatments at 30°C								
	Control		3 Min.		10 Min		20 Min.	
Trial #	'96	'97	'96	'97	'96	'97	'96	'97
1	29	9	55	34	47	41	141	98
2	9	11	36	51	74	60	148	133
3	20	17	110	46	46	59	99	124
4	9	15	31	43	37	67	95	109
Total	67	52	232	174	204	227	483	464
Total %	7%	5%	23%	17%	20%	23%	48%	46%

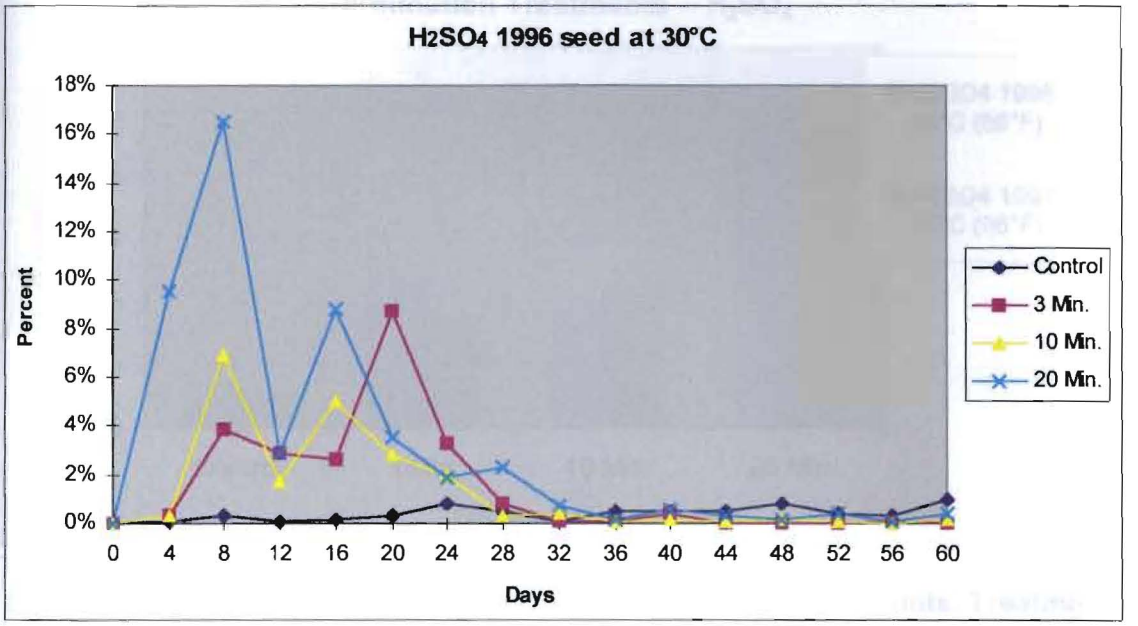

Figure 34. Germination time chart for H_2SO_4 1996 *Lespedeza cuneata* seed 30°C (86°F). Seedling emergence of the four treatments over a 60-day period.

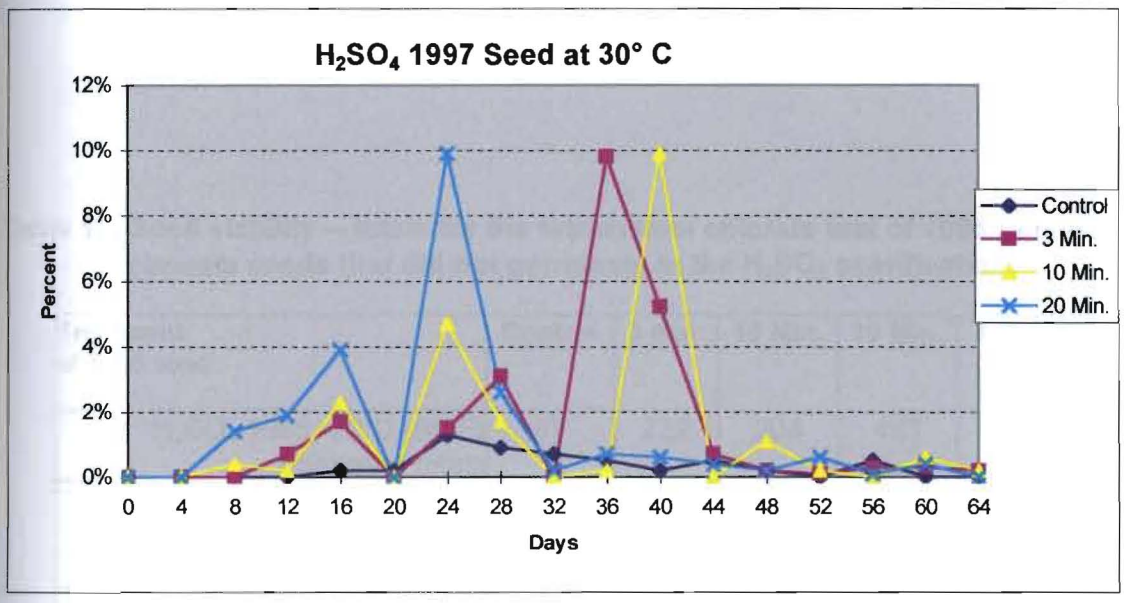

Figure 35. Germination time chart for H_2SO_4 1997 *Lespedeza cuneata* seed 30°C (86°F). Seedling emergence of the four treatments over a 60-day period.

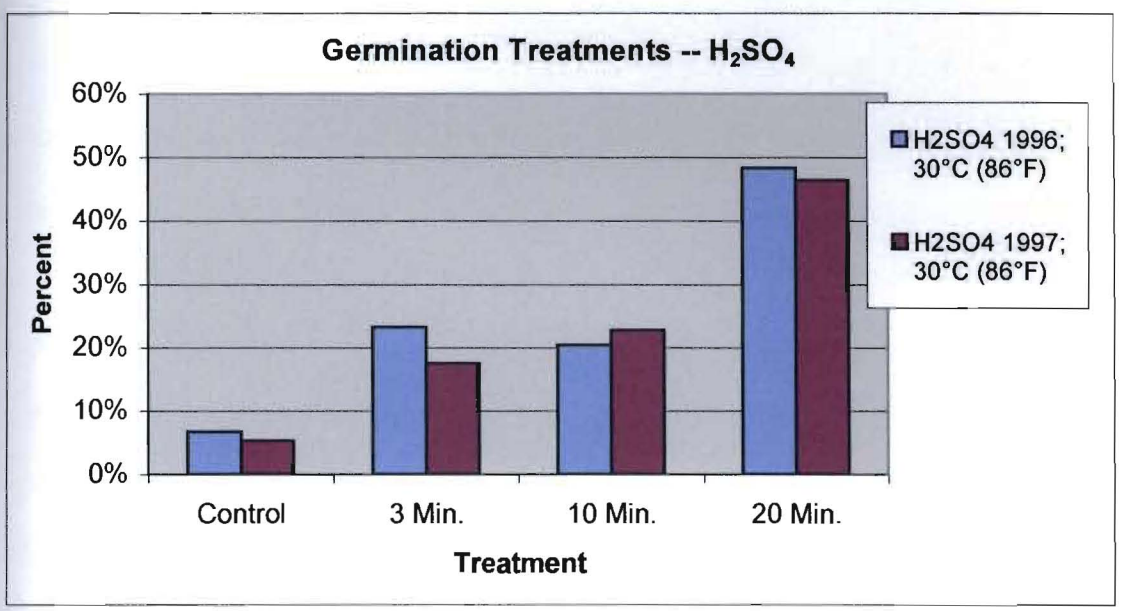

Figure 36. Germination percentages for H_2SO_4 1996 and 1997 seeds. Treatments were Control, 3-minute, 10-minute, and 20-minute immersion.

Table 12. Seed viability -- totals for the tetrazolium chloride test of 1996 *Lespedeza cuneata* seeds that did not germinate in the H_2SO_4 scarification.

Treatment of 1996 seed	**Control**	**3 Min.**	**10 Min.**	**20 Min.**	**Total** of 4000 seeds
H_2SO_4 1996; 30°C (86°F) treatment totals	67	232	204	483	707
Total Stained (Tetrazolium chloride)	342	434	445	355	1666
Total % Stained	34%	43%	45%	36%	42%
Total Living	**409**	**666**	**649**	**838**	**2373**
Total % Living	10%	17%	16%	21%	59%

CHAPTER 4 -- DISCUSSION

Seedling Emergence

Seeds shed from the *Lespedeza cuneata* plants are not mechanically or chemically scarified. What initiates germination of seeds that lie on the soil surface or fall in the shade dominated by prairie grasses?

Freeze/Thaw. Lespedeza cuneata seedling establishment is increased by soil microflora (Wade, 1989) breaking down the seed coat. Seed coats are also broken down by freeze/thaw cycles. McPherson, Kansas weather station data for the one-hundred year period of 1904 to 1994 and the months of November 1st to March 31st shows an average minimum temperature of 26°F. The average number of days in which the maximum temperature was greater or equal to 30°F was 135 days, and the average number of days in which the minimum temperature less than or equal to 29°F was 88 days. (Thirty degrees Fahrenheit was chosen to ensure a thorough freezing.) In the Emporia area (same latitude as McPherson), the average number of times the temperature dropped and rose should be similar during these months. Although my research only subjected the lespedeza seeds to three freeze/thaw cycles, it is likely that more freeze/thaw cycles would further break down the seed coat allowing the total number of germinations to increase beyond my data of 39%. The data on Figure 33 show that freezing and thawing has a favorable influence on *Lespedeza cuneata* germination. What is not favorable was the effect freezing had on the grasses. It is possible that this might be one of the factors that influences lespedeza dominance in the grasslands.

Temperature. In research done by Mosjidis (1990) and Qiu *et al.* (1995), using mechanically scarified seed, temperature had the greatest influence over germination. I also found in this study that increased temperatures also increased the germination percent of lespedeza seed (with the exception of the 30°C test) and decreased the germination percent of the grass seed. No explanation can be offered to indicate why the lespedeza germination was reduced for the trial one 30°C treatment when compared to the 25°C and 40°C treatments. (Refer to Table 8.) If trial one of the 30°C treatment were excluded, percentage of germination would be similar to the 25°C treatment.

The 40°C treatment increased the germination of the lespedeza and decreased the germination of the grasses. The local dark soils are certainly capable of reaching 40°C and above; lespedeza seeds would have no problem germinating if adequate moisture exists. During the clipping studies of the plant control treatments, seedlings were seen throughout the summer with the exception of the two hottest months of August and September. It was not noted if the spring seedlings survived the hot months of summer or if the fall seedlings survived the cold winter drought until spring.

Light. The light treatment did not significantly increase the germination of any species except *Sorghastrum nutans* when compared to the 25°C treatment used as a control. *Sorghastrum nutans* seed germination appears to be increased by light.

Water Potential. To create water stress, mannitol was used as an osmoticum to create negative water potentials of –1.01 MPa and –2.03 MPa. Wright *et al.* (1978) studied the effects of both temperature and water stress on cool season grasses and legumes, including *Lespedeza cuneata.* Their study did not include mechanical scarification of the lespedeza seed. They incubated the seeds at 28°C, and the highest

water stress was a -0.91 MPa, similar to that used in my study (25°C and –1.01 MPa). Results obtained by Wright *et al.* (1978) showed that emergence of lespedeza was poor or lacking by day 19. My data show for –1.01 MPa 5% total germination with first germination by day eight. The lespedeza did not germinate at –2.03 MPa due to the induced xeric conditions. There was not enough moisture for imbibition. The grass germinations were also reduced. *Andropogon gerardi* withstood any treatment given it, including mannitol at –2.03 MPa. Figure 27 shows the initial *Andropogon gerardi* germinations were delayed to day eight. The –1.01 MPa treatment returned the initial germination back to two days similar to the 25°C treatment.

Chemical Control. Germination of the grass seed under Escort® (metsulfuron methyl) was steady, but lespedeza germination gradually increased on the last two trials. (Refer to Table 9.) I suspect that because of the time between the initial test and the final test (four months had elapsed), the Escort® might have reacted with the water and was rendered less effective. In germination trials three and four, seed and seedlings appeared only to have swelled and exserted from the seed coat or totally escaped from the achene. According to the AOSA Seedling Evaluation Handbook (1992), the seeds on trials three and four are defined as "Bound by coat – roots may appear stubby as a result of being bound by the seed coat. Such seedlings are to be classified as normal." In trial three, 26 seedlings showed primordial root development as compared to the 41 'normal' seeds as defined by the above AOSA rule. In trial four, 48 seeds had primordial root development as compared to 57 normal seedlings. When compared to total germination in trial one and two, one would discredit the last two trials as faulty. According to the MSD sheets supplied, this chemical is taken up by contact; however, lespedeza seedling structures developed normally and some root elongation

was evident. (See Figure 30.) In a few cases, the lespedeza primordial root, upon touching the substrate, appeared to curl upward to avoid the Escort®. Dow Chemical was contacted several times in order to find out the functional life of the solution, but the company was recently restructured and no representative was available to answer questions. If trials three and four for lespedeza are disregarded, the percentage of germination would be five percent. Even that relatively high germination rate might have resulted from the water potential in the germination tray. Some lespedeza roots reached one-half inch long but afterwards lost their waxy sheen and became yellowed and wilted. The seedlings died shortly afterward. On the other hand, the grasses were healthy, almost appearing promoted, and developed secondary leaves and fine root hairs, with no decrease in germination percentage. *Andropogon scoparius* reached highest germination rates in this treatment.

Remedy™ (triclopyr) had a distinctive odor throughout the treatment and apparently remains effective longer in solution. Germination did not vary during any of the trials. Remedy™ was very detrimental to germination of both lespedeza and grasses. This would indicate that when used as a post-emergence spray in the spring, Remedy™ might prevent new lespedeza germination but would also have an equal effect on the grasses, perhaps even reducing their existing populations.

Fire. Temperatures during scheduled burns at the soil surface are around 300°F (150°C) for three to four minutes in the southern pine woods (Cushwa *et al.*, 1968). To determine if germination of *Cassia nictitans* (partridge pea) was induced during burns, Cushwa *et al.* (1968) treated *Cassia nictitans* and other legume seeds, namely *Lespedeza cuneata*, to varied dry and moist heat regimes. They first tested *Cassia nictitans* seeds using dry heat treatments, with either a decrease or no significant

increase in germination rate. Wet heat treatments were tried next at 80°C (176°F); germination percentage increased to 95%, as compared to the control with 12% germination. After determining that increased temperatures in association with a saturated atmosphere increased germination, a varied temperature regime, and *Lespedeza cuneata,* were included in their trials. Dry heat temperatures ranged from 45°C to 110°C; 45°C produced the best germinations for *Lespedeza cuneata* (93%), at 100°C germinations dropped (2%), and at 110°C there were no germinations (0%). Wet heat temperatures in their research ranged from 45°C to 98°C; 70°C obtained the best germination rates for *Lespedeza cuneata* (91%), and at 90°C germination was lowest (0%).

Segelquist (1971) also worked with *Lespedeza cuneata* seeds following the procedure of Cushwa *et al.* (1968) to determine if moist heat on *Lespedeza cuneata* seeds collected in the prairies of Oklahoma would increase germination. Temperatures used were 40, 60, 80, and 100°C. The best germination percentage (85%) was obtained at eight minutes at 100°C. Segelquist had no germination after 32 minutes at 100°C. I repeated Segelquist's study to determine if the same treatment would increase germination of lespedeza seed collected near the plant control sites in the clipping/burning treatments, but without success. I used the temperature of 100°C for six minutes that was selected based upon Segelquist's (1991) best germination data. My treatment time was divided between the eight minutes of Segelquist and the four minutes (at 150°C) of soil temperature forest burn in Cushwa *et al* (1968).

In my study, wet heat at 100°C was unsuccessful, although Segelquist's (1971) seed was reportedly to be also collected in a pasture. My failed results might have been better understood if Segelquist had used seed of crop/forage/improved variety

Lespedeza cuneata, which are notably larger and plumper, instead of the common Asian *Lespedeza cuneata* of our prairies. Immediately after the heat treatment, the grass seed showed no visible differences in morphology from seeds that had no treatment. The treated lespedeza seeds were visibly swollen and the seed coat split with the lighter colored embryo visible. There was no germination of *Lespedeza cuneata* or the grass seeds after incubation. I did no repeats of this particular treatment because this technique apparently was not valid for the seeds collected near my study site; my results were similar to those obtained by Cushwa *et al.* (1968).

Because Wright and Bailey (1982) had indicated that soil temperatures during grassland burns usually fall between 102-388°C (with the average at 143°C and some extremes of 682°C caused by wind), I also attempted an exposure of the lespedeza seed and the native grasses to a dry 400°C treatment of passing the seeds through a flame until the Omaga digital thermometer registered the target temperature. Soil temperatures during a grass fire do not seem to be affected by air temperature, soil moisture, or relative humidity. Peak temperatures during a burn rise rapidly and are attained within one minute on average and gradually diminish to around 100°C in about five minutes. Temperatures slightly below the soil surface, 1 mm to 0.3 cm (0.04 to 0.12 inch) rise only to 66-79°C. Grass seeds can survive to 116°C up to five minutes [Samson, 1944, as cited in Wright and Bailey (1982)]. Seeds with hard seed coats should be able to survive 140°C or higher (Wright and Bailey, 1982).

Germination results for the 400°C treatment showed that *Andropogon scoparius* (Little Bluestem) was the only species to germinate (4%). Studies by Wink and Wright (1973) [as cited in Wright and Bailey (1982)] indicated *Andropogon scoparius* germination increased 58% by burning during dry seasons. However, these results for

Andropogon scoparius did not continue for the 200°C and 100°C treatments. The subsequent treatments did not support the hypothesis that fire increases seed germination or resistance in the grasses or the lespedeza.

All burn treatments had only one trial because the methods I used were not successful in demonstrating that seed germination of any of the species, especially lespedeza, was promoted by fire. However, when looking at results from the plant control treatments (Table 6), the number of ramets per square meter was increased significantly after a one-time burn in the spring. This number included any ramet or seedling over 5 cm in height. The number of seedlings, evidenced by the presence of cotyledons, was not noted. The means of plant control treatment ramet weight per square meter (Table 7), show that the biomass increased from pre-burn to post-burn, but not significantly. The ramet count means from pre- to post-burn, which did increase significantly, might include seedlings that germinated because of the fire.

Leachate. The lespedeza filtrate (equivalent to fresh leaves at peak tannin levels), when applied to both the grass seeds and the lespedeza seeds, did not affect the germination percentage of either the grasses or the lespedeza.

Seed Hardness/Viability. Concentrated sulfuric acid (H_2S0_4) was used to chemically scarify the lespedeza seed. Seeds were separated from each quadrant by a partition to prevent any soluble seed inhibitors from leaching and affecting the other treatments. [The *Lespedeza cuneata* seed apparently has a germination and growth inhibitor in the seed coat that can be leached out by immersing for several hours in water (Buta and Lusby, 1986). These authors did not mention if these inhibitors existed in the leaves and stems of the developed lespedeza plants. After 60 days of incubation, the seeds were again put into 5°C in order to maintain the integrity of the seeds until a tetrazolium

test for dehydrogenase activity could be conducted on the remainder of the seeds. It should be noted that a seed that stained red in the tetrazolium solution does not necessarily indicate that the seed has the ability to produce a normal seedling if germination requirements had been met, but the staining does indicate that some tissues in the seed are respiring. Because the total percent of viable lespedeza seed was previously determined to be 59%, I believe that some of the lespedeza seed expired after the H_2SO_4 treatment and before the tetrazolium test could be used; if a tetrazolium test could have been used to test the seed immediately after collection from the field, the viability would have been higher.

Plant Control Methods

Control. The control counts increased by 5% but the mean weight increased significantly by 54%. So although not many ramets were produced the next year, the biomass of the plants increased significantly. (Refer to Table 6, Table 7, Figure 20, and Figure 21.) This indicates the plant reserves were increased.

Mowing/Clipping. Dudley and Fick (1996) indicated a reduction of stem counts by 50% after early season mowing. My results from two early season clippings resulted in only a 17% reduction in ramet counts from pre- to post-treatment, and an 8% reduction in ramet counts per squared meter was obtained in the treatment that was clipped every 30 days until leaf abscission. (Refer to Table 6 and Figure 20.) Secondary shoot production increased in my study as was found in Hoveland and Anthony's study (1974). (See Figure 37.) However, these secondary shoots were clipped at the next 30-day clipping if they extended 5 cm above the soil surface. No significant difference between the amount of biomass reduction (ramet weight per square meter) between the two clipping treatments existed, although both clipping treatments resulted in a

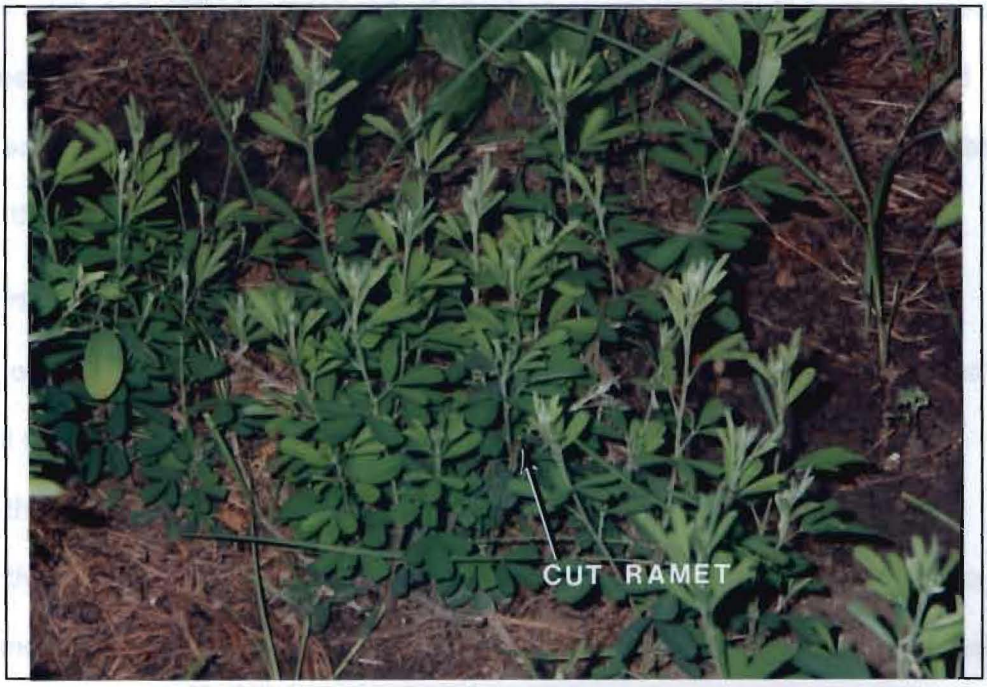

Figure 37. Plant control treatments -- *Lespedeza cuneata* clipped with secondary shoot production.

significant (69% and 72%) biomass reduction when comparing pre- to post-treatment means, respectively. (Refer to Table 7 and Figure 21.) Root reserves still remained because secondary shoots were still being produced at the last clipping in September; however, the production was small (0.736 grams per square meter) in October.

Burning. Spring burning used as a control method by Dudley and Fick (1996) showed no significant reduction in the lespedeza stem count. My research indicated a significant increase in ramet count when burning occurred only once in the spring, although the biomass produced after this spring burn was increased but not significantly. This would lead one to speculate that either the plant was promoted to produce more ramets, or seeds were promoted by fire to germinate, thereby increasing the count by an increased number of seedlings. After burning the pasture once in spring and again during August, the ramet count was reduced the following spring but not significantly. When visually comparing the burn twice treatment to the control in the summer of 1998, a notable decrease in the amount of biomass could be seen. (See Figures 38 and 39.)

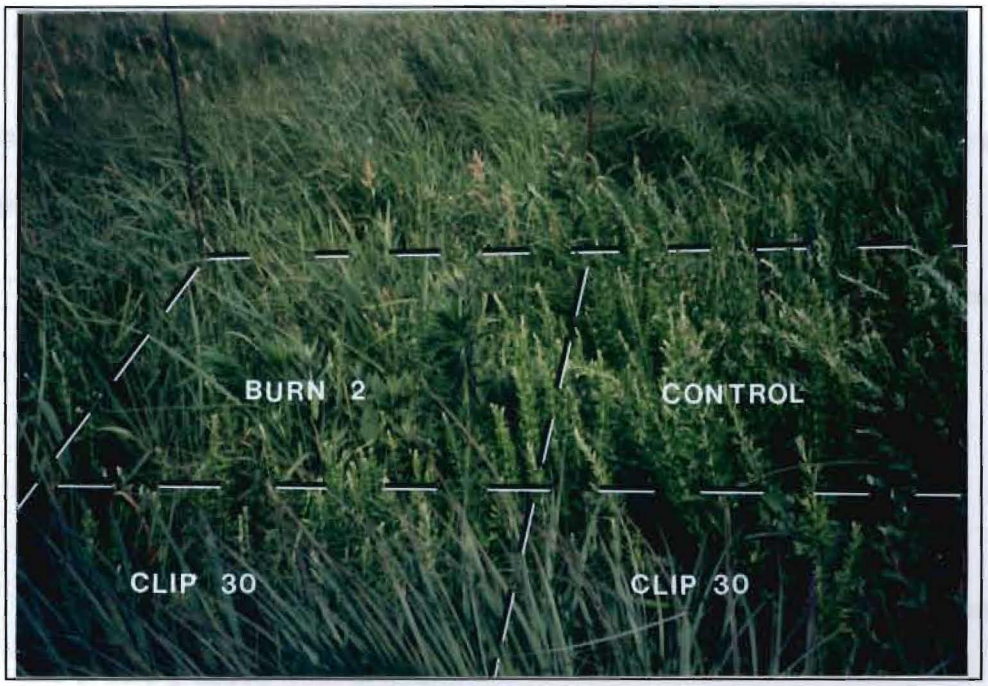

Figure 38. Plant control treatments -- *Lespedeza cuneata* spring comparison between Burn 2X, Clip Every 30 Days, and Control treatments.

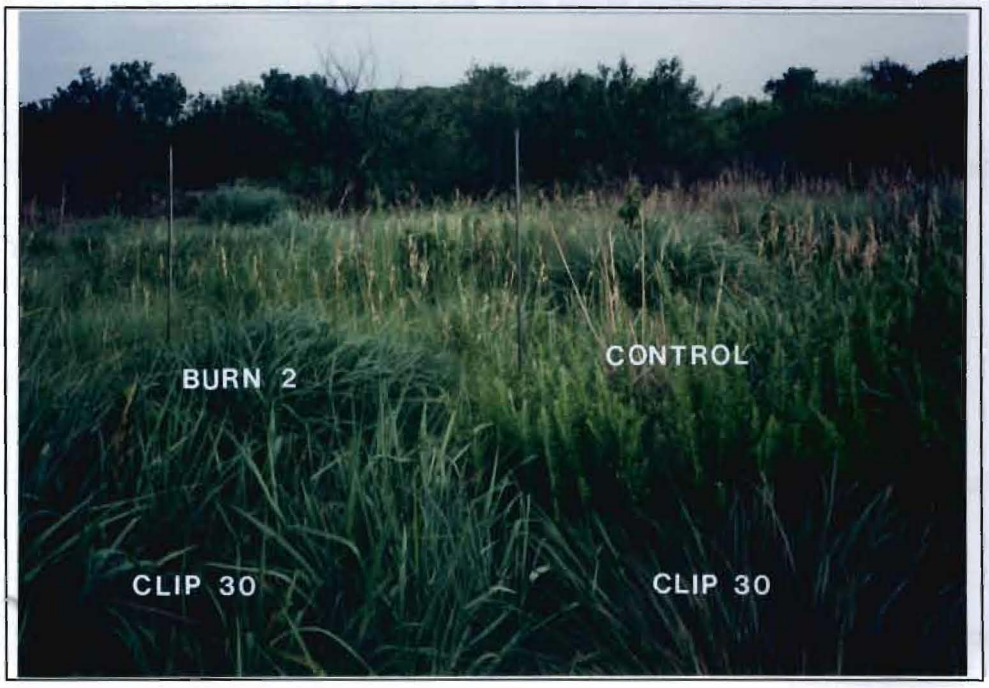

Figure 39. Plant control treatments -- *Lespedeza cuneata* mid-summer comparison between Burn 2X, Clip Every 30 Days, and Control treatments.

CHAPTER 5 -- CONCLUSIONS

Some of the statistically significant factors that influence *Lespedeza cuneata's* minance in the Flint Hills area are as follows:

1. Burning once in spring promotes *Lespedeza cuneata* either in ramet numbers or through increased seed germination.
2. Severe clipping in June and July can decrease the amount of biomass produced by *Lespedeza cuneata*.
3. The xylem water potential in *Lespedeza cuneata* can decrease to half that of the prairie grasses without death.
4. *Lespedeza cuneata* will not germinate under low water potential; however, *Andropogon gerardi* will germinate. This might explain why *Andropogon gerardi* survives in dry years.
5. Freezing and thawing of the lespedeza seed favors germination, but does not favor the grasses.
6. The herbicide Escort® favors the germination of the grasses but not the *Lespedeza cuneata*.
7. The herbicide Remedy™ prohibits germination of both the *Lespedeza cuneata* and the grasses.
8. *Lespedeza cuneata* leaf leachate/filtrate does not inhibit germination of its own seeds or the germination of the grasses.

eneral Observations

Lespedeza does not require much light for metabolism (Brown and Radcliffe, 86). The grassland might afford a unique niche for lespedeza establishment. Dark, oist, and warm conditions exist in the clump of bunch grasses, and this I have served more than once, single seedlings 20 to 30 cm tall emerging from the center of large bunch of *Sorghastrum nutans* (Indiangrass). (See Figure 40.) The accepted otion of a struggle for resources during establishment of a single seedling (the spedeza) in an already established tight community of grasses might be negated ecause of this unique niche being offered by the grasses.

The adaptation of *Lespedeza cuneata* to the Flint Hills region and further west and orth appears to be evident. The plant is cold-hardy and is able to withstand long eriods of temperatures below freezing. Guernsey's (1970) note that the plant requires ainfall amounts of 30 to 35 inches appears to be negated when observing the maximum and minimum xylem water potential values obtained in this study (refer to Appendix; Preliminary Investigations) in comparing the grasses to the lespedeza. The lespedeza would seem to be able to withstand longer periods with less water than the grasses.

Recommendations

The lespedeza plants used in this study were first cut when the ramets were, on the average, 15.6 inches high. The best treatment for significantly reducing both the number of ramets and the amount of biomass produced per meter was by two severe (5 cm height) cuttings, once in mid-June and the second, thirty days later, in mid-July. As Dodd *et al.* (1948) and Guernsey (1970) indicated, the lespedeza forage should not be mowed below three inches in order to maintain viability of the stand. The logistics of

Figure 40. Plant control treatments -- *Lespedeza cuneata* emerging from a dense clump of *Sorghastrum nutans*.

owing to a 5 cm height on native pastures is beyond the capability of normal haying quipment. Most pastures are not conducive to haying or mowing because rock tcrops and slopes are a problem. Lespedeza is usually first established in the trees, rush, creek bottoms, and draws (Kilgore, KSU Ext. Services, personal communication; hlenbusch, KSU, personal communication). Seed is conveyed to these areas by ntered cattle coming off an infested pasture, as well as deer, birds, and small ammals.

Because these areas cannot be mowed, another method of severe clipping must e innovated by the rancher. Animals such as goats, and deer, will eat browse, cluding stems of lespedeza. Goats are presently being studied as a control measure r hedge, cedars, and lespedeza. The goats do not compete with the cattle for grass unless raised only on grass); thus the two types of livestock can be placed in the same addock or pasture. When raised together, the cattle and goats can bond (Hulet *et al.*, 989; 1991). Using goats allows the clipping of the lespedeza, even in draws and reeks, to control seed production and reduce the stand's vigor. No study, including this ne, indicates that continuous clipping can eradicate *Lespedeza cuneata*. Using goats ould make the stands manageable, thereby reducing the cost of herbicides and their pplication. Stopping seed production is a major step in control. The weight gain on the marketable goats is an additional financial incentive to use this management method.

Cattle will graze the lespedeza if it is no higher than fourteen inches, to avoid ncreased tannins (leaves) and indigestible crude proteins (stems); thus the rancher might employ a rest/rotation method of grazing. The grasses and the lespedeza could be hit hard for one season, with the rest period during the following year in order to allow the vigor of the grasses to increase. In that year of rest, spring burning is

recommended to promote *Lespedeza cuneata* seedlings. Additionally, Remedy™, the preferred post-emergence herbicide, could be used on the lespedeza, or if goats were employed, the goats could be paddocked to employ at least two clippings of the lespedeza. The rancher must ensure enough forage for the goats and move the livestock off before grazing of the grass occurs. Escort® could also be used after grazing in the fall if the populations of lespedeza were noted or marked as to location, and then the Escort® residue would still be active the following spring until soil temperatures rise.

Cattle do not actively seek the lespedeza and, when offered a choice, prefer to graze the prairie grasses. This choice of forage always has the effect of decreasing the grass quantity and allowing the lespedeza greater advantage for resources. In periods of drought, in which the lespedeza appears a superior competitor, the grasses can experience further stress. The only alternative would be to use browsers unless the cattle were tightly paddocked per Savory and Parson's (1980) method of grazing rotation, and the rest/rotated method of subsequent seasonal rest (Merrill, 1954; Hormay, 1961) in combination with herbicide application when needed.

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APPENDIX

Climatological Data of 1997 and 1998

Table A-1. Weather data for years 1997 and 1998 showing the monthly average temperature highs (°F), average temperature lows (°F), and average precipitation (inches).

Weather Data '97/'98		Average High °F	Average Low °F	Precipitation (Inches)
Jan.	1997	38	18	0.1
Feb.		42	28	2.85
Mar.		59	35	1.07
April		60	39	3.7
May		74	49	4.02
June		85	61	3.58
July		89	68	4.47
Aug.		84	66	3.57
Sept.		82	59	2.19
Oct.		68	47	3.92
Nov.		50	33	1.56
Dec.		40	27	3.02
				Total Precipitation - 34.05
Jan.	1998	39	27	0.17
Feb.		47	32	0.62
Mar.		46	32	3.23
April		63	43	2.29
May		84	59	2.25
June		87	64	4.42
July		90	70	8.68
Aug.		93	65	0.49
Sept.		88	62	9.61
Oct.		69	48	8.86
Nov.		58	40	7.85
Dec.		46	26	1.1
				Total Precipitation - 49.57

Climatological Statistics of 1997 and 1998

Analysis of 1997 and 1998 average high temperatures for plant control treatments:

Table A-2. Weather Data -- Average High Temperatures ANOVA

ANOVA: Single Factor -- Average High Temperature '97/'98						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
1997	12	771	64.25	352.5682		
1998	12	810	67.5	409		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	63.375	1	63.375	0.166433	0.687245	4.300944
Within Groups	8377.25	22	380.7841			
Total	8440.625	23				

Ho: The mean high temperatures of 1997 and 1998 are equal.

F-table 0.05 (1), 1, 22 = 4.30; F-cal.= 0.166433. F-cal. < F-table; Do not reject the Ho:

P > 0.25 (P=0.687245).

Ha: The mean high temperatures of 1997 and 1998 are not equal.

Analysis of 1997 and 1998 average low temperatures for plant control treatments:

Table A-3. Weather Data -- Average Low Temperatures ANOVA

ANOVA: Single Factor -- Average Low Temperature '97/'98						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
1997	12	530	44.16667	277.7879		
1998	12	568	47.33333	260.6061		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	60.16667	1	60.16667	0.223504	0.641039	4.300944
Within Groups	5922.333	22	269.197			
Total	5982.5	23				

Ho: The mean low temperatures of 1997 and 1998 are equal.

F-table 0.05 (1), 1, 22 = 4.30; F-cal.= 0.223504. F-cal. < F-table; Do not reject the Ho:

P > 0.25 (P=0.641039).

Ha: The mean low temperatures of 1997 and 1998 are not equal.

Analysis of 1997 and 1998 average precipitation for plant control treatments:

Table A-4. Weather Data -- Average Precipitation ANOVA

ANOVA: Single Factor -- Average Precipitation '97/'98						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
1997	12	34.05	2.8375	1.797239		
1998	12	49.57	4.130833	13.19914		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	10.03627	1	10.03627	1.338492	0.259708	4.300944
Within Groups	164.9601	22	7.498187			
Total	174.9964	23				

Ho: The mean precipitation of 1997 and 1998 are equal.

F-table 0.05 (1), 1, 22 = 4.30; F-cal.= 1.338492. F-cal. < F-table; Do not reject the Ho:

P > 0.25 (P=0.259708).

Ha: The mean precipitation of 1997 and 1998 are not equal.

Ramet Height Data and Statistic of First Clipping

Analysis of spring and fall 1997 for ramet height in clipping treatments.

Table A-5. Ramet Height Data

Spring '97		Fall '97		*Spring '97*		Fall '97		*Spring '97*		Fall '97	
Plot #1-0		Plot #0-2		Plot #0-3		Plot #1-3		Plot #5-7.5		Plot #6-10	
Size Inch	*Frequency*	*Size Inch*	*Frequency*	*Size Inch*	*Frequency*	*Size Inch*	*Frequency*	*Size Inch*	*Frequency*	*Size Inch*	*Frequency*
0	0	0	0	0	0	0	0	0	0	0	0
3	3	4	4	3	10	4	4	3	4	4	5
4	10	5	2	5	2	5	3	6	2	6	3
5	9	6	3	8	2	6	1	8	3	7	3
6	10	7	5	9	3	7	4	10	17	8	2
7	5	8	7	10	5	8	4	11	4	9	3
8	11	9	9	12	14	9	4	12	13	11	2
9	4	10	10	14	6	10	2	13	6	12	7
10	5	11	8	15	6	11	2	14	5	13	8
11	6	12	3	16	5	12	9	15	14	14	4
12	6	13	4	18	20	13	2	16	7	15	2
13	6	14	5	19	11	14	10	17	7	16	2
14	7	15	5	20	20	15	2	18	13	17	6
15	12	16	14	22	13	16	4	19	7	18	8
16	6	17	9	23	3	17	4	21	7	19	4
17	13	18	2	24	4	18	5	22	2	20	6
18	9	19	6	25	1	19	2	23	3	21	5
19	6	20	4	26	1	20	4	26	4	22	4
20	14	21	13	27	1	21	2	30	1	23	8
21	6	22	5	29	1	22	7			24	8
22	14	23	10	31	1	23	8			25	4
23	7	24	9			24	10			26	4
24	8	25	8			25	5			27	6
25	9	26	12			26	7			28	3
26	4	27	6			27	9			29	2
27	8	28	6			28	8			30	3
28	4	29	6			29	6			31	3
29	3	30	5			30	4			32	7
30	3	31	4			31	4			33	5
31	2	33	3			32	3			34	6
32	1	34	3			33	6			35	4
34	1	35	2			34	4			36	2
		36	2			35	2			37	3
		37	3			36	4			38	1
		39	2			37	4			39	2
		40	1			39	7			48	1
		41	3			41	4				
		42	1			42	3				
		43	1			43	1				
		44	2			44	1				
		45	1			45	1				
		46	1			47	2				
		47	1			49	2				
		48	1								
		49	1								
		56	1								
Count	**213**		**213**		**130**		**180**		**119**		**146**
Mean=	16		21		16		24		15		22
Mode =	20		16		18		14		10		13
Median =	17		21		18		24		15		22

Table A-6. Ramet Height Analysis

t-Test: Paired Two Sample for Means		
SIZED CLIPPINGS - Inches	*Fall '97*	*Spring '97*
Mean	22.33333333	15.66666667
Variance	2.333333333	0.333333333
Observations	3	3
Pearson Correlation	0.188982237	
Hypothesized Mean Difference	0	
df	2	
t Stat	7.55928946	
P(T<=t) one-tail	0.008526813	
t Critical one-tail	2.91998731	
P(T<=t) two-tail	0.017053626	
t Critical two-tail	4.302655725	

Ho: There is no difference between the population size of Fall 1997 and the population size of Spring 1997 ($\mu_{d'FALL97} = \mu_{d'SPRING97}$).

T-table 0.05 (1), 2 =2.920; t-cal.= 7.55928946. T-cal. > t-table; Reject the Ho: 0.01 > P > 0.005 (P=0.008526813).

Ha: There is a difference between the population size of Fall 1997 and the population size of Spring 1997 ($\mu_{d'FALL97} \neq \mu_{d'SPRING97}$). The ramets were not fully grown upon the first clipping treatment.

Treatment Statistics of Ramet Counts

The following tables list the analysis of the treatments using the paired-plot statistic.

Table A-7. Ramet Count of Control Treatment -- Paired Plot Analysis

t-Test: Paired Two Sample for Means		
CONTROL	*Spring '98*	*Spring 97*
Mean	260.6	247.8
Variance	24684.48889	16747.51111
Observations	10	10
Pearson Correlation	0.931112489	
Hypothesized Mean Difference	0	
df	9	
t Stat	0.677578601	
P(T<=t) one-tail	0.257538924	
t Critical one-tail	1.833113856	
P(T<=t) two-tail	0.515077847	
t Critical two-tail	2.262158887	

Ho: There is no difference between the control population size of Spring 1998 and the population size of Spring 1997 ($\mu_{d'98} = \mu_{d'97}$).

T-table 0.05 (1), 9 = 1.833; t-cal.= 0.67758. T-cal. < t-table; Do not reject the Ho: P > 0.25 (P=0.257538924). The treatment had no detrimental effect on the plant population.

Ha: There is a difference between the control population size of Spring 1998 and the population size of Spring 1998 ($\mu_{d'98} \neq \mu_{d'97}$).

Table A-8. Ramet Count of Burn One Time Treatment -- Paired Plot Analysis

t-Test: Paired Two Sample for Means		
BURN 1X Spring	*Spring '98*	*Spring 97*
Mean	376.9	281.3
Variance	33746.1	20500.23
Observations	10	10
Pearson Correlation	0.966289102	
Hypothesized Mean Difference	0	
df	9	
t Stat	5.172952828	
P(T<=t) one-tail	0.000292422	
t Critical one-tail	1.833113856	
P(T<=t) two-tail	0.000584845	
t Critical two-tail	2.262158887	

Ho: There is no difference between the burn one time population size of Spring 1998 and the population size of Spring 1997 ($\mu_{d'98} = \mu_{d'97}$).

T-table 0.05 (1), 9 = 1.833; t-cal.= 5.172952828. T-cal. > t-table; Reject the Ho: P < 0.0005 (P=0.000292422).

Ha: There is a difference between the burn one time population size of Spring 1998 and the population size of Spring 1997 ($\mu_{d'98} \neq \mu_{d'97}$). Traditional spring burning increased the mean number of ramets per plot by 15.6.

Table A-9. Ramet Count of Burn Two Times Treatment -- Paired Plot Analysis

t-Test: Paired Two Sample for Means		
BURN 2X Spring/Fall	*Spring '98*	*Spring 97*
Mean	255.6	275.6
Variance	34432.04444	26487.37778
Observations	10	10
Pearson Correlation	0.928918028	
Hypothesized Mean Difference	0	
df	9	
t Stat	-0.911584645	
P(T<=t) one-tail	0.192876582	
t Critical one-tail	1.833113856	
P(T<=t) two-tail	0.385753165	
t Critical two-tail	2.262158887	

Ho: There is no difference between the burn two times population size of Spring 1998 and the population size of Spring 1997 ($\mu_{d'98} = \mu_{d'97}$).

T-table 0.05 (1), 9 = 1.833; t-cal.= -0.911584645. T-cal. < t-table; Do not reject the Ho:

0.25 > P > 0.10 (P=0.192876582).

Ha: There is a difference between the burn two times population size of Spring and the population size of Spring 1997 ($\mu_{d'98} \neq \mu_{d'97}$).

Table A-10. Ramet Count of Clip June/July Treatment -- Paired Plot Analysis

t-Test: Paired Two Sample for Means		
Clip June/July	*Spring '98*	*Spring 97*
Mean	293.6	325.8
Variance	21504.48889	24023.06667
Observations	10	10
Pearson Correlation	0.899506034	
Hypothesized Mean Difference	0	
df	9	
t Stat	-1.495176906	
P(T<=t) one-tail	0.084540565	
t Critical one-tail	1.833113856	
P(T<=t) two-tail	0.169081131	
t Critical two-tail	2.262158887	

Ho: There is no difference between the Clip June/July population size of Spring 1998 and the population size of Spring 1997 ($\mu_{d'98} = \mu_{d'97}$.

T-table 0.05 (1), 9 = 1.833; t-cal.= -1.495176906. T-cal. < t-table; Do not reject the Ho: The treatment has not reduced the numbers of ramets.

0.10 > P > 0.05 (P=0.084540565).

Ha: There is a difference between the Clip June/July population size of Spring 1998 and the population size of Spring 1997 ($\mu_{d'98} \neq \mu_{d'97}$).

Table A-11. Ramet Count of Clip Every 30 Days – June-Sept. Treatment -- Paired Plot Analysis

t-Test: Paired Two Sample for Means		
CLIP EVERY 30 DAYS – June-Sept.	*Spring '98*	*Spring 97*
Mean	277.1	300.3
Variance	13977.21111	18895.56667
Observations	10	10
Pearson Correlation	0.855022818	
Hypothesized Mean Difference	0	
df	9	
t Stat	-1.029112986	
P(T<=t) one-tail	0.165144418	
t Critical one-tail	1.833113856	
P(T<=t) two-tail	0.330288837	
t Critical two-tail	2.262158887	

Ho: There is no difference between the Clip Every 30 Days – June-Sept. population size of Spring 1998 and the population size of Spring 1997 ($\mu_{d'98} = \mu_{d'97}$).

T-table 0.05 (1), 9 = 1.833; t-cal.= -1.029112986. T-cal. < t-table; Do not reject the Ho:

0.25 > P > 0.10 (P=0.165144418).

Ha: There is a difference between the Clip Every 30 Days – June-Sept. population size of Spring 1998 and the population size of Spring 1997 ($\mu_{d'98} \neq \mu_{d'97}$).

The variables were also analyzed using a two-way analysis of variance, analyzing if an interaction existed between treatment and years.

Table A-12. Ramet Count -- Plant Control Treatments vs. Years 2-Way ANOVA

ANOVA: Two-Factor With Replication						
SUMMARY	Control	Burn 1X Spring	Burn 2X Spring/Fall	Clip mid-June/Mid-July	Clip Every 30 Days	Total
Count *Spring 97*	10	10	10	10	10	50
Sum	2478	2813	2756	3258	3003	14308
Average	247.8	281.3	275.6	325.8	300.3	286.16
Variance	16747.51	20500.23	26487.38	24023.07	18895.57	20278.83
Count *Spring '98*	10	10	10	10	10	50
Sum	2606	3769	2556	2936	2771	14638
Average	260.6	376.9	255.6	293.6	277.1	292.76
Variance	24684.49	33746.1	34432.04	21504.49	13977.21	25561.33
Count *Total*	20	20	20	20	20	
Sum	5084	6582	5312	6194	5774	
Average	254.2	329.1	265.6	309.7	288.7	
Variance	19668.8	28100.73	28961.83	21838.54	15712.96	
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
(years) Sample	1089	1	1089	0.046341	0.830045	3.946866
(treatmt) Columns	75882.64	4	18970.66	0.807269	0.523729	2.47293
(a x b) Interaction	55302.4	4	13825.6	0.588328	0.67192	2.47293
(error) Within	2114983	90	23499.81			
Total	2247257	99				

Ho: There is no effect of treatment on the mean of plants in the population sampled.

F-cal. 0.8073; F-table 0.05(1),4,90 = 2.47; F-cal. < F-table; Fail to reject the Ho:.

P > 0.25 (P = 0.523729).

Ho: There is no difference in the mean concentration of plants between years "97 and '98.

F-cal. 0.0463; F-table 0.05(1),1,90 = 3.95; F-cal. < F-table; Fail to reject the Ho:.

P > 0.25 (P = 0.830045).

Ho: There is no interaction of years and treatment affecting the mean concentration of plants in the population sampled.

F-cal. 0.5883; F-table 0.05(1),4,90 = 2.47; F-cal. > F-table; Fail to reject the Ho:.

P > 0.25 (P = 0.67192).

Treatment Statistics on Ramet Weight

The following tables list the analysis of the treatments using the paired-plot statistic.

Table A-13. Ramet Weights Control Treatment -- Paired Plot Analysis

t-Test: Paired Two Sample for Means		
CONTROL	*Fall '98*	*Fall '97*
Mean	263.3	121.875
Variance	9280.013333	5344.595833
Observations	4	4
Pearson Correlation	0.987315852	
Hypothesized Mean Difference	0	
df	3	
t Stat	10.55506587	
P(T<=t) one-tail	0.000908238	
t Critical one-tail	2.353363016	
P(T<=t) two-tail	0.001816475	
t Critical two-tail	3.182449291	

Ho: There is no difference between the control population weight of Fall 1998 and the population weight of Fall 1997 [$\mu_{d'98} = 0$ ($\mu_{d'97}$)].

T-table 0.05 (1), 3 = 2.35; t-cal.= 10.55506587. T-cal. > t-table; Reject the Ho: 0.0005 < P < 0.001 (P=0.000908238).

Ha: There is a difference between the control population weight of Fall 1998 and the population weight of Fall 1997 [$\mu_{d'98} \neq 0$ ($\mu_{d'97}$)]. The mean weight of the control plots increased by 141.4 grams.

Table A-14. Ramet Weights Burn One Time Treatment -- Paired Plot Analysis

t-Test: Paired Two Sample for Means		
BURN ONE TIME Spring	*Fall '98*	*Fall '97*
Mean	290.6	216.4
Variance	20907.75	10467.48
Observations	3	3
Pearson Correlation	0.98943269	
Hypothesized Mean Difference	0	
df	2	
t Stat	2.80407581	
P(T<=t) one-tail	0.053564485	
t Critical one-tail	2.91998731	
P(T<=t) two-tail	0.107128971	
t Critical two-tail	4.302655725	

Ho: There is no difference between the Burn One Time population weight of Fall 1998 and the population weight of Fall 1997 ($\mu_{d'98} = \mu_{d'97}$).

T-table 0.05 (1), 2 = 2.92; t-cal.= 2.80407581. T-cal. < t-table; Do not reject the Ho: The treatment had no affect on the reduction of plant biomass.

$0.05 < P < 0.1$ (P=0.053564485).

Ha: There is a difference between the Burn One Time population weight of Fall 1998 and the population weight of Fall 1997 ($\mu_{d'98} \neq \mu_{d'97}$).

Table A-15. Ramet Weights Clip June/July Treatment -- Paired Plot Analysis

t-Test: Paired Two Sample for Means		
CLIP JUNE/JULY	*June '98*	*June '97*
Mean	39.78	129.62
Variance	142.864	1658.935111
Observations	10	10
Pearson Correlation	0.683529155	
Hypothesized Mean Difference	0	
df	9	
t Stat	-8.42806403	
P(T<=t) one-tail	7.28053E-06	
t Critical one-tail	1.833113856	
P(T<=t) two-tail	1.45611E-05	
t Critical two-tail	2.262158887	

Ho: There is no difference between the Clip June/July population weight of June 1998 and the population weight of June 1997 ($\mu_{d'98} = \mu_{d'97}$).

T-table 0.05 (1), 9 = 1.833; t-cal.= -8.42806403. T-cal. < t-table; Reject the Ho: $P < 0.0005$ ($P=0.00000728$).

Ha: There is a difference between the Clip June/July population weight of June 1998 and the population weight of June 1997 ($\mu_{d'98} \neq \mu_{d'97}$). The treatment has reduced the mean weight of the plants by 89.84 grams.

Table A-16. Ramet Weights Clip Every 30 Days – June-Sept. Treatment -- Paired Plot Analysis

t-Test: Paired Two Sample for Means		
CLIP EVERY 30 DAYS – JUNE-SEPT.	*June '98*	*June '97*
Mean	34.92	124.71
Variance	540.244	9075.605444
Observations	10	10
Pearson Correlation	0.759501938	
Hypothesized Mean Difference	0	
df	9	
t Stat	-3.59092564	
P(T<=t) one-tail	0.002915173	
t Critical one-tail	1.833113856	
P(T<=t) two-tail	0.005830347	
t Critical two-tail	2.262158887	

Ho: There is no difference between the Clip Every 30 Days – June-Sept. population weight of June 1998 and the population weight of June 1997 ($\mu_{d'98} = \mu_{d'97}$). T-table 0.05 (1), 9 = 1.833; t-cal.= -3.59092564. T-cal. < t-table; Reject the Ho: 0.0025 < P < 0.005 (P=0.002915173).

Ha: There is a difference between the Clip Every 30 Days – June-Sept. population weight of June 1998 and the population weight of June 1997 ($\mu_{d'98} \neq \mu_{d'97}$). The treatment has reduced the mean weight of the plants by 89.79 grams.

Germination Statistics for Treatments (with the exception of the Heat/Fire Treatments)

The following table lists the ANOVA of the germination treatments. The pre-chill treatment at 5° C and all Heat/Fire Treatments were not included in these statistical tests.

Table A-17. Germination Treatments for *Lespedeza cuneata* -- One-Way ANOVA

LESCU - ANOVA: Single Factor	SUMMARY					
Groups	*Count*	*Sum*	*Average*	*Variance*		
25°C (77°F)	4	184	46	78		
30°C (86°F)	4	128	32	238		
40°C (104°F)	4	295	73.75	299.5833		
Light; 25°C (77°F)	4	237	59.25	1695.583		
Freeze/Thaw; 30°C (86°F)	4	393	98.25	933.5833		
Mannitol –2.03 mPa; 25°C (77°F)	4	2	0.5	0.333333		
Mannitol –1.01 mPa; 25°C (77°F)	4	54	13.5	35		
Escort; 30°C (86°F)	4	121	30.25	515.5833		
Remedy; 30°C (86°F)	4	2	0.5	1		
Leachate; 30°C (86°F)	4	214	53.5	999		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	36388.5	9	4043.167	8.430875	3.78E-06	2.210697
Within Groups	14387	30	479.5667			
Total	50775.5	39				

Ho: There is no effect of treatment on the means of the germination requirements in the population sampled.

F-cal. = 8.430875; F-table 0.05(1),9,30 = 2.21; F-cal. > F-table; Reject the Ho:

P < 0.0005 (P=0.00000378).

Ha: There is an effect of treatment on the means of all germinations conducted.

Table A-18. Germination Treatments for *Andropogon gerardi* -- One-Way ANOVA

ANGE - ANOVA: Single Factor	SUMMARY					
Groups	*Count*	*Sum*	*Average*	*Variance*		
25°C (77°F)	4	716	179	8.666667		
30°C (86°F)	4	666	166.5	59		
40°C (104°F)	4	611	152.75	224.9167		
Light; 25°C (77°F)	4	687	171.75	122.9167		
Freeze/Thaw; 30°C (86°F)	4	12	3	6		
Mannitol –2.03 mPa; 25°C (77°F)	4	415	103.75	30.91667		
Mannitol –1.01 mPa; 25°C (77°F)	4	546	136.5	667		
Escort; 30°C (86°F)	4	658	164.5	3		
Remedy; 30°C (86°F)	4	113	28.25	375.5833		
Leachate; 30°C (86°F)	4	606	151.5	769.6667		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	138716.5	9	15412.94	67.9683	1.73E-17	2.210697
Within Groups	6803	30	226.7667			
Total	145519.5	39				

Ho: There is no effect of treatment on the means of the germination requirements in the population sampled.

F-cal. = 67.9683; F-table 0.05(1),9,30 = 2.21; F-cal. > F-table; Reject the Ho:

P < 0.0005 (P=0.00000000000000173).

Ha: There is an effect of treatment on the means of all germinations conducted.

Table A-19. Germination Treatments for *Andropogon scoparius* -- One-Way ANOVA

ANSC - ANOVA: Single Factor	SUMMARY					
Groups	*Count*	*Sum*	*Average*	*Variance*		
25°C (77°F)	4	314	78.5	267.6667		
30°C (86°F)	4	292	73	267.3333		
40°C (104°F)	4	195	48.75	6.25		
Light; 25°C (77°F)	4	334	83.5	101.6667		
Freeze/Thaw; 30°C (86°F)	4	5	1.25	1.583333		
Mannitol –2.03 mPa; 25°C (77°F)	4	15	3.75	2.25		
Mannitol –1.01 mPa; 25°C (77°F)	4	241	60.25	95.58333		
Escort; 30°C (86°F)	4	352	88	4		
Remedy; 30°C (86°F)	4	13	3.25	12.91667		
Leachate; 30°C (86°F)	4	291	72.75	121.5833		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	44863.9	9	4984.878	56.59275	2.28E-16	2.210697
Within Groups	2642.5	30	88.08333			
Total	47506.4	39				

Ho: There is no effect of treatment on the means of the germination requirements in the population sampled.

F-cal. = 56.59275; F-table 0.05(1),9,30 = 2.21; F-cal. > F-table; Reject the Ho:

P < 0.0005 (P=0.000000000000000228).

Ha: There is an effect of treatment on the means of all germinations conducted.

Table A-20. Germination Treatments for *Sorghastrum nutans* -- One-Way ANOVA

SONU - ANOVA: Single Factor	SUMMARY					
Groups	*Count*	*Sum*	*Average*	*Variance*		
25°C (77°F)	4	256	64	54.66667		
30°C (86°F)	4	274	68.5	44.33333		
40°C (104°F)	4	237	59.25	114.9167		
Light; 25°C (77°F)	4	440	110	92		
Freeze/Thaw; 30°C (86°F)	4	2	0.5	0.333333		
Mannitol –2.03 mPa; 25°C (77°F)	4	1	0.25	0.25		
Mannitol –1.01 mPa; 25°C (77°F)	4	37	9.25	6.25		
Escort; 30°C (86°F)	4	284	71	131.3333		
Remedy; 30°C (86°F)	4	10	2.5	4.333333		
Leachate; 30°C (86°F)	4	284	71	390.6667		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	55026.13	9	6114.014	72.8654	6.47E-18	2.210697
Within Groups	2517.25	30	83.90833			
Total	57543.38	39				

Ho: There is no effect of treatment on the means of the germination requirements in the population sampled.

F-cal. = 72.8654; F-table 0.05(1),9,30 = 2.21; F-cal. > F-table; Reject the Ho:

P < 0.0005 (P=0.00000000000000000647).

Ha: There is an effect of treatment on the means of all germinations conducted.

Tukey Multicomparison for Germination Treatments

The following tables list the Tukey analysis of the germination treatments. The pre-chill treatment at 5°C and all fire/heat treatments were not included in these statistical tests.

Table A-21. Tukey Comparison of *Lespedeza cuneata* One-Way ANOVA Germination Treatment

Treatment - Lespedeza	LESCU's q	q0.05,30,10 = 4.824
FREEZE vs. -2.03 mPa.	9	Reject Ho: uFREEZE = u-2.03 mPa.
FREEZE vs. REMEDY	9	Reject Ho: uFREEZE = uREMEDY
FREEZE vs. -1.01 mPa.	8	Reject Ho: uFREEZE = u-1.01 mPa.
FREEZE vs. ESCORT	6	Reject Ho: uFREEZE = u ESCORT
FREEZE vs. 30	6	Reject Ho: uFREEZE = u30
FREEZE vs. 25	5	Reject Ho: uFREEZE = u25
FREEZE vs. LEACHATE	4	Accept Ho: uFREEZE = u LEACHATE
FREEZE vs. LIGHT	4	Accept Ho: uFREEZE = u LIGHT
FREEZE vs. 40	2	Accept Ho: uFREEZE = u 40
40 vs. -2.03 mPa.	7	Reject Ho: u40 = u-2.03 mPa.
40 vs. REMEDY	7	Reject Ho: u40 = u REMEDY
40 vs. -1.01 mPa.	6	Reject Ho: u40 = u-1.01 mPa.
40 vs. ESCORT	4	Accept Ho: u40 = u ESCORT
40 vs. 30	4	Accept Ho: u40 = u30
40 vs. 25	3	Accept Ho: u40 = u25
40 vs. LEACHATE	2	Accept Ho: u40 = u LEACHATE
40 vs. LIGHT	1	Accept Ho: u40 = u LIGHT
LIGHT vs. -2.03 mPa.	5	Reject Ho: u LIGHT = u-2.03 mPa.
LIGHT vs. REMEDY	5	Reject Ho: u LIGHT = u REMEDY
LIGHT vs. -1.01 mPa.	4	Accept Ho: u LIGHT = u-1.01 mPa.
LIGHT vs. ESCORT	3	Accept Ho: u LIGHT = u ESCORT
LIGHT vs. 30	2	Accept Ho: u LIGHT = u30
LIGHT vs. 25	1	Accept Ho: u LIGHT = u25
LIGHT vs. LEACHATE	1	Accept Ho: u LIGHT = u LEACHATE
LEACHATE vs. -2.03 mPa.	5	Reject Ho: u LEACHATE = u-2.03 mPa.
LEACHATE vs. REMEDY	5	Reject Ho: u LEACHATE = u REMEDY
LEACHATE vs. -1.01 mPa.	4	Accept Ho: u LEACHATE = u -1.01 mPa.
LEACHATE vs. ESCORT	2	Accept Ho: u LEACHATE = u ESCORT
LEACHATE vs. 30	2	Accept Ho: u LEACHATE = u30
LEACHATE vs. 25	1	Accept Ho: u LEACHATE = u25
25 vs. -2.03 mPa.	4	Accept Ho: u25 = u-2.03 mPa.
25 vs. REMEDY	4	Accept Ho: u25 = u REMEDY
25 vs. -1.01 mPa.	3	Accept Ho: u25 = u-1.01 mPa.
25 vs. ESCORT	1	Accept Ho: u25 = u ESCORT
25 vs. 30	1	Accept Ho: u25 = u30
30 vs. -2.03 mPa.	3	Accept Ho: u30 = u-2.03 mPa.
30 vs. REMEDY	3	Accept Ho: u30 = u REMEDY
30 vs. -1.01 mPa.	2	Accept Ho: u30 = u-1.01 mPa.
30 vs. ESCORT	0	Accept Ho: u30 = u ESCORT
ESCORT vs. -2.03 mPa.	3	Accept Ho: u ESCORT = u-2.03 mPa.
ESCORT vs. REMEDY	3	Accept Ho: u ESCORT = u REMEDY
ESCORT vs. -1.01 mPa.	2	Accept Ho: u ESCORT = u-1.01 mPa.
M-1.01 mPa. vs. -2.03 mPa.	1	Accept Ho: u -1.01 mPa. = u-2.03 mPa.
M-1.01 mPa. vs. REMEDY	1	Accept Ho: u -1.01 mPa. = u REMEDY
REMEDY vs. -2.03 mPa.	0	Accept Ho: u REMEDY = u-2.03 mPa.

Table A-22. Tukey Comparison of *Andropogon gerardi* One-Way ANOVA Germination Treatment

Treatment - ANGE	ANGE's q	q0.05,30,10 = 4.824
25 vs. FREEZE	23	Reject Ho: u25 = u FREEZE
25 vs. REMEDY	20	Reject Ho: u25 = uREMEDY
25 vs. -2.03 mPa.	10	Reject Ho: u25 = u-2.03 mPa.
25 vs. -1.01 mPa.	6	Reject Ho: u25 = u -1.01 mPa.
25 vs. LEACHATE	4	Accept Ho: u25 = u LEACHATE
25 vs. 40	3	Accept Ho: u25 = u40
25 vs. ESCORT	2	Accept Ho: u25 = u ESCORT
25 vs. 30	2	Accept Ho: u25 = u 30
25 vs. LIGHT	1	Accept Ho: u25 = u LIGHT
LIGHT vs. FREEZE	22	Reject Ho: u LIGHT = u FREEZE
LIGHT vs. REMEDY	19	Reject Ho: u LIGHT = uREMEDY
LIGHT vs. -2.03 mPa.	9	Reject Ho: u LIGHT = u-2.03 mPa.
LIGHT vs. -1.01 mPa.	5	Reject Ho: u LIGHT = u -1.01 mPa.
LIGHT vs. LEACHATE	3	Accept Ho: u LIGHT = u LEACHATE
LIGHT vs. 40	3	Accept Ho: u LIGHT = u40
LIGHT vs. ESCORT	1	Accept Ho: uLIGHT = u ESCORT
LIGHT vs. 30	1	Accept Ho: uLIGHT = u 30
30 vs. FREEZE	22	Reject Ho: u30 = u FREEZE
30 vs. REMEDY	18	Reject Ho: u30 = uREMEDY
30 vs. -2.03 mPa.	8	Reject Ho: u30 = u-2.03 mPa.
30 vs. -1.01 mPa.	4	Accept Ho: u30= u -1.01 mPa.
30 vs. LEACHATE	2	Accept Ho: u30 = u LEACHATE
30 vs. 40	2	Accept Ho: u30 = u40
30 vs. ESCORT	0	Accept Ho: u30 = u ESCORT
ESCORT vs. FREEZE	21	Reject Ho: u ESCORT = u FREEZE
ESCORT vs. REMEDY	18	Reject Ho: u ESCORT = uREMEDY
ESCORT vs. -2.03 mPa.	8	Reject Ho: u ESCORT = u-2.03 mPa.
ESCORT vs. -1.01 mPa.	4	Accept Ho: u ESCORT= u -1.01 mPa.
ESCORT vs. LEACHATE	2	Accept Ho: u ESCORT = u LEACHATE
ESCORT vs. 40	2	Accept Ho: u ESCORT = u40
40 vs. FREEZE	20	Reject Ho: u40 = u FREEZE
40 vs. REMEDY	17	Reject Ho: u40 = uREMEDY
40 vs. -2.03 mPa.	7	Reject Ho: u40 = u-2.03 mPa.
40 vs. -1.01 mPa.	2	Accept Ho: u40= u -1.01 mPa.
40 vs. LEACHATE	0	Accept Ho: u40 = u LEACHATE
LEACHATE vs. FREEZE	20	Reject Ho: u LEACHATE = u FREEZE
LEACHATE vs. REMEDY	16	Reject Ho: u LEACHATE = uREMEDY
LEACHATE vs. -2.03 mPa.	6	Reject Ho: u LEACHATE = u-2.03 mPa.
LEACHATE vs. -1.01 mPa.	2	Accept Ho: u LEACHATE= u -1.01 mPa.
M-1.01 mPa. vs. FREEZE	18	Reject Ho: u M-1.01 mPa. = u FREEZE
M-1.01 mPa. vs. REMEDY	14	Reject Ho: u M-1.01 mPa. = u REMEDY
M-1.01 mPa. vs. -2.03 mPa.	4	Accept Ho: u M-1.01 mPa. = u-2.03 mPa.
M-2.03 mPa. vs. FREEZE	13	Reject Ho: u -2.03 mPa. = u FREEZE
M-2.03 mPa. vs. REMEDY	10	Reject Ho: u -2.03 mPa. = u REMEDY
REMEDY vs. FREEZE	3	Accept Ho: u REMEDY = u FREEZE

Table A-23. Tukey Comparison of *Andropogon scoparius* One-Way ANOVA Germination Treatment

Treatment – ANSC	ANSC's q	q0.05,30,10 = 4.824
ESCORT vs. FREEZE	18	Reject Ho: u ESCORT = u FREEZE
ESCORT vs. REMEDY	18	Reject Ho: u ESCORT = uREMEDY
ESCORT vs. -2.03 mPa.	18	Reject Ho: u ESCORT = u-2.03 mPa.
ESCORT vs. 40	8	Reject Ho: u ESCORT = u 40
ESCORT vs. 25	6	Reject Ho: u25 = u ESCORT
ESCORT vs. -1.01 mPa.	6	Reject Ho: u ESCORT = u -1.01 mPa.
ESCORT vs. LEACHATE	3	Accept Ho: u ESCORT = u LEACHATE
ESCORT vs. 30	3	Accept Ho: u ESCORT = u30
ESCORT vs. LIGHT	1	Accept Ho: u ESCORT = u LIGHT
LIGHT vs. FREEZE	18	Reject Ho: uLIGHT = u FREEZE
LIGHT vs. REMEDY	17	Reject Ho: uLIGHT = uREMEDY
LIGHT vs. -2.03 mPa.	17	Reject Ho: uLIGHT = u-2.03 mPa.
LIGHT vs. 40	7	Reject Ho: uLIGHT = u 40
LIGHT vs. 25	5	Reject Ho: u25 = u LIGHT
LIGHT vs. -1.01 mPa.	5	Reject Ho: uLIGHT = u -1.01 mPa.
LIGHT vs. LEACHATE	2	Accept Ho: uLIGHT = u LEACHATE
LIGHT vs. 30	2	Accept Ho: uLIGHT = u30
30 vs. FREEZE	15	Reject Ho: u30 = u FREEZE
30 vs. REMEDY	15	Reject Ho: u30 = uREMEDY
30 vs. -2.03 mPa.	15	Reject Ho: u30 = u-2.03 mPa.
30 vs. 40	5	Reject Ho: u30 = u 40
30 vs. 25	3	Accept Ho: u25 = u30
30 vs. -1.01 mPa.	3	Accept Ho: u30 = u -1.01 mPa.
30 vs. LEACHATE	0	Accept Ho: u LEACHATE = u30
LEACHATE vs. FREEZE	15	Reject Ho: u LEACHATE = u FREEZE
LEACHATE vs. REMEDY	15	Reject Ho: u LEACHATE = uREMEDY
LEACHATE vs. -2.03 mPa.	15	Reject Ho: u LEACHATE = u-2.03 mPa.
LEACHATE vs. 40	5	Reject Ho: u LEACHATE = u 40
LEACHATE vs. 25	3	Accept Ho: u25 = u LEACHATE
LEACHATE vs. -1.01 mPa.	3	Accept Ho: u LEACHATE = u -1.01 mPa.
M-1.01 mPa. vs. FREEZE	13	Reject Ho: U-1.01 mPa. = u FREEZE
M-1.01 mPa. vs. REMEDY	12	Reject Ho: u-1.01 mPa. = uREMEDY
M-1.01 mPa. vs. -2.03 mPa.	12	Reject Ho: u-1.01 mPa. = u-2.03 mPa.
M-1.01 mPa. vs. 40	2	Accept Ho: u-1.01 mPa. = u 40
M-1.01 mPa. vs. 25	1	Accept Ho: u25 = u -1.01 mPa.
25 vs. FREEZE	12	Reject Ho: u25 = u FREEZE
25 vs. REMEDY	12	Reject Ho: u25 = uREMEDY
25 vs. -2.03 mPa.	12	Reject Ho: u25 = u-2.03 mPa.
25 vs. 40	2	Accept Ho: u25 = u 40
40 vs. FREEZE	10	Reject Ho: u40 = u FREEZE
40 vs. REMEDY	10	Reject Ho: u40 = uREMEDY
40 vs. -2.03 mPa.	10	Reject Ho: u40 = u-2.03 mPa.
M-2.03 mPa. vs. FREEZE	1	Accept Ho: u -1.01 mPa. = u FREEZE
M-2.03 mPa. vs. REMEDY	0	Accept Ho: u-1.01 mPa. = uREMEDY
REMEDY vs. FREEZE	0	Accept Ho: u REMEDY = u FREEZE

Table A-24. Tukey Comparison of *Sorghastrum nutans* One-Way ANOVA Germination Treatment

Treatment - SONU	SONU's q	q0.05,30,10 = 4.824
LIGHT vs. -2.03 mPa.	24	Reject Ho: uLIGHT = u -2.03 mPa.
LIGHT vs. FREEZE	24	Reject Ho: uLIGHT = u FREEZE
LIGHT vs. REMEDY	23	Reject Ho: uLIGHT = u REMEDY
LIGHT vs. -1.01 mPa.	22	Reject Ho: uLIGHT = u -1.01 mPa.
LIGHT vs. 40	11	Reject Ho: uLIGHT = u 40
LIGHT vs. 25	10	Reject Ho: uLIGHT = u25
LIGHT vs. 30	9	Reject Ho: uLIGHT = u 30
LIGHT vs. ESCORT	9	Reject Ho: uLIGHT = u ESCORT
LIGHT vs. LEACHATE	9	Reject Ho: uLIGHT = u LEACHATE
LEACHATE vs. -2.03 mPa.	15	Reject Ho: u LEACHATE = u -2.03 mPa.
LEACHATE vs. FREEZE	15	Reject Ho: u LEACHATE = u FREEZE
LEACHATE vs. REMEDY	15	Reject Ho: u LEACHATE = u REMEDY
LEACHATE vs. -1.01 mPa.	13	Reject Ho: u LEACHATE = u -1.01 mPa.
LEACHATE vs. 40	3	Accept Ho: u LEACHATE = u 40
LEACHATE vs. 25	2	Accept Ho: u LEACHATE = u25
LEACHATE vs. 30	1	Accept Ho: u LEACHATE = u 30
LEACHATE vs. ESCORT	0	Accept Ho: u ESCORT = u LEACHATE
ESCORT vs. -2.03 mPa.	15	Reject Ho: u ESCORT = u -2.03 mPa.
ESCORT vs. FREEZE	15	Reject Ho: u ESCORT = u FREEZE
ESCORT vs. REMEDY	15	Reject Ho: u ESCORT = u REMEDY
ESCORT vs. -1.01 mPa.	13	Reject Ho: u ESCORT = u -1.01 mPa.
ESCORT vs. 40	3	Accept Ho: u ESCORT = u 40
ESCORT vs. 25	2	Accept Ho: u ESCORT = u25
ESCORT vs. 30	1	Accept Ho: u ESCORT = u 30
30 vs. -2.03 mPa.	15	Reject Ho: u 30 = u -2.03 mPa.
30 vs. FREEZE	15	Reject Ho: u 30 = u FREEZE
30 vs. REMEDY	14	Reject Ho: u 30 = u REMEDY
30 vs. -1.01 mPa.	13	Reject Ho: u 30 = u -1.01 mPa.
30 vs. 40	2	Accept Ho: u 30 = u 40
30 vs. 25	1	Accept Ho: u 30 = u25
25 vs. -2.03 mPa.	14	Reject Ho: u 25 = u -2.03 mPa.
25 vs. FREEZE	14	Reject Ho: u 25 = u FREEZE
25 vs. REMEDY	13	Reject Ho: u 25 = u REMEDY
25 vs. -1.01 mPa.	12	Reject Ho: u 25 = u -1.01 mPa.
25 vs. 40	1	Accept Ho: u 25 = u 40
40 vs. -2.03 mPa.	13	Reject Ho: u 40 = u -2.03 mPa.
40 vs. FREEZE	13	Reject Ho: u 40 = u FREEZE
40 vs. REMEDY	12	Reject Ho: u 40 = u REMEDY
40 vs. -1.01 mPa.	11	Reject Ho: u 40 = u -1.01 mPa.
M-1.01 mPa. vs. -2.03 mPa.	2	Accept Ho: u-1.01 mPa. = u -2.03 mPa.
M-1.01 mPa. vs. FREEZE	2	Accept Ho: u-1.01 mPa. = u FREEZE
M-1.01 mPa. vs. REMEDY	1	Accept Ho: u-1.01 mPa. = u REMEDY
REMEDY vs. -2.03 mPa.	0	Accept Ho: u REMEDY = u -2.03 mPa.
REMEDY vs. FREEZE	0	Accept Ho: u REMEDY = u FREEZE
FREEZE vs. -2.03 mPa.	0	Accept Ho: u FREEZE = u -2.03 mPa.

Germination Statistics for Heat Treatments

The following table lists the ANOVA of the fire/heat treatments.

Table A-25. Heat Germination Treatments -- 2-Way ANOVA

ANOVA: Two-Factor Without Replication						
Heat Treatments						
SUMMARY	*Count*	*Sum*	*Average*	*Variance*		
Burn 400°C	4	7	1.75	12.25		
Burn 200°C	4	58	14.5	603		
100°C Wet	4	0	0	0		
Burn 100°C	4	107	26.75	636.9166667		
LESCU.	4	15	3.75	18.91666667		
ANGE	4	115	28.75	1130.25		
ANSC	4	24	6	64.66666667		
SONU	4	18	4.5	81		
ANOVA *Source of Variation*	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
(species) Rows	1866.5	3	622.1666667	2.774777007	0.102749	3.862539
(treatmt) Columns	1738.5	3	579.5	2.584489594	0.117924	3.862539
(within) Error	2018	9	224.2222222			
Total	5623	15				

Ho: There is no effect of treatment on the mean of germination requirements in the population sampled.

F-cal. 2.584489594; F-table 0.05(1),3,9 = 3.86; F-cal. < F-table; Fail to reject the Ho:. 0.25 > P > 0.10 (P=0.117924).

Ho: There is no difference in the mean germination requirements of seeds between the four species.

F-cal. 2.774777007; F-table 0.05(1),3,9 = 3.86; F-cal. < F-table; Fail to reject the Ho:. 0.25 > P > 0.10 (P=0.102749).

Germination Statistics for H_2SO_4 Treatments

The following table lists the ANOVA of the H_2SO_4 germinations.

Table A-26. Germination Treatment -- H_2SO_4 '96 and '97 Treatments vs. Years 2-Way ANOVA

ANOVA: Two-Factor With Replication						
SUMMARY	Control	3 Min.	10 Min.	20 Min.	Total	
H_2SO_4 '96; 30°C (86°F)						
Count	4	4	4	4	16	
Sum	67	232	204	483	986	
Average	16.75	58	51	120.75	61.625	
Variance	93.58333	1308.667	255.3333	762.9167	1986.917	
H_2SO_4 '97; 30°C (86°F)						
Count	4	4	4	4	16	
Sum	52	174	227	464	917	
Average	13	43.5	56.75	116	57.3125	
Variance	13.33333	51	122.9167	242	1578.896	
Total						
Count	8	8	8	8		
Sum	119	406	431	947		
Average	14.875	50.75	53.875	118.375		
Variance	49.83929	642.7857	171.5536	437.125		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
(years) Sample	148.7813	1	148.7813	0.417668	0.524235	4.259675
(treatmt) Columns	44526.84	3	14842.28	41.6662	1.13E-09	3.008786
(a x b) Interaction	411.0938	3	137.0313	0.384683	0.764983	3.008786
(error) Within	8549.25	24	356.2188			
Total	53635.97	31				

Ho: There is no effect of treatment on the mean of germinations in the population sampled.

F-cal. 41.6662; F-table 0.05(1),3,24 = 3.01; F-cal. > F-table; Reject the Ho:.

P < 0.0005 (P = 0.00000000113).

Ho: There is no difference in the mean concentration of germinations between years "96 and '97.

F-cal. 0.417668; F-table 0.05(1),1,24 = 4.26; F-cal. < F-table; Fail to reject the Ho:.

P > 0.25 (P = 0.524235).

Ho: There is no interaction of years and treatment affecting the mean concentration of germinations in the population sampled.

F-cal. 0.384683; F-table 0.05(1),3,24 = 3.01; F-cal. < F-table; Fail to reject the Ho:.

P > 0.25 (P = 0.764983).

APPENDIX – PRELIMINARY INVESTIGATIONS

MATERIALS AND METHODS

Drought Tolerance -- Xylem Pressure Potential

Xylem pressure potential tests were conducted comparing the *Lespedeza cuneata* to the three species of grasses: *Andropogon gerardi* (Big Bluestem), *Andropogon scoparium* (Little Bluestem), and *Sorghastrum nutans* (Indiangrass). The four species were grown from seed in five-inch pots with Cornell mix as the potting medium. Martin soil (approximately 28 grams from the plant control treatment studies) was added as a microflora inoculum. The 28 pots were partitioned into quarters; one species in each quarter. (See Figure A-1.) The plants were grown in a greenhouse with supplemental lighting. When the plants reached a height of 20 to 30 cm, all pots were watered to excess of field capacity and then allowed to drain overnight. Pots were not watered again to induce drought stress. See Figures A-2 and A-3 for plant appearance at field capacity and at water stress conditions, respectively. Xylem pressure potential was measured at dawn, each day, using the Scholander pressure-chamber (Scholander *et al.*, 1964). The treatment continued until the xylem pressure potential lowered to the point of not being measurable. (See Figure A-4.) Data taken for each measurement period were: day number, time of day, temperature in greenhouse, and plant height. The stems for testing were chosen for similar diameters, not heights. Usually only one *Lespedeza cuneata* plant remained at the end of testing.

Figure A-1. Xylem pressure potential – five-inch pot partitioned with *Lespedeza cuneata* and three species of prairie grasses: (*Andropogon gerardi*, *Andropogon scoparium*, and *Sorghastrum nutans*).

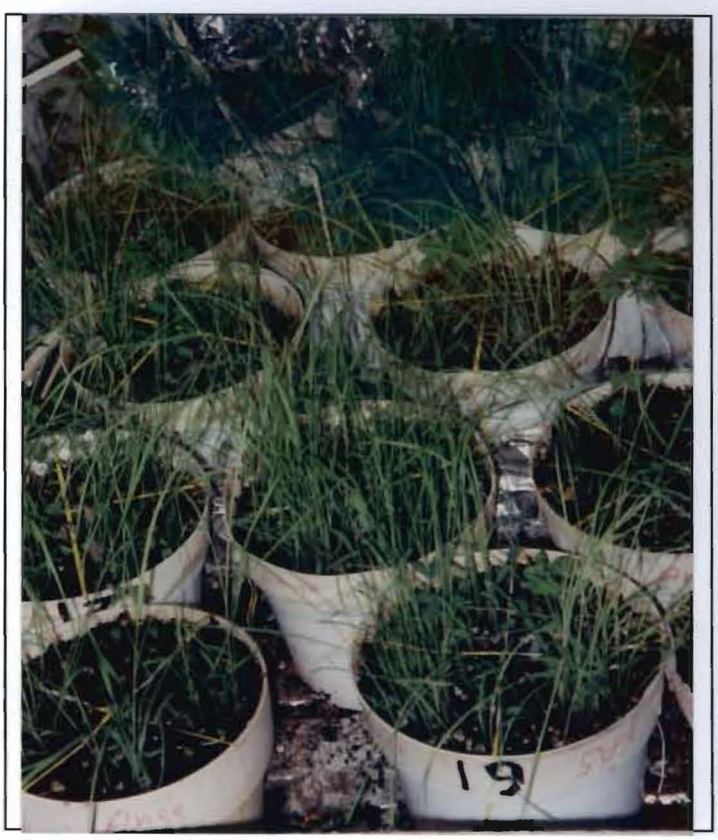

Figure A-2. Xylem pressure potential -- plants at field capacity.

Figure A-3. Xylem pressure potential -- effects of drought stress on plants.

Root Development Studies

Joost and Hoveland (1986) prepared root boxes in order to compare the root development of alfalfa to lespedeza in limed and unlimed soils. Using this study as a guide, I wanted to investigate a possible correlation between the prairie grasses and lespedeza seedlings in initial root development. This would determine if the *Lespedeza cuneata* rooting system elongates or seeks out resources sooner than the grasses.

The soil bulk density was sampled twice near the clipping/burning permanent plots discussed in the Plant Control Treatment studies section. Readings were 1.31 and 1.07 g/cm^3. This soil is a Martin silty clay loam. The moist bulk density of a silty clay loam should be approximately 1.49 g/cm^3 at the soil surface to 1.69 g/cm^3 at 55 cm. Rooting boxes were prepared with Martin subsoils at the bottom and the Martin topsoil at the top. The soils were collected near the Plant Control Treatment studies. The rooting boxes were packed with the soils to the depths noted at the site and in the Lyon County Soil Survey (United States Department of Agriculture Soil Conservation Service, 1981).

Two rooting boxes, constructed of plywood and measuring 12x12 inches square, were tilted at a 15° angle toward a plexiglass front. (See Figure A-4.) One box was reserved for the grasses, which were planted and marked in groups in order to distinguish between the species. The other box was reserved for the lespedeza. Seedlings from the germination tests were transplanted to the rooting boxes and positioned approximately 5 cm from the plexiglass face, allowing the growing roots to penetrate the soil vertically until the clear plastic face was reached. This would allow me to make periodic root length measurements. The boxes were placed under a 14-hour photoperiod and were watered as necessary.

Figure A-4. Root development of *Lespedeza cuneata* and three species of prairie grasses. Seedlings were planted 5 cm from a 15° tilted plastic face for periodic root measurements.

RESULTS

Drought Tolerance -- Xylem Pressure Potential

Note, on Figure A-5, that between day 12 and day 13, the plants received unintentional water because the greenhouse roof vents leaked during a heavy rain. The amount of water could not be determined but was not up to or in excess of field capacity, and soil appearances indicated the watering was uneven from pot to pot. This might have seemed disastrous to some researchers; however, the curves in Figure A-5 show a less negative xylem pressure potential that reached maximum on day 16. It was then followed by a decrease in xylem pressure, which would not have been evident in a strict drying period. One lespedeza plant was dead on day twenty-one. The small sample size precluded statistical analysis. However, a trend in xylem pressure potential under drought stress can be seen for these four species. Table A-27 lists the results of the test and Figure A-5 shows the xylem pressure potential curves.

Root Development Studies

Establishment of the lespedeza seed was extremely poor. Eight plants eventually were established but failed to reach the visible health of the pasture plants. The grasses were easy to establish. The rooting boxes were unsuccessful due to the undeveloped status of the plants.

Replications in clear glass jars, also tilted to a 15° angle, were used and establishment of plants were more successful. After roots reached the bottom of the jars, the plants were removed, root measurements taken, and the plants repotted in plastic containers. One *Andropogon gerardi* reached anthesis after being repotted. The

rooting jars, although partially successful, never produced enough replications to statistically analyze.

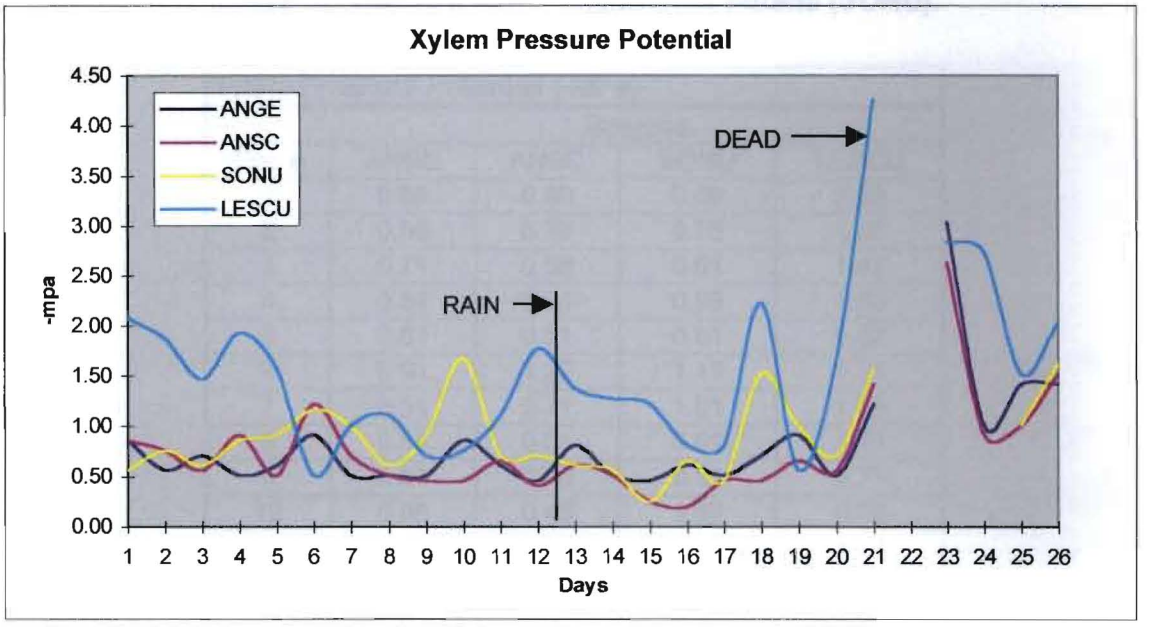

Figure A-5. Xylem pressure potential curves at dawn, over a 26-day period, of *Lespedeza cuneata* (LESCU) and three species of prairie grasses: *Andropogon gerardi* (ANGE), *Andropogon scoparius* (ANSC), and *Sorghastrum nutans* (SONU).

Table A-27. Xylem pressure potential data of Lespedeza cuneata (LESCU) and three species of prairie grasses: Andropogon gerardi (ANGE), Andropogon scoparius (ANSC), and Sorghastrum nutans (SONU).

Xylem Pressure Potential (-MPa)				
	Species			
Day #	ANGE	ANSC	SONU	LESCU
1	0.86	0.86	0.56	2.08
2	0.56	0.76	0.76	1.87
3	0.71	0.56	0.61	1.47
4	0.51	0.91	0.86	1.93
5	0.61	0.51	0.91	1.57
6	0.91	1.22	1.17	0.51
7	0.51	0.71	1.01	1.01
8	0.51	0.51	0.61	1.11
9	0.51	0.46	0.91	0.71
10	0.86	0.46	1.67	0.76
11	0.61	0.66	0.71	1.11
12	0.46	0.41	0.71	1.77
13	0.81	0.61	0.61	1.37
14	0.51	0.51	0.56	1.27
15	0.46	0.25	0.25	1.22
16	0.61	0.20	0.66	0.81
17	0.51	0.46	0.46	0.81
18	0.71	0.46	1.52	2.23
19	0.91	0.66	1.01	0.56
20	0.51	0.56	0.71	1.67
21	1.22	1.42	1.57	4.26+
22	No reading			
23	2.63	1.42	2.03	2.84
24	1.01	0.91	- -	2.74
25	1.42	1.01	1.01	1.52
26	1.42	1.52	1.62	2.03

DISCUSSION

Xylem Pressure Potential

Lespedeza cuneata appears to be able to withstand periods of drought (Brown and Radcliffe,1986). The data in this thesis indicate that xylem pressure potential drops to half that of the grasses, but is able to rehydrate and regain cell turgidity the same as the grasses. (See Figure A-5.)

The grasses reached maximum xylem pressure potential four days after watering to excess of field capacity. The lespedeza followed at day six and to the same level as the grasses. Xylem pressure potential on the lespedeza was, for the most part, half that of the grasses and usually lagged two days behind. On October 31, 1998 and November 1, 1998 (days 12 and 13 on Figure A-5), Emporia, Kansas received nine inches of rain. Although the plants were located in the greenhouse, the rain leaked through roof vents and all the plants received water, but not in equal amounts. Because the test took so much time and resources to set up, water potential measurements were continued. The data obtained confirmed earlier observations that the grasses reached maximum water potential three to four days after being watered and the lespedeza followed five to six days after receiving water. Because all plants tested were in the same pot, one outlier usually resulted in like data from the other species in the pot (refer to day eighteen). These "outliers" might have been pots that did not receive as much water during the rain. These data indicate that the amount of tissue fluid in the lespedeza can be decreased to less than half that of the grasses and remain alive.

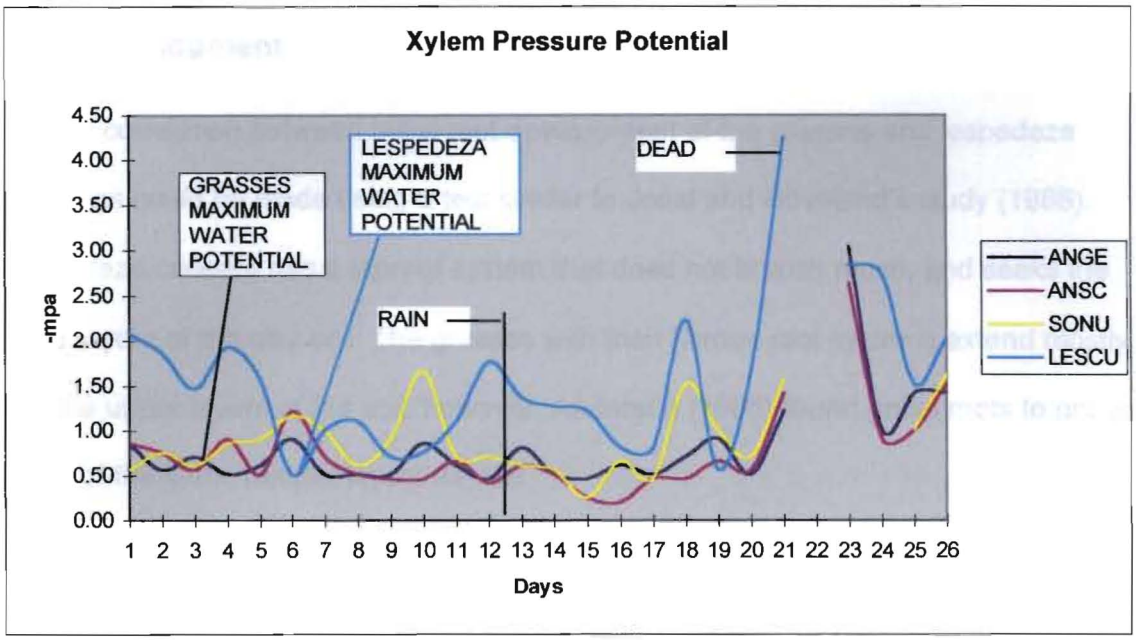

Figure A-6. Xylem pressure potential of Lespedeza cuneata and three species of grasses.

Root Development

No correlation between initial root development of the grasses and lespedeza seedlings could be made using a test similar to Joost and Hoveland's study (1986). *Lespedeza cuneata* has a taproot system that does not branch much, and seeks the lower layers of the clay soil. The grasses with their fibrous root systems extend mostly into the upper layers of the soil; however, Anderson (1965) found grass roots to occupy some of the same deeper layers as well.

Establishment of lespedeza seedlings was extremely poor. Using the results from the rooting studies, it is unclear how lespedeza plants could be established at the soil compaction found in the field. The treatment soil bulk density was detrimental to seedling root establishment when compared to potting in an unpacked soil. Additionally, most transplanted seedlings were first established but then suffered damping off, even when water with fungicide was used. Note that 631 germinated lespedeza seeds were transplanted both to the rooting boxes and to potting containers for establishment in order to obtain root measurements and water stress data. All transplants were unsuccessful. The grasses were not difficult to transplant or establish.

Joan M. Young

Signature of Graduate Student

James M Mayo

Signature of Major Advisor

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Joan M. Young

Signature of Author

November 30, 2000

Date

A comparison of *Lespedeza cuneata* (Dumont) G. Don. (sericea lespedeza) with three prairie grasses: *Andropogon gerardi* (Big Bluestem), *Andropogon scoparius* (Little Bluestem), and *Sorghastrum nutans* (Indiangrass).

Mary Cooper

Signature of Graduate Office Staff Member

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