EMERGENCE, CONTROL, AND TOTAL NONSTRUCTURAL CARBOHYDRATE LEVELS OF SERICEA LESPEDEZA

(Lespedeza cuneata)

By

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INTRODUCTION

Chapters II and III of this thesis are to be submitted for publication in Weed Technology, published by the Weed Science Society of America. Chapter IV of this thesis is to be submitted for publication in Weed Science, published by the Weed Science Society of America.

CHAPTER I

LITERATURE REVIEW

Literature Review

BACKGROUND

Sericea lespedeza (*Lespedeza cuneata* [Dum.Cours] G. Don) is an introduced, warm-season, perennial, herbaceous, allelopathic legume that is becoming a major weed problem in tallgrass prairies and improved pastures of Oklahoma and Kansas. Sericea lespedeza is currently listed as a noxious weed in 56 counties of eastern Kansas (State of Kansas House Bill 2289, 1997), and in June 2000 it will be considered a noxious weed for the entire state of Kansas. The ability of sericea lespedeza to grow under a wide range of climates, soil types and conditions, produce large quantities of seed, and survive for many years are some of the reasons for sericea lespedeza becoming a major weed problem.

Sericea lespedeza was introduced to the southeastern United States for its haying and grazing potential in 1896 from plants collected in Japan [Lynd and Ansman (1993);Hoveland and Donnelly (1985); and Pieters (1939)]. Sericea lespedeza was planted in the southeastern United States for soil conservation and forage production during the 1930's, with peak production occurring in the 1950's [Hoveland and Donnelly (1985) and McGraw and Hoveland (1995)]. Sericea lespedeza is adapted to a wide range of climates, soil types, and considered to be more drought tolerant than other forage legume species (Cope, 1966). Sericea lespedeza is adapted to grow in the eastern two-thirds of Oklahoma and Kansas, and eastward to the Atlantic coast (Hoveland and

Donnelly, 1985). Pieters (1950) and Buchanan and Burns (1968) reported that sericea lespedeza is well adapted to infertile soil conditions and useful for soil conservation purposes on eroded land and strip mine areas. Sericea lespedeza has also been valuable in re-vegetating mined sites, where soil pH levels of 5 or lower are common and high levels of aluminum are often found (Powell et al., 1983).

Sericea lespedeza is long-lived and capable of producing dense stands and competing with desirable forage species for many years. Lynd and Ansman (1993) reported in a twenty year study, biomass yields of sericea lespedeza in an eroded field were 791, 2439, and 1657 kg dry matter ha^{-1} for years 1, 10, and 20, respectively. Lynd and Ansman (1993) reported that sericea lespedeza has exceptional nitrogen fixation capabilities. However, very little nitrogen is given up by sericea lespedeza for uptake by plant species growing in association with sericea lespedeza (Hoveland and Donnelly, 1985). In a study conducted by Hoveland et al. (1975a) forage yields of 'Kentucky 31' tall fescue and 'Boone' orchardgrass when growing alone were not different when compared to forage yields for these two cool season grasses when grown in combination with sericea lespedeza.

MORPHOLOGY

Sericea lespedeza is an erect to semi-erect species with course stems that grow to heights of 0.6 to 1.1 meters in fields where it is utilized for haying and grazing purposes [Mcgraw and Hoveland (1995) and Ball et al. (1991)]. Established plants of sericea lespedeza initiate stem growth each spring from crown buds located at or just below ground level; stems grow during the summer months, with flower development occurring in late summer and seed development in early fall. All above ground growth of sericea lespedeza dies each fall after the first killing frost, with mature persistent stems remaining upright and intact through the next growing season. Sericea lespedeza is drought tolerant, with roots commonly reaching soil depths of 1.5 meters [Ball et al. (1991) and Hoveland and Donnelly (1985)]. Trifoliolate leaves of sericea lespedeza are alternately distributed, along the entire stem. Leaflets (3 leaflets comprise a trifoliolate leaf) are spatula shaped, 1.3 to 3.9 centimeters in length, truncate (squared ends), and end with a conspicuous point. Flowers are located on short pedicels in leaf axils along the stem, and are white or purple in color. Sericea lespedeza produces two types of flowers; flowers without petals (apetalous) that are self-fertilized before the calyx opens, and flowers with conspicuous petals (petalous) that can be self- or cross- fertilized by bees [Stitt (1946) and McKee and Hyland (1941)]. Stitt (1946) also found that cross-fertilization of petalous flowers was essential for genetic diversity in sericea lespedeza. McKee and Hyland (1941) reported that seed pods of petalous flowers are larger than pods of apetalous flowers and have the remnant of the flowers style as a sharp point at the seed tip. Variations in numbers of apetalous and petalous flowers appear to be due to environmental conditions during the flowering season and possibly natural populations of pollinating bees. Cope (1966) found that cross-fertilization of individual plants, and variation in petalous and apetalous flower numbers was not consistent from year to year, indicating that a variation in environmental conditions may have an effect on the type of flowers. Day length and/or amount of light during the flowering season may effect the kind of flower produced. In a greenhouse experiment conducted by McKee and Hyland (1941) short day length during the winter months produced only apetalous flowers, while under longer days with artificial light some petalous flowers were formed.

SEED PRODUCTION AND GROWTH OF SERICEA LESPEDEZA

Sericea lespedeza is a prolific seed producer. Guernsey (1970) reported that established plants of sericea lespedeza produce 340 to 670 kg of seed ha^{-1}, with approximately 770,925 seed kg. Logan et al. (1969) reported that seeds of sericea lespedeza have a water insoluble inhibitor in the seed coat that must degrade and/or dissolve naturally before germination can occur.

Mosjidis (1990) found that both temperature and daylength influence the germination of sericea lespedeza seed, with a 20% reduction in germination for each – 14.4°C decrease in day/night temperatures. He also found that germination of sericea lespedeza seed was highest (80%) at 20°C and lowest (42%) at 13°C. Average mean daily temperatures during these months (March-June) in north central Oklahoma were 11, 13, 19, and 23°C (Oklahoma Climatological Survey, 1997).

Daylength and temperature also affect growth of established sericea lespedeza plants. Pieters (1939) first observed that growth of sericea lespedeza was less when subjected to daylengths of less than 12 hours; and Bates (1955) reported similar findings in that plants greater than 30.5 centimeters in height grew very little when exposed to daylengths of less than 12 hours. Mosjidis (1990) found that plants increased in height when subjected to daylengths of 13 and 14 hours, and plant height decreased at daylengths of 15 hours or more.

INFLUENCE ON OTHER PLANT SPECIES

Sericea lespedeza is known to have allelopathic properties towards the growth of other plant species. In a greenhouse experiment conducted by Kalburtji and Mosidjis (1992), dry weights of bermudagrass and bahiagrass, when grown in association with plant residues of sericea lespedeza, were reduced by 17 and 16% respectively; and nitrogen concentrations in bermudagrass and bahiagrass shoots were reduced by 28 and 21%. Kalburtji and Mosjidis (1993a) also reported that radicle lengths of bermudagrass and bahiagrass plants were significantly reduced by 1.9 and 0.7% respectively when planted in soil that contained plant residues of sericea lespedeza. In a study with cool-season grasses, Kalburtji and Mosjidis (1993a) reported that seed germination of rye was significantly reduced by 6%; and radicle and coleoptile length of rye and tall fescue were significantly reduced by 1.1 and 1.6% and 0.5 and 0.5% respectively. In a similar study, Kalburtji and Mosjidis (1993b) reported significant reduction in radicle and coleoptile lengths for rye, ryegrass, and tall fescue. Growth of some plant species is also inhibited when growing in soil taken from fields where plants of sericea lespedeza exist. Dornbos et al. (1990); Kil and Lee (1987); and Guenzi and McCalla (1962) reported that compounds produced and deposited in the surrounding soil by some plant species can accumulate and become harmful to the growth of other plant species. Kalburtji and Mosjidis (1992) reported that radicle and coleoptile lengths of bahiagrass plants were significantly reduced when planted in soil extracted from a field that contains 4 year old sericea lespedeza plants. While growth of some plant species is inhibited by residues and/or compounds produced by sericea lespedeza, it appears that growth of sericea lespedeza seedlings is not inhibited when growing in association with established plants of sericea lespedeza. In a greenhouse study conducted by Cope (1982) germination and emergence of sericea lespedeza was not inhibited when growing in association with established plants of sericea lespedeza.

Sericea lespedeza also interferes with the growth of desirable native, perennial forage species in pastures. Koger et al. (1998) reported biomass yields for perennial tallgrass species of 1680 kg ha^{-1} in plots where established plants of sericea lespedeza exist, compared to grass yields of 3920-4700 kg ha^{-1} in plots where sericea was controlled with herbicides 2 years before yields were taken.

NUTRITIVE AND GRAZING POTENTIAL

Upon introduction into the United States, sericea lespedeza was assumed to be a high quality forage. However, research has shown sericea lespedeza to be a forage species of low palatability and digestibility when fed to cattle as hay or when growing in pastures. Low forage quality and low levels of digestible crude protein is attributed to high levels of lignin and tannin, which are two compounds commonly found in sericea lespedeza. Lignin is an organic compound very low in digestibility that strengthens and hardens the walls of plant cells (Hoveland and Donnelly, 1985). Tannins are a broad class of polyphenol compounds that combine with otherwise digestible proteins in the plant to form insoluble and indigestible substances (McGraw and Hoveland, 1995). Plants of sericea lespedeza are readily grazed by cattle during the early months of the growing season when plants are small in size. However, with increasing maturity and plant height, lignin and tannin content in plants of sericea lespedeza increase; causing decreased utilization by grazing animals. In a study conducted by Hawkins (1955) low digestibility of sericea lespedeza dry matter is associated with high lignin content of sericea lespedeza, which averaged 14% when plants were 38 centimeters in height. Increasing levels of tannin compounds in sericea lespedeza during the growing season contribute to a bitter taste, decreased utilization of sericea lespedeza by grazing animals, and a reduction in digestible plant cell protein levels [McGraw and Hoveland (1995); Hawkins (1955); Donnelly (1954); Stitt et al. (1946); Stitt and Clarke (1941); and Clarke et al.(1939)]. In an experiment conducted by Stitt (1943) tannin levels in sericea lespedeza increased from 6 to 21%, as plant height increased from 10 to 91 centimeters. Tannin levels in leaves of sericea lespedeza plants are typically higher throughout the growing season than levels commonly found in stems of sericea lespedeza [Cope and Burns (1974); Donnelly and Anthony (1973); Donnelly (1959); Donnelly (1954); and Stitt and Clarke (1941)]. In a study conducted by Stitt and Clarke (1941) tannin levels in leaves and stems were 18 and 2.7% in June, 17 and 2.0% in July, 14 and 2.2% in August, and 13 and 2.4% in September. Digestible crude protein levels typically decrease as tannin levels increase in sericea lespedeza. Hawkins (1955) and Holdaway et al. (1936) found that as digestibility of crude protein decreased with increasing tannin levels, digestible dry matter content of the forage also decreased.

Tannin levels in sericea lespedeza are reduced when it is cut and cured for hay. Terril et al. (1989) reported that tannin levels were reduced from 8% for standing sericea lespedeza to 1.4% after the sericea was cut and field dryed. Goldstein and Swain (1963) attributed the reduction in tannin levels of cut and field dried sericea lespedeza to oxidative changes in the tannins molecular chemistry.

CONTROL OF SERICEA LESPEDEZA

Several chemicals have been investigated for their effect on established and seedling plants of sericea lespedeza. These chemicals are clopyralid, 3,6-dichloro-2-pyridinecarboxylic acid; dicamba, 3,6-dichloro-2-methyoxybenzoic acid; fluroxypyr, [(4-amino-3,5-dichloro-6-fluoro-2-pyridinyl)oxy]acetic acid; 2,4-D, (2,4-dichlorophenoxy) acetic acid; metsulfuron-methyl, methyl 2-[[[[(4-metoxy-6-methyl-1,3,5-triazin-2-yl) amino]carbonyl]amino]sulfonyl]benzoate; picloram, 4-amino-3,5,6-trichloro-2-pyridine carboxylic acid; and triclopyr, [(3,5,6-trichloro-2- pyridinyl)oxy]acetic acid. In three field studies conducted in 1988 and three in 1989 by Altom and Stritzke (1992), triclopyr at 0.56 kg ae ha^{-1} applied in mid-May to early June resulted in 85 to 99% stem density reduction 1 year after treatment (YAT); and 97% or better with 1.12 kg ae ha^{-1}. Applications of triclopyr at 0.14 and 0.28 kg ae ha^{-1} also resulted in significant stem density reductions, but stem density was not reduced enough to be considered acceptable control, with stem density between 65 and 775 stems per m^2 remaining 1 YAT. Applications of fluroxypyr at 0.56 kg ae ha^{-1} resulted in 99% stem density reduction 1 YAT. They also reported significant stem density reductions with picloram at 0.28 and 0.56 kg ae ha^{-1}, and metsulfuron-methyl at 0.0175 and 0.035 kg ai ha^{-1}; but stem density with these treatments were 194 stems per m^2 or better respectively. Combinations of 2,4-D and dicamba, and clopyralid, 2,4-D, and dicamba alone resulted in stem density no different than that of the untreated plots. Fick (1990) found that triclopyr at rates higher than 0.56 kg ae ha^{-1} and metsulfuron-methyl at .0035 kg ai ha^{-1} resulted in greater than 80% control of sericea lespedeza. Fick (1990) also reported that picloram, dicamba, clopyralid, chlorsulfuron, and 2,4-D provided less than 50% control.

Sericea lespedeza can be controlled with combinations of mowing plus herbicides. Koger and Stritzke (1997) reported that triclopyr at 0.56 and 0.82 kg ae ha^{-1}, fluroxypyr at 0.2 and 0.56 kg ae ha^{-1}, and metsulfuron-methyl at 0.0126 and 0.021 kg ai ha^{-1} applied 1 and 3 months after June mowing and 2 months after July mowing resulted in 86% or better stem density reductions. Stem reduction in plots mowed in June and not treated with a herbicide averaged 19%, compared to 11% in plots mowed in July and not treated with a herbicide.

It would appear that complete control of sericea lespedeza with herbicides is short lived, with re-establishment of sericea lespedeza from plants not killed by the herbicide and from establishment of new plants from seed found in the soil-seed bank. Koger and Stritzke (1997) reported similar results for bermudagrass pastures infested with sericea lespedeza. Percent of sericea lespedeza stems remaining 1 and 2 YAT with triclopyr in June were 3 and 13%; and 8 and 25% stems remaining 1 and 2 YAT with metsulufuron-methyl, respectively. Seedling density 2 YAT in the triclopyr and metsulfuron-methyl plots were 43 and 86 seedlings per m^2 respectively. Koger et al. (1998) reported the percent of original sericea lespedeza stem density remaining in a tallgrass prairie infested with sericea lespedeza 1 and 2 YAT with triclopyr (0.56 kg ae ha^{-1}) applied in June was 0 and 8%, and 0 and 38% remaining 1 and 2 YAT with metsulfuron-methyl (21.0 g ai ha^{-1}) applied in September. Koger et al. (1998) also documented new seedling density of 43 and 150 seedlings per m^2 2 YAT in plots treated with triclopyr and metsulufuron-methyl respectively.

It also appears that prescribed burning, a common management tool used to improve palatability of desirable forages and to control weeds, may lead to increased seed germination and establishment of new sericea lespedeza plants. Seedling sericea lespedeza plants appear to be as tolerant to herbicides as established plants. Koger and Stritzke (1998) found that only metsulfuron-methyl at 0.0084 kg ai ha^{-1} and picloram + 2,4-D at 0.07 and 0.28 kg ae ha^{-1} applied in June significantly reduced sericea lespedeza seedling density, with 71 and 57% of the pre-treatment seedling density remaining 150 DAT (days after treatment) . Density of sericea lespedeza seedlings treated with triclpoyr (0.28 kg ae ha^{-1}), metsulfuron-methyl (0.042 kg ai ha^{-1}), picloram plus 2,4-D (0.07 and 0.28 kg ae ha^{-1}), and dicamba plus 2,4-D (0.14 and 0.42 kg ae ha^{-1}) in early June were not significantly reduced by 150 DAT.

TOTAL NOÑSTRUCTURAL CARBOHYDRATE LEVELS IN ROOTS OF SERICEA LESPEDEZA

Sericea lespedeza is a perennial, warm season, herbaceous, leguminous species that is a major weed problem in grazing lands of Oklahoma and Kansas. It is a deep-rooted, drought tolerant species capable of producing roots 125 cm in length (Ball et al. 1991), and can survive in excess of 20 years (Lynd and Ansman 1993). The ability of some perennial plant species to re-grow and persist is believed to be dependant upon the plants ability to produce and store carbohydrates in the roots. [Buwai and Trlica 1977; and McIlvanie 1942]. , it is important to know what the seasonal root CHO levels are for sericea lespedeza. Little is known about the effects of season, environment, and herbage removal on total nonstructural carbohydrate (TNC) levels in roots of sericea lespedeza plants. However, much is known of TNC levels in roots of alfalfa, a perennial leguminous species that is used for haying and grazing purposes. Starch and sugars (glucose, fructose, and sucrose) make up the TNC components in roots of alfalfa plants during the growing season, with starch comprising 90% and sugars 10% of the TNC found in alfalfa roots [Olson and Wallander 1997; Smith and Marten 1970; and Ueno and Smith 1970]. However, sucrose becomes the major carbohydrate fraction in alfalfa roots during drought, onset of cold hardening, and early spring re-growth following winter dormancy (Nelson and Smith 1968). Most TNC storage occurs in the upper 10 cm segment of alfalfa roots and less progressively downward (Escalada and Smith 1972).

Little is known of seasonal fluctuations and the effects of control options such as mowing, grazing, and herbicides on carbohydrate levels in roots of sericea lespedeza plants that are growing in association with tallgrass and improved foraged species. However, seasonal fluctuations in TNC of roots of uncut alfalfa plants typically decrease in the spring as vegetative growth is initiated from crown buds. This growth is supported by TNC located in the roots until leaf growth is sufficient to sustain photosynthetic C assimilation (Heichel et al. 1988). Once carbon is assimilated by photosynthetic pathways in aboveground tissue of alfalfa plants, root TNC reserves increase with maximum concentrations occurring at 10% flower and full bloom (Cooper and Watson 1968; and Reynolds and Smith 1962). Typically there is a slight decrease in root TNC concentrations with fruit development in perennial plants. Heichel et al. (1988) reported a 10% decrease in TNC of alfalfa roots with the initiation of fruit development. Temperature effects TNC accumulation in roots of alfalfa plants.

Clipping frequency and height effects root carbohydrate levels of established sericea lespedeza plants that are grown for haying purposes. Hoveland et al. (1972) reported root TNC levels as a percent of biomass dryweight for plants clipped two times during the growing season at a 3.5 cm height were 15% compared to 6% for plants clipped four times. Plants clipped four times during the growing season at a 12.5 cm cutting height contained 12% root carbohydrate levels compared to 6% for roots of plants clipped at a 3.5 cm cutting height (Hoveland et al. 1975b). Little is known about the sink sources of TNC following harvest of above ground biomass of sericea lespedeza. However, Brown et al. (1972) reported that 25% of the reserve root TNC consumed following harvest of alfalfa plants were lost in root respiration, 39 to 45% lost in respiration by the crowns and shoots, and 30 to 36% were incorporated into shoot growth. Close grazing of sericea lespedeza plants also effects root carbohydrate levels. Ball et al. (1991) and Hoveland and Donnelly (1985) documented that sericea lespedeza plants grown for grazing use should not be grazed lower than 10.0 cm in height. They also reported that plants should not be grazed late in the growing season, as this is a period when plants are storing food reserves in the roots. Again, little is known about fluctuating TNC levels in roots of sericea lespedeza plants. However, as temperatures decrease in the fall, aboveground growth of alfalfa slows and TNC accumulation in roots increase (Heichel et al. 1988). This accumulation continues until first frost, when aboveground growth dies back until the next spring.

Better control of troublesome perennial weed species and gaining the most from control inputs can be achieved by applying control options when plants are storing root reserves rather than relocating reserves to aboveground portions of the plant [Becker and Fawcett 1998; Olson and Wallander 1997; Pakeman and Marrs 1994; Buchache et al. 1993; Otzen and Koridon 1970; Ilnicki and Fertig 1962; Gerhardt 1929; and Welton et al. 1929]. Becker and Fawcett (1998) recommended control of hemp dogbane (*Apocynum* *cannabinum*), a perennial weed species whose large reserves of root carbohydrates likely contribute to its aggressiveness and persistence in the corn belt region, with herbicide application after mid- to late-flowering stage through leaf senescence. This is the time frame when plants are translocating carbohydrates from aboveground tissue to roots for storage [Becker and Fawcett 1998; MacIsaac and Bewely 1992; and Heichel et al. 1988]. They reported root carbohydrate levels as a percent of biomass dry weight after mid- to late-flowering of 30 to 45% compared to 15 to 20% at early to late flowering stage, respectively. Leafy spurge (*Euphorbia esula* L.) is a perennial Eurasian forb with a deep rhizomatous root system that is invading grazing lands of the north central United States. It is very difficult to control with herbicides partly due to large quantities of root carbohydrate reserves during the summer months (Whitson et al. 1996). Carbohydrate levels in the roots of leafy spurge plants fluctuate significantly during the growing season, with accumulations occurring after seed dispersal in the fall until top growth dies back in the winter and a decline in the spring as buds emerge (MacIsaac and Bewely 1992). Control (40 to 95% by 1 YAT) of leafy spurge with picloram, imazethapyr, imazaquin, and nicosulfuron typically occurs in the fall when plants are translocating storage reserves to the roots (Christianson et al. 1992). Like the plant species previously mentioned, sericea lespedeza is a troublesome weed and knowing seasonal fluctuations in root carbohydrate levels could play a large role when considering possible control options for sericea lespedeza.

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CHAPTER II

RESPONSE OF SERICEA LESPEDEZA TO BURNING AND SELECTED HERBICIDES

Response of Sericea Lespedeza to Burning and Selected Herbicides

T.H. Koger, J.F. Stritzke, D. M. Engle, C.L. Goad

Abstract: Six experiments were established at three locations in 1997 and 1998 to evaluate timing of sericea lespedeza seedling emergence and response of sericea lespedeza seedlings and established plants to burning and selected herbicides. Flushes of new seedlings emerged in the spring of both years when sufficient precipitation occurred for germination of sericea lespedeza seed. Spring burning resulted in higher seedling densities in graze and no graze experiments. Interference from decadent grasses in the no-burn and no-graze treatment resulted in the lowest percent summer survival of seedlings, while survival was highest with grazing and no-burn. Burning also resulted in higher stem densities and standing crop yields of established sericea lespedeza plants in the no-graze experiments. Utilization of sericea lespedeza forage by cattle grazing in a heavy, continuous grazing system was higher with spring burning. Reduced rates of triclopyr, metsulfuron-methyl, picloram plus 2,4-D, and dicamba plus 2,4-D applied in June did not result in satisfactory control of seedlings. Triclopyr at 0.56 kg ha-1 applied to established plants in June, reduced sericea lespedeza seedling density by 88% or better (60 DAT) in both graze and no-graze experiments. Triclopyr at 0.56 kg ha-1 applied in June 1998 killed all stems of established sericea lespedeza plants by 60 DAT.

Nomenclature: dicamba, 3,6-dichloro-2-methyoxybenzoic acid; fluroxypyr, [(4-amino-3,5-dichloro-6-fluoro-2-pyridinyl)oxy]acetic acid; 2,4-D, (2,4-dichlorophenoxy)acetic acid; metsulfuron-methyl, methyl 2-[[[[(4-metoxy-6-methyl-1,3,5-triazin-2-yl)amino]carbonyl]amino]sulfonyl] benzoate; picloram, 4-amino-3,5,6-trichloro-2-pyridinecarboxylic acid; and triclopyr, [(3,5,6-trichloro-2- pyridinyl)oxy]acetic acid; sericea lespedeza, *Lespedeza cuneata* (Dumont) G. Don. # LESCU.

Additional index words: Seed dormancy, grazing sericea lespedeza, and forage yields.

Abbreviations: DAT, days after treatment.

INTRODUCTION

Sericea lespedeza (*Lespedeza cuneata* [Dum.Cours] G. Don) is an aggressive warm-season, perennial, herbaceous, allelopathic legume that was introduced into the Southeastern United States in the late 1800's as a forage species and for re-vegetation of erosive sites [McGraw and Hoveland 1995; Hoveland and Donnelly 1985; Pieters 1950; and Pieters 1939]. Plants of sericea lespedeza reproduce by seed produced by established plants, which are capable of producing 340- to 670-kg of seed ha^{-1} (Guernsey 1970). Established plants can survive for many years in a wide range of climates, soil types, and conditions and once established (Lynd and Ansman 1993). Sericea lespedeza plants are grazed by cattle at an early vegetative growth stage, but as plants mature they become course and unpalatable. [McGraw and Hoveland 1995; Hawkins 1955; Donnelly 1954; Stitte and Clarke 1941; and Clarke et al.1939]. Dense stands of sericea lespedeza interfere with growth of palatable grasses in tallgrass prairies (Koger et al. 1998). The ability of sericea lespedeza to produce large amounts of seed, survive for many years in a wide range of environments, and interfere with growth of desirable grasses are reasons why it is a major weed problem in tallgrass prairies and improved pastures of Oklahoma and Kansas.

Seeds of sericea lespedeza germinate in the spring and early summer, when daytime temperatures are between 13 and 20°C (Mosjidis 1990). Temperatures in that range occur in April and May (average mean daily temperatures = 13 and 19°C) in north central Oklahoma where sericea lespedeza is a major weed problem (Oklahoma Climatological Survey 1997). Conditions favorable for germination of sericea lespedeza seed typically occurs after March in north central Oklahoma, which is when most prescribed burning, a common management tool used to control weeds and improve palatability of forages, is done in tallgrass prairies. Burning in the spring, may lead to increased seed germination and establishment of sericea lespedeza, but data to prove this is not available.

Control of sericea lespedeza with chemicals has been investigated in recent years. Chemicals commonly used to control broadleaf weeds in tallgrass prairies and improved pastures such as: 2,4-D, dicamba, picloram, and clopyralid do not control sericea lespedeza [Altom and Stritzke 1992; and Fick 1990]. Applications of metsulfuron-methyl, triclopyr, and fluroxypyr control established plants of sericea lespedeza, with 80 to 99% stem density reduction by 1 YAT [Koger and Stritzke 1997; Altom and Stritzke 1992; and Fick 1990].

Control of sericea lespedeza with chemicals may be short-lived, with re-establishment of sericea lespedeza from plants not killed by the herbicide and from seed found in the soil-seed bank (Koger et al. 1998). Sericea lespedeza stem density in bermudagrass pastures that were infested with sericea lespedeza before treatment with triclopyr and metsulfuron-methyl were 3 and 13% 1 and 2 YAT with triclopyr; and 8 and 25% with metsulufuron-methyl, respectively. Seedling density 2 YAT in the triclopyr and metsulfuron-methyl plots were 43 and 86 seedlings per m^2 respectively (Koger and Strtizke 1997). Koger et al. (1998) reported the percent of original sericea lespedeza stem density remaining in a tallgrass prairie 1 and 2 YAT with triclopyr were 0 and 8, and 0 and 38% with metsulfuron-methyl, respectively. They also reported, sericea lespedeza seedling density at the tallgrass prairie site 2 YAT with triclopyr and metsulfuron-methyl were 43 and 150 seedlings per m^2.

Germination of sericea lespedeza seed occurs in the spring when environmental conditions are favorable, but little is known about the effects of precipitation on germination and seed dormancy. Applications of triclopyr and metsulfuron-methyl provide excellent control of established plants of sericea lespedeza. Little is known however about the effects of triclopyr, metsulfuron-methyl, and other herbicides commonly used to control broadleaf weeds, on seedlings of sericea lespedeza. Little is known of the effects of prescribed burning on sericea lespedeza seed germination and established plants of sericea lespedeza. The objectives of this research were to document timing of sericea lespedeza seedling emergence, effects of herbicides on sericea lespedeza seedlings, and effects of burning used in conjunction with triclopyr on seedlings and established plants of sericea lespedeza in systems grazed by cattle.

MATERIALS AND METHODS

Six experiments were established on dense stands of sericea lespedeza in 1997 and 1998 at locations near Stillwater, Fairfax, and Roff Oklahoma. The Stillwater location (Zaneis-Huska loam soil) is a decadent "Jose" tall wheatgrass pasture that was not burned or grazed by cattle and was nearly a solid stand of sericea lespedeza. The Fairfax location (Kiomatia loamy fine sand soil) is a tallgrass prairie that was burned each spring and double stocked annually with stocker cattle at 1.25 head/ha from April 1 to July 15. The Roff location (Fitzhugh loam soil) is a tallgrass prairie that was not burned and was grazed by stocker cattle at 5 head/ha for 4 days followed by 44 days of rest from April to October.

Stillwater site: Two randomized-complete-block-design experiments were established in the spring of 1997 in an area where established plants of sericea lespedeza were controlled with herbicides in 1995. Plot size was 3.6- by 7.3-m with four replications of each treatment in both experiments. Dry conditions in the spring of 1996 resulted in essentially no sericea lespedeza seedling emergence. Conditions in the springs of 1997 and 1998 were favorable for seed germination.

One experiment was initiated to evaluate timing of sericea lespedeza seedling emergence. Newly emerged seedlings were counted on April 7, May 5, June 5, and July 9 of 1997 in four 15- by 92-cm quadrats per plot. Quadrats were randomly placed along a diagonal transect in each plot. Flags placed in the corners of each quadrat on the first count date were used to position quadrats in the same location for later count dates. All newly emerged seedlings were killed immediately after counts were taken each month with an application of glyphosate at 2.24 kg ai ha^{-1}. Newly emerged seedlings were again counted in the same permanent quadrats on April 3, May 8, and June 9 of 1998. Glyphosate was used as in 1997 to kill seedlings after monthly counts were taken. No new seedlings emerged after June 9 count due to dry weather.

The second experiment was initiated in 1997 to determine the response of sericea lespedeza seedlings to five herbicide treatments. Sericea lespedeza seedlings were counted in four 15- by 92-cm quadrats per plot on June 5, 1997 before applying treatments. Quadrats were randomly placed along a diagonal transect in each plot and flags were placed in corners of quadrats for future sampling. Herbicides and rates are listed in Table 1. Environmental conditions at time of treatment were as follows: air temperature 28C; Humidity 28%; 21C soil temperature at 10 cm depth; and sericea lespedeza seedling height 10.0cm. Seedling counts were taken again on November 14, 1997, in the same four 15- by 92-cm permanent quadrats per plot to determine effectiveness of herbicide treatments.

Fairfax and Roff sites: Two randomized complete block design experiments were established at the Fairfax and Roff locations in early March of 1998. One experiment at each location was fenced in late March to exclude grazing by cattle, with the second experiment subjected to grazing by cattle with the grazing system used at each location. Treatments for all four experiments were arranged in a 2 x 2 factorial arrangement of burning (burn and no-burn) by herbicide treatments (no-herbicide and triclopyr at 0.56 kg ae ha^{-1}), with all four treatment combinations replicated four times in 3.6- by 7.3-m plots. All above-ground biomass in burn plots was removed with a prescribed fire (March 10 at Fairfax and March 11 at Roff) before emergence of sericea lespedeza stems from established plants and seedlings. Stems of established sericea lespedeza plants were counted in two 45- by 92-cm permanent quadrats per plot and sericea lespedeza seedlings were counted in four 15- by 92-cm permanent quadrats per plot on June 2 at Fairfax and June 3 at Roff. Quadrats for all counts were randomly placed along a diagonal transect in each plot. June counts from the untreated plots and plots to be treated with triclopyr were pooled to make eight replications of both burn and no-burn treatments.

Percent grass and sericea lespedeza by mass was visually estimated and current year herbage standing crop was harvested from two randomly placed 45- by 92-cm quadrats per plot in the no-herbicide plots on June 13 at the Fairfax site and June 16 at the Roff site. Mass by weight of all grass species in each plot was pooled to determine a total percent grass composition for each plot. Grass composition consisted mainly of indiangrass (*Sorghastrum nutans*), switchgrass (*Panicum virgatum*), big bluestem (*Andropogon gerardii*) and little bluestem (*Schizachyrium scoparium*) at the Fairfax location and indiangrass, big bluestem and little bluestem at the Roff location. Harvested forage was oven dried at 48°C. Triclopyr was applied on June 13 at Fairfax and June 16 at Roff using a CO2 pressurized sprayer in a carrier volume of 186 liters ha^{-1}. Environmental conditions and height of sericea lespedeza seedlings and stems of established plants at time of treatment are listed on Table 2. Stems of established sericea lespedeza plants and seedlings in the permanent quadrats were counted again in all plots on August 27 at Fairfax and September 10 at Roff to determine effect of triclopyr on stems of established plants and seedlings of sericea lespedeza.

Data for all experiments were analyzed using ANOVA (SAS Institute 1989) and treatment means were separated using a Fisher's protected LSD at $P = 0.05$ (Steel and Torrie, 1980). The percent of seedlings present 150 DAT across all four replications were transformed using an arcsin function to adjust for heterogeneity of variances of seedling densities before and 150 DAT.

RESULTS AND DISCUSSION

Stillwater location: *Timing of sericea lespedeza seeding emergence.* Timing of seedling emergence appears to be dependent upon receiving adequate precipitation and daytime temperatures necessary for germination of sericea lespedeza seed. Density of seedlings that emerged in March of 1997 (21 seedlings per m^2) were significantly lower ($P<0.05$) than density that emerged in April 1997 (Table 3). Levels of precipitation received at the location in March of 1997 were 5.31 cm below the 30-year average (Table 4), while 5.92 cm above the 30-year average was received in April of 1997. Mean daytime temperatures for the months of March and April (18 and 18°C) were within the temperature range of 13 and 19°C that is required for germination of sericea lespedeza seed as reported by Mosjidis (1990). Density of sericea lespedeza seedlings that emerged in March and April of 1998 (355 and 344 seedlings per m^2) were not significantly different at $P=0.05$ (Table 3). Precipitation received in March and April of 1998 was above the 30-year average for each month, with 16.63 and 11.4 cm of precipitation received in March and April 1998 (Table 4).

Density of sericea lespedeza seedlings that emerged in May and June of 1997 and 1998 (Table 3) were significantly lower ($P<0.05$) than density that emerged in March and April of both years. Temperatures above those required for germination of sericea lespedeza seed appears to be the cause for lower density of sericea lespedeza seedlings in May and June of both years. Mean daytime temperatures in May and June of 1997 and 1998 (Table 4) were between 25 and 31°C, which is above the optimal temperature range (13 to 19°C) for germination of sericea lespedeza seed as reported by Mosjidis (1990).

Sericea lespedeza seed germination may be affected by seed dormancy, with all seedlings that emerged after established plants were controlled in 1995 come from seed that was produced in 1994 or earlier. No seedlings emerged in 1996 due to dry conditions, however a total of 367 seedlings per m^2 emerged in 1997 and 751 per m^2 in 1998 when environmental conditions were favorable for germination of sericea lespedeza seed.

High density of sericea lespedeza seedlings were counted in both years when adequate precipitation and optimal temperatures occurred for the germination of sericea lespedeza seed. Sericea lespedeza seedling emergence was reduced in May and June of both years when temperatures were too high for germination of sericea lespedeza seed.

Control of seedlings. Control of sericea lespedeza seedlings was not satisfactory with the evaluated herbicide treatments. Density of sericea lespedeza seedlings ranged from 118 to 302 seedlings per m^2 before treatment with herbicide in June of 1997 across all plots and 65 to 159 seedlings per m^2 by 150 DAT (Table 5). Applications of metsulfuron-methyl at 0.0084 and picloram+2,4-D significantly reduced seedling densities by 150 DAT, with 29 and 43 percent of the seedlings remaining by 150 DAT respectively (Table 5).

Fairfax and Roff locations: *Emergence and survival of seedlings.* Data for sericea lespedeza seedling density observed in June in the graze and no-graze experiments were pooled across locations. Burning in March resulted in significantly higher ($P<0.05$) June seedling density in the graze and no-graze experiments (Table 6). Higher seedling density with the burn treatment is possibly attributed to the removal of decadent standing biomass that may have competed with germinating seed and emerged seedlings for space, light and water in the burned plots. Burning in combination with grazing resulted in significantly higher ($P<0.05$) June seedling density (105 seedlings per m^2) when compared to density in the burn plus no-graze treatment (70 seedlings per m^2). Utilization of standing crop forage by cattle in the burn treatment apparently caused decreased competition on emergence of sericea lespedeza seedlings. The implications of burning and grazing, which are common practice in grasslands of Oklahoma, attribute to higher density of sericea lespedeza seedlings and possibly to the establishment of sericea lespedeza stands.

Extremely dry weather during the summer of 1998 at the Roff location resulted in no survival of sericea lespedeza seedlings by the September 10 sampling date in the grazed and no-graze experiments. Therefore, no statistical comparisons could be made between grazing systems at the Fairfax and Roff locations. Survival of sericea lespedeza seedlings by the August 27 sampling date in the graze experiment at Fairfax was significantly higher ($P<0.05$) with the no-burn treatment (50%) when compared to survival (27%) for the burn treatment (Table 7). Survival of seedlings in the no-burn treatment of the no-graze experiment was significantly lower ($P<0.05$) when compared to survival with the burn treatment. Lower percent survival of seedlings in plots not burned may be attributed to competition from the layer of decadent plant material that covered the soil surface in the no-burn plots. June applications of triclopyr in the graze experiment resulted in 5% remaining by the August 27 sampling date in the burn treatment and 9% in the no-burn treatment, with no significant ($P>0.05$) difference between the burn and no-burn treatment. Percent of seedlings remaining following June applications of triclopyr in the no-graze experiment was 12 and 0% for the burn and no-burn treatments, with no significant difference ($P<0.05$) between percent survival in the no-burn + triclopyr (0%) and no-burn + no-herbicide (7%) treatments.

Stem density in June and percent survival of established sericea lespedeza plants. Data for stem density of established plants in June and estimates of percent survival of established sericea lespedeza stems in August were pooled across locations. Burning in March, used with and without grazing, increased stem density of established sericea lespedeza plants. Density of stems of established sericea lespedeza plants in June (Table 8) were significantly higher ($P<0.05$) with the burn plus graze and burn without graze treatments (82 and 83 stems per m^2) compared to stem density with the no-burn and no-graze treatment (62 stem per m^2). However, stem density in the burn treatment of the graze and no-graze experiments was not significantly lower ($P>0.05$) compared to stem density with the no-burn plus graze treatment (77 stems per m^2). Loss of apical dominance in sericea lespedeza plants with burning and grazing may cause an increase in stem development from crown buds and higher density of stems of established sericea lespedeza plants. Lower stem survival in the no-burn treatment of the grazed experiment may be attributed to competition from decadent grasses growing in association with plants of sericea lespedeza.

June applications of triclopyr killed all stems of established sericea lespedeza plants by the August sampling date in all plots of graze and no-graze experiments at both locations. Percent of stems of established sericea lespedeza plants remaining by late summer in plots not treated with triclopyr were affected by burning and grazing treatments. Burning and grazing resulted in significantly lower ($P<0.05$) survival of stems of established plants (Table 9). Percent survival of stems with the burn and no-burn treatments of the graze experiments (44 and 47 stems per m^2) and burn treatment of the no-graze experiments (55 stems per m^2) were significantly lower ($P<0.05$) than percent stem survival for the no-burn treatment of the no-graze experiments. Burning lowers the percent survival of stems of established sericea lespedeza plants and when used in conjunction with grazing appears to result in increased utilization of sericea lespedeza as a forage to cattle.

Standing crop of sericea lespedeza and grasses. Spring burning resulted in increased utilization of sericea lespedeza by cattle at the Fairfax location. Dry matter yields of sericea lespedeza standing crop for the March burn treatment of the grazed experiment at Fairfax, based on June 13 sampling, was only 841 kg ha^{-1}, compared to 1353 kg ha^{-1} for the no-burn treatment (Table 10). Spring burning removes decadent standing crop of sericea lespedeza and grass forages and appears to improve utilization of new sericea lespedeza growth that emerges after the spring burn. Dry matter yields of sericea lespedeza standing crop in the burn and no-burn treatments of the no-graze experiment were in different proportions when compared to yields for the graze experiment. Spring burning, used without grazing by cattle, resulted in significantly higher ($P<0.05$) standing crop yields of sericea lespedeza. Dry matter standing crop yields of sericea lespedeza in the burn treatment of the no-graze experiment was 1391 kg ha^{-1} compared to yields in the no-burn treatment of 606 kg ha^{-1}. Spring burning, when used without burning, resulted in increased standing crop yields of sericea lespedeza. Spring burning also removed decadent standing crop of sericea lespedeza that remains from the previous years growth and may be used as a management option to increase grazing utilization of new sericea lespedeza growth that emerges after the spring burn.

Dry matter standing crop yields of forage grasses at the Fairfax location were higher when standing crop yields of sericea lespedeza were low (Table 10). Dry matter standing crop yields of grasses in the burn plus graze treatment (704 kg ha^{-1}) were significantly higher ($P<0.05$) than yields in the no-burn plus graze treatment (360 kg ha^{-1}). Higher standing crop yields of grasses in the burn plus graze treatment may be attributed to low levels of competition from sericea lespedeza, which yielded much less in the burn treatment compared to yields in the no-burn treatment of the graze experiment. Spring burning in the no-graze experiment resulted in significantly lower standing crop yields of grasses (926 kg ha^{-1}) compared to yields with the no-burn treatment (1881 kg ha^{-1}). Competition from sericea lespedeza in the burn treatment may have attributed to low grass yields in the burn treatment of the no-graze experiment.

Dry matter yields of sericea lespedeza and grasses in the grazed experiment at Roff were in different proportions when compared to yields at Fairfax. Dry matter standing crop yields of sericea lespedeza in the graze experiment at Roff were significantly higher ($P<0.05$) with the burn treatment (1401 kg ha^{-1}), compared to dry matter yields of 800 kg ha^{-1} in the no-burn treatment (Table 11). Cattle were not allowed to graze between early April and late May with the rotational grazing system that was used at the Roff location. During this time, palatability of sericea lespedeza forage probably decreased and cattle found sericea lespedeza forage to be undesirable when allowed to graze again in late May. Competition from sericea lespedeza with the burn treatment probably attributed to decreased standing crop yields of grasses in the graze experiment. The effects of burning in the no-graze experiment at Roff were very similar to that reported for Fairfax. Burning at Roff resulted in large standing crop yields of sericea lespedeza (1182 kg ha^{-1}) and low yield of grasses (673 kg ha^{-1}) compared to no-burning where yields of sericea lespedeza (725 kg ha^{-1}) were lower than yields of grasses (1061 kg ha^{-1}).

Burning used in conjunction with continuous heavy stocking pressure results in increased utilization of sericea lespedeza forage. Increased utilization of sericea lespedeza by cattle in the burn treatment of the Fairfax location, where heavy stocking pressure was used, resulted in lower stem density of sericea lespedeza compared to stem density in the no-burn treatment. Plants of sericea lespedeza however became course and unpalatable when allowed to rest from grazing pressure during the growing season at the Roff location, where cattle were allowed to graze for three days in early April and not allowed to graze again until late May. Decreased utilization of sericea lespedeza by returning cattle in late May at the Roff location resulted in larger yields and stem density of sericea lespedeza in the burn treatment when compared to the no-burn treatment of the grazed experiment at Roff.

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Table 1. Herbicide treatments applied to seedlings of sericea lespedeza at the Stillwater location. 1997.

Herbicide	Rate
	(kg/ha)
Metsulfuron-methyl[a]	0.0042
Metsulfuron-methyl[a]	0.0084
Triclopyr[b]	0.28
Picloram + 2,4-D amine[c]	0.075 + 0.28
Dicamba + 2,4-D amine[d]	0.14 + 0.4
No-herbicide	———

[a] Metsulfuron-methyl received 0.25% v/v X-77 surfactant.
[b] Tricloyr treatments are butoxyethyl formulations.
[c] Picloram and 2,4-D amine treatments are triisopropylanolamine salt formulations.
[d] Dicamba and 2,4-D amine treatments are dimethylamine salt formulations.

Table 2. Environmental conditions and height of sericea lespedeza seedlings and established plants at time of triclopyr application in burn by herbicide experiments at the Fairfax and Roff locations. 1998.

	Location	
	Fairfax	Roff
Application date	6/13/98	6/16/98
Air temperature (C)	20	26
Humidity (%)	71	60
Soil temperature (C)	20	21
Height of LESCU in grazed experiments	(cm)	(cm)
Burned plots		
New seedlings	6	8
Established plants	24	34
No-burn plots		
New seedlings	6	7
Established plants	39	57
Height of LESCU in no-graze experiments		
Burned plots		
New seedlings	6	7
Established plants	31	47
No-burn plots		
New seedlings	5	7
Established plants	45	61

Table 3. Density of sericea lespedeza seedlings that emerged in March, April, May, and June of 1997 and 1998 at the Stillwater location.[ab]

Month	1997	1998
	—— new seedlings per m^2	——
March	21 b	355 a
April	302 a	344 a
May	86 b	84 b
June	80 b	0 b
LSD(.05)	112	248

[a] Glyphosate at 2.24 Kg ae ha^{-1} was applied after counting seedlings each month to remove existing seedlings.
[b] Seedling densities for each month were determined within 10 days after the last day of listed month. For example: seedlings that emerged in March 1997 were counted on April 7, 1997.

Table 4. Thirty year average and precipitation that was received and average monthly daytime temperature for March, April, May, and June of 1997 and 1998 at the Stillwater location.

	Precipitation			Daytime temperature		
Month	30 year ave.	1997	1998	30 year ave.	1997	1998
	—— cm ——			—— C ——		
March	7.44	2.13	16.63	11	18	13
April	7.74	13.66	11.4	13	18	19
May	13.56	7.16	9.19	19	25	28
June	10.74	12.97	5.13	23	29	31

Table 5. Percent of sericea lespedeza seedling density remaining 150 DAT at the Stillwater location. 1997.[abc]

Treatment	Rate	150 DAT
	(kg/ha)	– % remaining –
Metsulfuron-methyl[c]	0.0042	53 ab
Metsulfuron-methyl[c]	0.0084	29 a
Triclopyr	0.28	58 ab
Picloram + 2,4-D amine	0.075 + 0.28	43 a
Dicamba + 2,4-D amine	0.14 + 0.4	97 c
No-herbicide	————	86 bc
LSD (.05)		38

[a] Percentages were transformed across all four replications using an arcsin function to adjust for heterogeneity of variances of seedling densities.

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

[c] Metsulfuron-methyl treatment received 0.25% v/v X-77 surfactant before application.

Table 6. Effects of March burning in combination with graze and no-graze treatments on density of sericea lespedeza seedlings observed in June 1998 – Pooled for Fairfax and Roff locations. 1998.[ab]

Treatments	Seedling density in June 1998
	—— seedlings per m^2 ——
Grazed experiments	
Burn	105 a
No-burn	45 c
No-Graze experiments	
Burn	70 b
No-burn	30 c
LSD (.05)	22

[a] Means followed by the same letter are not different at P <0.05 according to Fishers Protected LSD test.

[b] Plots were burned on March 10, 1998 at Fairfax and March 11, 1998 at Roff.

Table 7. Effects of March burning in combination with triclopyr applied in June on survival of sericea lespedeza seedlings between the June and August sampling dates for grazed and no-graze experiments at the Fairfax location. 1998.[abc]

	Sericea lespedeza seedling survival	
Treatments	Graze experiment	No-graze experiment
	—— % Remaining ——	
Burn + triclopyr	5 c	12 b
Burn + no herbicide	27 b	46 a
No-burn + triclopyr	9 c	0 b
No-burn + no herbicide	50 a	7 b
LSD (.05)	15	14

[a] Means within each column followed by the same letter are not different at P <0.05 according to Fishers Protected LSD test.

[b] Percent seedling remaining values were calculated using an arcsin conversion of the seedlings remaining between the June and August sampling dates from all four replications in each experiment.

[c] Plots were burned on March 10, 1998 and triclopyr was applied on June 13, 1998.

Table 8. Effects of March burning in combination with graze and no-graze treatments on stem density of established sericea lespedeza plants observed in June 1998 – Pooled for Fairfax and Roff locations. 1998.[ab]

Treatments	stem densities of established plants
	stems per m^2
Grazed experiments	
Burn	82 a
No-burn	77 ab
No-Graze experiments	
Burn	83 a
No-burn	62 b
LSD (.05)	17

[a] Means followed by the same letter are not different at $P < 0.05$ according to Fishers Protected LSD test.
[b] Plots were burned on March 10, 1998 at Fairfax and March 11, 1998 at Roff.

Table 9. Effects of March burning on survival of stems of established sericea lespedeza plants between the June and late-summer sampling dates in graze and no-graze experiments – Pooled for Fairfax and Roff locations. 1998.[abcd]

Treatments	Survival of stems of established plants
	% Remaining
Grazed experiments	
Burn	44 b
No-burn	47 ab
No-Graze experiments	
Burn	55 ab
No-burn	74 a
LSD (.05)	28

[a] Means followed by the same letter are not different at $P < 0.05$ according to Fishers Protected LSD test.
[b] Percent remaining values were calculated using an arcsin conversion of the stems remaining between the June and August sampling dates from all four replications in each experiment.
[c] At Fairfax, Plots were burned on March 10, 1998 and triclopyr was applied on June 13, 1998.
[d] At Roff, plots were burned on March 11, 1998 and triclopyr was applied on June 16, 1998.

Table 10. Standing crop yields of established sericea lespedeza (LESCU) and grasses in burn and no-burn treatments of graze and no-graze experiments on June 13, 1998 at the Fairfax location.[a]

	Experiment				
	Graze			No-graze	
Treatment	LESCU	Grasses[b]		LESCU	Grasses[b]
			kg ha^{-1}		
Burn	841 a	704 a		1391 b	926 b
No-burn	1353 b	360 b		606 a	1881 a
LSD (0.05)	301	43		108	116

[a] Means within a column followed by the same letter are not statistically different at P = 0.05 according to Fishers Protected LSD test.

[b] Grasses were a mixture of indiangrass (*sorghastrum nutans*), switchgrass (*Panicum virgatum*), big bluestem (*Andropogon gerardii*), and little bluestem (*Schizachyrium scoparium*).

Table 11. Standing crop yields of established sericea lespedeza (LESCU) and grasses in burn and no burn treatments of graze and no-graze experiments on June 16, 1998 at Roff, OK. 1998.[a]

	Experiment				
	Graze			No-graze	
Treatment	LESCU	Grasses[b]		LESCU	Grasses[b]
			kg ha^{-1}		
Burn	1401 a	391 a		1182 a	673 a
No-burn	800 b	1231 b		725 b	1061 b
LSD (0.05)	227	241		274	230

[a] Means within a column followed by the same letter are not statistically different at P = 0.05 according to Fishers Protected LSD test.

[b] Grasses were a mixture of indiangrass (*sorghastrum nutans*), big bluestem (*Andropogon gerardii*), and little bluestem (*Schizachyrium scoparium*).

CHAPTER III

RESPONSE OF SERICEA LESPEDEZA TO TIMING OF HERBICIDE TREATMENTS UNDER DIFFERENT GRAZING REGIMES

Response of Sericea Lespedeza to Timing of Herbicide Treatments Under Different Grazing Regimes

T.H. Koger, J.F. Stritzke, C.L. Goad

Abstract: Experiments were established at three locations in 1997 to determine response of sericea lespedeza to herbicide treatment under different grazing regimes. Applications of triclopyr at 0.56 kg ha^{-1} in June 1997 and metsulfuron-methyl at 0.0126 kg ha^{-1} in late summer 1997 resulted in 3% or less of stems remaining by June 1998. Triclopyr at 0.28 kg ha^{-1} applied in June and metsulfuron-methyl at 0.0084 kg ha^{-1} applied in late summer resulted in 13% or less stems remaining. Mowing in June 1997 followed by herbicide treatment with metsulfuron-methyl at 0.0042, 0.0084, and 0.0126 kg ha^{-1} and triclopyr at 0.28 and 0.56 kg ha^{-1}in August on the no graze location resulted in 16% or less stems remaining. Mowing alone had no effect on stem density of established sericea lespedeza. However, mowing in June 1997 did significantly increase seedling emergence in the spring of 1998, with density in the no-herbicide treatments averaging 12 seedlings per m^2 in the no mow treatment compared to 110 seedlings per m^2 in the mow treatment. Applying herbicide treatments 1 month after June 1997 mowing had no effect on emergence of seedlings the following spring. However, applying herbicide treatments in August (2 months after mowing) significantly decreased germination of new seedlings (33 vs. 104 in no-herbicide). Density of seedlings in 1998 were significantly lower when herbicide was applied in 1997.

Nomenclature: metsulfuron-methyl, methyl 2-[[[[(4-metoxy-6-methyl-1,3,5-triazin-2-yl)amino]carbonyl]amino]sulfonyl] benzoate; and triclopyr, [(3,5,6-trichloro-2-pyridinyl)oxy]acetic acid; sericea lespedeza, *Lespedeza cuneata* (Dumont) G. Don. # LESCU.

Additional index words: No grazing, heavy-continuous and rotational grazing, mowing, stems of established plants, sericea lespedeza seedlings, summer survival.

INTRODUCTION

Sericea lespedeza (*Lespedeza cuneata* [Dum.Cours] G. Don) is an introduced, warm-season, perennial, herbaceous, allelopathic legume that is becoming a major weed problem in tallgrass prairies and improved pastures of Oklahoma and Kansas. Sericea lespedeza is currently considered a noxious weed in 56 counties of eastern Kansas, by June 2000 it will be considered a noxious weed statewide (State of Kansas House Bill 2289, 1997). It is a drought tolerant species that is planted for forage purposes and used for soil conservation in highly erodible soils and highway right of ways [Mcgraw and Hoveland 1995; and Pieters 1950]. Plants of sericea lespedeza originate from seed produced by established plants, which are capable of producing 340 to 670 kg of seed ha^{-1} (Guernsey 1970). Sericea lespedeza, once established, is capable of surviving for many years in a wide range of climates, soil types and conditions (Lynd and Ansman 1993). Sericea lespedeza plants are readily grazed during the early months of the growing season when plants are small in size. However, with increasing maturity and plant height, increasing lignin and tannin content causes decreased utilization by grazing animals [McGraw and Hoveland 1995; Hawkins 1955; Donnelly 1954; Stitte and Clarke 1941; and Clarke et al. 1939].

Sericea lespedeza interferes with the growth of desirable perennial forage grass species in tallgrass prairies. Koger et al. (1998) reported biomass yields for perennial tallgrass species of 1680 kg ha^{-1} in plots where established plants of sericea lespedeza exist, compared to yields of 3920-4700 kg ha^{-1} where sericea was controlled with herbicides 2 years before yields were estimated. Sericea lespedeza also interferes with emergence and growth of some improved forage grass species [Kalburtji and Mosjidis

1993a; Kalburtji and Mosjidis 1993b; Dornbos et al. 1990; Kil and Lee 1987; and Guenzi and McCalla 1962]. The ability of sericea lespedeza to survive for many years, grow under a wide range of environmental conditions, produce large quantities of seed, and interfere with the growth of desirable forage species are reasons for it becoming a major weed problem in tallgrass prairies and improved pastures. It also appears that prescribed burning, a common management tool used to control weeds and improve palatability of desirable forages, may lead to increased seed germination and establishment of new sericea lespedeza plants.

Herbicides that have been investigated for their effect on established plants of sericea lespedeza include: clopyralid, dicamba, fluroxypyr, 2,4-D, metsulfuron-methyl, picloram, and triclopyr. Applications of triclopyr, fluroxypyr, and metsulfuron-methyl resulted in stem density reductions of 80 to 99% by 1 YAT [Altom and Stritzke 1992; and Fick 1990]. Combinations of 2,4-D and dicamba, 2,4-D, and dicamba alone, and clopyralid resulted in little reduction of sericea lespedeza stem densities [Altom and Stritzke 1992; and Fick 1990].

Established plants of sericea lespedeza can be effectively controlled after mowing with herbicides. Koger and Stritzke (1997) reported that triclopyr, fluroxypyr, and metsulfuron-methyl applied 1 and 3 months after June mowing and 2 months after July mowing resulted in 86% or better stem density reductions 1 YAT. Stem reduction in plots that were mowed in June and not treated with herbicide and plots mowed in July and not treated with herbicide averaged 19% and 11% stem reduction 1 YAT respectively.

Control of sericea lespedeza with herbicides is short-lived, with re-establishment of sericea lespedeza from plants not killed by the herbicide and from establishment of new plants from seed found in the soil-seed bank. In bermudagrass pastures infested with sericea lespedeza, Koger et al. (1998) reported the percent of sericea lespedeza stems remaining 1 and 2 YAT with triclopyr were 3 and 13% respectively; and 8 and 25% stems remaining 1 and 2 YAT with metsulufuron-methyl. Seedling density 2 YAT in the triclopyr and metsulfuron-methyl plots were 43 and 86 seedlings per m^2. On a tallgrass prairie site with sericea lespedeza, Koger et al. (1998) reported the percent of original sericea lespedeza stem density remaining 1 and 2 YAT with triclopyr was 0 and 8% respectively, and 0 and 38% remaining 1 and 2 YAT with metsulfuron-methyl. In addition, they documented new seedling density of 43 and 150 seedlings per m^2 2 YAT in plots treated with triclopyr and metsulufuron-methyl, respectively.

It is important that management of sericea lespedeza after established plants are controlled with herbicides be evaluated, since stand re-establishment may be possible from established plants not killed by the herbicide and from seedlings. The objectives of this research were to evaluate the effect of selected herbicides applied at different stages of plant maturity on established sericea lespedeza under different management regimes and to document successional re-establishment of sericea lespedeza after treatment with herbicide.

MATERIALS AND METHODS

Experiments were established in 1997 at three locations (Stillwater, Fairfax, and Roff OK) that contained dense populations of sericea lespedeza. The Stillwater location (Zaneis-Huska loam soil) is a decadent "Jose" tall wheatgrass pasture that is not burned or grazed and is nearly a solid stand of sericea lespedeza. The Fairfax location is a tallgrass prairie (Kiomatia loamy fine sand soil) that is burned each spring and double stocked at 1.25 head/ha with stocker cattle from April 1 to July 15. The Roff location is a tallgrass prairie (Fitzhugh loam soil) that is not burned and is grazed with stocker cattle at 5 head/ha for 4 days followed 44 days of rest from April to October (high intensity-low frequency grazing system).

Stillwater location: One split-plot design experiment, with five main plot treatments and five subplot treatments, was established in the summer of 1997. Main and subplot treatment combinations are listed in Table 1. Sericea lespedeza stem density were determined prior to main and subplot treatment application by counting stems in two 45- by 92-cm permanent quadrats per plot. Plot size was 2.1- by 9.1-m with four replications of each main by subplot treatment combination. Environmental conditions and sericea lespedeza stem heights at time of herbicide applications are listed in Table 2. Herbicides were applied using a CO_2 pressurized sprayer in a carrier volume of 186 liters ha^{-1}. Stems and seedlings of sericea lespedeza were counted on June 9, 1998 (1 YAT) in two 45- by 92-cm permanent quadrats per plot to determine effect of treatments on density of established sericea lespedeza and to document density of new sericea lespedeza seedlings. Sericea lespedeza stem and seedling counts were taken again on September 18 in two 45- by 92-cm permanent quadrats per plot to monitor summer survival.

Fairfax and Roff locations: A three by five factorial arrangement of treatments in a randomized complete block design experiment with four replications was established in the summer of 1997 at each location. One factor was timing of herbicide treatments (late June, late July, late August) and the second factor was herbicide treatment (Table 3). A no herbicide treatment was also included for comparison to herbicide treatments. Stem density of sericea lespedeza were determined in two 45- by 92-cm quadrats per plot on June 19 at Fairfax and June 20 at Roff before herbicide treatments were applied. Herbicide treatments were applied in late June, late July, and late August at both sites in 3.6- by 7.3-m plots, using a CO_2 pressurized sprayer in a carrier volume of 186 liters ha^{-1}. Herbicide application dates, environmental conditions, and sericea lespedeza stem heights at time of treatment are listed in Table 4. Total number of sericea lespedeza stems and those that contain seed were counted in 0.9- by 3.0-m interior of each plot on October 30 at Fairfax and October 31, 1997 at Roff to monitor effect of treatments on plants and seed development. Forage re-growth since removal of cattle on July 15 was harvested with hand clippers in two 45- by 92-cm permanent quadrats per plot on November 7 at the Fairfax location. Percent composition for the various plant species in the sampling area was estimated for each plot to calculate production of the various species. Forage samples were oven dried (48°C) to remove moisture, so that dry-matter estimates could be made. Forage yields were not estimated at the Roff location since cattle were allowed to graze the location 3 out of every 44 days from April to October. Stems of established sericea lespedeza plants and seedlings were counted in two 45- by 92-cm quadrats per plot on June 2 at Fairfax and June 3, 1998 at Roff to determine effect of treatments on sericea lespedeza and to document density of seedlings that emerged in the spring of

1998. Stems and seedlings were counted again on August 27 at Fairfax and September 10 at Roff to document summer survival of sericea lespedeza stems and seedlings.

ANOVA procedures were used to test for effects of mowing and low application rates of metsulfuron-methyl and for interactions between treatment combinations. Means for treatments and treatment combinations were separated using Fisher's protected LSD. All tests were conducted at the 0.05 level. (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

Stillwater location: *Stems of established plants.* Interactions ($P<0.05$) between June 1998 stem densities with metsulfuron-methyl treatments across main plot treatments prevented pooling data across main plots. Applications of triclopyr at 0.28 and 0.56 kg ha^{-1} in June and July of 1997 to non-mowed plants resulted in excellent control of established plants of sericea lespedeza (0 to 7% of pre-treatment stem density remaining by June 1998), with no significant difference ($P>0.05$) between treatment rates (Table 5). Applications of triclopyr at 0.28 and 0.56 kg ha^{-1} in late August to plants not mowed were not as effective at controlling established plants of sericea lespedeza, with 16 and 8% stem density remaining by June of 1998. Other research (Altom and Stritzke 1992; Fick 1990) has shown 80 to 99% control of sericea lespedeza with applications of triclopyr at 0.56 kg ha^{-1}. Applications of metsulfuron-methyl at 0.0042 and 0.0126 kg ha^{-1} in late August of 1997 also resulted in excellent control of non-mowed established plants, with only 6 and 3% stem density remaining by June 1998. This agrees with other work (Fick 1990) where stem density of established plants of sericea lespedeza were reduced by 80% or higher.

Mowing in June of 1997, followed by application of herbicide treatments in July had little effect on stem density of sericea lespedeza with any treatment when compared to stem density with July applications of herbicide treatments in the no-mow main plot (Table 6). Percent of stem density remaining in June 1998 with August applied herbicide treatments to plants mowed in June was lower for all treatments compared to percent stem density remaining with August applied herbicide treatments in the no-mow main plot (Table 5). Only 16 and 5% of pre-treatment stem density remained by June 1998 with the 0.28 and 0.56 kg ha^{-1} triclopyr treatments and 0% remained with the metsulfuron-methyl treatments.

Dry summer weather resulted in stem density reduction for all sericea lespedeza plants not treated with herbicides between the June and September 1998 sampling dates. Percent stems remaining values by September 1998 in the no-mow - June, July, and August applied herbicide main plots were 79, 67, and 79%, respectively. This compared to 91, 94, and 86% remaining in June 1998, respectively. Mowing alone did not significantly reduce stem density by September 1998 compared to density with the no-mow treatment. Stem density of sericea lespedeza plants treated with triclopyr were lower by the September 1998 sampling date, when compared to stem density in June 1998. Stem density of sericea lespedeza by September 1998 with triclopyr at 0.28 kg ha^{-1} were not significantly different, with percent stem remaining values ranging from 8% for plants treated with triclopyr in September to 3% for plants mowed in June and treated with triclopyr in August. Percent of stem density remaining by September 1998 were not significantly different for all plants not treated with herbicides, with only 1% of stems remaining for plants treated in August and not mowed (Table 5). This compared to 0% remaining for stem density not mowed and treated with triclopyr at 0.56 kg ha^{-1} in June and July and plants mowed and sprayed 1 and 2 months after mowing, respectively.

Applications of metsulfuron-methyl in June and July for the no-mow treatments resulted in lower stem density of sericea lespedeza by September 1998 compared to stem density in June 1998. Percent stems remaining with applications of metsulfuron-methyl one month after June mowing also resulted in lower stem remaining values in September 1998 compared to June 1998 values, respectively. Applications of metsulfuron-methyl 2 months after June mowing resulted in 0% stems remaining by June and September 1998. Stem density of sericea lespedeza not mowed and treated in August with metsulfuron-methyl at 0.0042 and 0.0126 kg ha^{-1} showed an increase in stem density by September 1998 (17 and 5% remaining) when compared to values for June 1998 (6 and 3% remaining). It is possible that estimating control of sericea lespedeza in June 1998 may have been to early to determine actual control of established plants of sericea lespedeza, since an increase in stem density between June and September 1998 sampling dates was reported for some herbicide treatments.

Seedlings of sericea lespedeaza. Mowing in June 1997 had a significant effect on emergence of sericea lespedeza seedlings in June 1998. Seedling density for the no-herbicide treatment in the no-mow main plots (11 to 13 seedlings per m^2) was significantly lower ($P<0.05$) compared to seedling density of 104 to 117 seedlings per m^2 in the mow plots (Table 7). Seedling density in the herbicide treatments of the no-mow main plots were not significantly different ($P>0.05$), with 0 to 15 seedlings per m^2 respectively (Table 7). Mowing in June 1997 followed by herbicide application in July 1997 resulted in significantly higher ($P<0.05$) sericea lespedeza seedling density in June 1998, when compared to seedling density in the June mow plus August herbicide treatments. Seedling density in June of 1998 for the July applied herbicide treatments varied from 91 seedlings per m^2 with metsulfuron-methyl at 0.0042 kg ha^{-1} to 158 seedlings per m^2 with triclopyr at 0.28 kg ha^{-1}. Seedling density in June of 1998 for the June mow-August applied herbicide treatments varied from 27 seedlings per m^2 with triclopyr (0.28 and 0.56 kg ha^{-1}) to 54 seedlings per m^2 with metsulfuron-methyl at 0.0042 kg ha^{-1}.

Percent survival of sericea lespedeza seedlings through the summer of 1998 in all treatments was very low, with no significant difference (P>0.05) between percent survival of sericea lespedeza seedlings for all treatments. Nearly all seedlings died in the no-mow plots, with seedling density ranging from 0 to 2 seedlings per m^2, respectively (Table 8). Survival of seedlings in the mow plots was also very low when comparing differences between June and September 1998 seedling density. However, seedling density in some of the herbicide treatments of the mow main plots were still significantly higher (P<0.05) compared to seedling density in the herbicide treatments of the no-mow main plots (Table 7). In order to determine density of sericea lespedeza seedlings that survive through summer conditions, seedlings should be counted in early and late summer to early fall. This will help in documenting re-establishment of sericea lespedeza stands after established plants are controlled.

Fairfax and Roff locations. Percent of sericea lespedeza stem density remaining in June and September 1998 and seedling density in June 1998 were pooled across locations with no significant location by treatment interaction (P>0.05).

Stems of established plants. Timing of application of triclopyr and metsulfuron-methyl affected stem density of established sericea lespedeza plants. Applications of triclopyr at 0.56 kg ha^{-1} in June, July, and August of 1997 resulted in excellent control of established plants of sericea lespedeza, with 1, 8, and 5% of pre-treatment stem density remaining by June of 1998 and no significant difference (P<0.05) between treatments (Table 9). These results are similar to work from the Stillwater location, where 0,0, and 8% of pre-treatment stem density remained by June 1998 with June, July, and August 1997 applications of triclopyr at 0.56 kg ha^{-1}. Applications of triclopyr at 0.28 kg ha^{-1} in July and August of 1997 resulted in excellent control of established plants, with 12 and 18% stem density remaining by June 1998. However, June application of triclopyr at 0.28 kg ha-1 was not as effective, with 40% stem density remaining by June 1998, respectively. Percent stem density remaining by June of 1998 with August applications of metsulfuron-methyl at 0.0042, 0.0084, and 0.0126 kg ha^{-1} was not significantly different ($P>0.05$) with 12, 7, and 2% of stem density remaining, respectively (Table 9). Other work conducted by Fick (1990) and Koger et al. (1998) showed 80 to 100% control of established plants of sericea lesepedeza with late season applications of metsulfuron-methyl. Similar results were reported for the Stillwater location, where control of established plants with August applications of metsulfuron-methyl at 0.0042 and 0.0126 kg ha^{-1} was 94 and 97%, respectively. June and July applications of metsulfruon-methyl were not as effective at controlling sericea lespedeza, with percent of pre-treatment stem density remaining by June 1998 ranging from 11% with the July applied 0.0126 kg ha^{-1} treatment to 61% with the July applied 0.0042 kg ha^{-1} treatment.

Dry weather resulted in reduction in stem density of established sericea lespedeza plants between the June and September 1998 for all treatments except metsulfuron-methyl at 0.0126 kg ha^{-1} applied in August, which resulted in 4% stems remaining in September 1998 compared to 2% in June 1998 (Table 9). August applications of metsulfuron-methyl at the Stillwater location also resulted in an increase in percent stem density remaining between the June and September 1998 sampling dates.

Seedlings of Sericea Lespedeza. Sericea lespedeza seedling density in the spring of 1998 were significantly lower ($P<0.05$) for all of the herbicide treatments when compared to seedling density in the untreated plots (Table 9). Seedling density for the herbicide treatments ranged from 6 to 24 seedlings per m^2, compared to 43 seedlings per m^2 for the no-herbicide treatment, respectively. Seedling density in the June applied triclopyr at 0.56 kg ha^{-1} and August applied metsulfuron-methyl at 0.0126 kg ha^{-1} (8 and 6 seedlings per m^2) treatments were significantly lower ($P<0.05$) when compared to density in plots of the other herbicide treatments. These two treatments also provide the best control of established plants.

Dry weather in the summer of 1998 resulted in variable survival of sericea lespedeza seedlings between treatments. No seedlings survived at the Roff location (Table 10) and at the Fairfax site, survival ranged from 1% with triclopyr (0.56 kg ha^{-1}) applied in June to 69% in the no herbicide treatment (Table 11). Applications of triclopyr (0.56 kg ha^{-1}) in June and August resulted in significantly lower ($P<0.05$) survival rates (1 and 8%) compared to survival with the other herbicide treatments.

Control of established plants of sericea lespedeza with applications triclopyr and metsulfuron-methyl at all locations was dependent upon timing of herbicide application. Previous work (Altom and Stritzke 1992; Koger et al. 1998; Fick 1990) has shown similar results, with the best control of established sericea lespedeza plants from June and July applications of triclopyr and August applications of metsulfuron-methyl. Applications of triclopyr in June and metsulfuron-methyl in August of 1997, which resulted in excellent control of established plants, resulted in significantly lower ($P<0.05$) sericea lespedeza seedling density the following spring. Excellent control of established plants and lower seedling density in the following spring with these treatments may slow the re-establishment process of sericea lespedeza that comes from plants not completely killed and from sericea lespedeza seedlings that germinate from seed in the soil seed-bank.

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Table 1. Main and subplot treatments at Stillwater location. 1997.

Main plots[a]
No-mow and herbicide treatments applied June 6, 1997
No-mow and herbicide treatments applied July 22, 1997
No-mow and herbicide treatments applied August 26, 1997
Mow June 13, 1997 and herbicide treatments applied July 22, 1997
Mow June 13, 1997 and herbicide treatments applied August 26, 1997

Subplots (herbicide treatments)	Rate
	(kg/ha)
Metsulfuron-methyl[b]	0.0042
Metsulfuron-methyl[b]	0.0126
Triclopyr[c]	0.28
Triclopyr[c]	0.56
No-herbicide	——

[a] Above ground biomass in mow plots was cut at 5 cm height and removed from plots.
[b] Metsulfuron-methyl treatments received 0.25% v/v X-77 surfactant.
[c] Triclopyr treatments are butoxyethyl formulations.

Table 2. Environmental factors and sericea lespedeza stem height at time of treatment at Stillwater location. 1997.

Environmental factors	Application dates		
	June 16, 1998	July 22, 1998	August 26, 1998
Air temperature (C)	26	32	29
Humidity (%)	71	65	56
Soil temperature (C)	21	28	26
Stem heights (cm) in plots not mowed	20-26	25-45	32-78
Stem heights (cm) in plots mowed in June	5	10-22	15-32

Table 3. Herbicide treatments applied in late June, late July, and late August for herbicide X timing experiments at Fairfax and Roff locations. 1997.

Herbicide treatment	Rate
	(kg/ha)
Metsulfuron-methyl[a]	0.0042
Metsulfuron-methyl[a]	0.0084
Metsulfuron-methyl[a]	0.0126
Triclopyr[b]	0.28
Triclopyr[b]	0.56
No-herbicide	——

[a] Metsulfuron-methyl treatments received 0.25% v/v X-77 surfactant.
[b] Triclopyr treatments are butoxyethyl formulations.

Table 4. Application dates, environmental conditions, and sericea lespedeza stem heights at time of treatment for herbicide X timing experiments at Fairfax and Roff locations. 1997.

		Fairfax	
Application date	June 25, 1997	July 26, 1997	August 28, 1997
Air temperature (C)	24	29	32
Humidity (%)	78	80	45
Soil temperature (C)	22	26	29
Stem heights (cm)	6-45	15-58	21-74
		Roff	
Application dates	June 19, 1997	June 23, 1997	August 30, 1997
Air temperature (C)	32	34	30
Humidity (%)	52	49	70
Soil temperature (C)	26	26	28
Stem heights (cm)	20-52	24-72	25-80

Table 5. Effects of June mowing and herbicide treatments applied in June, July, and August of 1997 and dry weather conditions in the summer of 1998 on remaining stem density of established sericea lespedeza plants in June and September 1998 at Stillwater location.[a,b]

Treatment	Rate	Remaining stem density	
		June 1998	September 1998
	(kg/ha)	%	
No-mow and June herbicides			
Metsulfuron-methyl[c]	0.0042	98 a	87 a
Metsulfuron-methyl[c]	0.0126	41 d	25 d
Triclopyr[d]	0.28	7 ef	4 e
Triclopyr[d]	0.56	0 f	0 e
No-herbicide	——	91 d	79 ab
No-mow and July herbicides			
Metsulfuron-methyl[c]	0.0042	86 b	65 bc
Metsulfuron-methyl[c]	0.0126	15 e	3 e
Triclopyr[d]	0.28	8 ef	6 de
Triclopyr[d]	0.56	0 f	0 e
No-herbicide	——	94 ab	67 bc
No-mow and August herbicides			
Metsulfuron-methyl[c]	0.0042	6 ef	17 d
Metsulfuron-methyl[c]	0.0126	3 ef	5 ed
Triclopyr[d]	0.28	16 e	8 de
Triclopyr[d]	0.56	8 ef	1 e
No-herbicide	——	86 b	79 ab
Mow June and July herbicides			
Metsulfuron-methyl[c]	0.0042	64 c	52 c
Metsulfuron-methyl[c]	0.0126	5 ef	2 e
Triclopyr[d]	0.28	3 ef	3 e
Triclopyr[d]	0.56	1 f	0 e
No-herbicide	——	104 a	86 a
Mow June and August herbicides			
Metsulfuron-methyl[c]	0.0042	0 f	0 e
Metsulfuron-methyl[c]	0.0126	0 f	0 e
Triclopyr[d]	0.28	16 e	3 e
Triclopyr[d]	0.56	5 ef	0 e
No-herbicide	——	86 b	74 ab
LSD (0.05)		14	20

[a] Means within a column followed by the same letter are not statistically different according to Fishers Protected LSD test at $P = 0.05$.

[b] Percent remaining values were calculated using an arcsin conversion of the June and September seedling densities.

[c] Metsulfuron-methyl treatments received 0.25% v/v X-77 surfactant.

[d] Triclopyr treatments are butoxyethyl formulations.

Table 6. Effects of June mowing and herbicide treatments applied in June, July, and August of 1997 and dry weather conditions in the summer of 1998 on stem density of established sericea lespedeza plants in June 1997 and June and September 1998 at Stillwater location.[a]

Treatment	Rate	Stem density of established plants		
		June 1997	June 1998	Sept. 1998
	(kg/ha)		stems per m^2	
No-mow and June herbicides				
Metsulfuron-methyl[b]	0.0042	101 de	97 b	82 a-d
Metsulfuron-methyl[b]	0.0126	120 a-d	57 d	31 e
Triclopyr[c]	0.28	125 a-d	7 e	5 f
Triclopyr[c]	0.56	139 a	0 e	0 f
No-herbicide	——	112 b-d	101 b	88 a-c
No-mow and July herbicides				
Metsulfuron-methyl[b]	0.0042	103 de	89 bc	61 d
Metsulfuron-methyl[b]	0.0126	95 e	15 e	4 f
Triclopyr[c]	0.28	106 c-e	8 e	8 f
Triclopyr[c]	0.56	119 a-d	0 e	0 f
No-herbicide	——	108 c-e	99 b	70 cd
No-mow and August herbicides				
Metsulfuron-methyl[b]	0.0042	105 c-e	11 e	20 ef
Metsulfuron-methyl[b]	0.0126	133 ab	5 e	3 f
Triclopyr[c]	0.28	87 e	14 e	7 f
Triclopyr[c]	0.56	107 c-e	9 e	1 f
No-herbicide	——	84 e	76 c	70 b-d
Mow June and July herbicides				
Metsulfuron-methyl[b]	0.0042	122 a-d	79 c	65 d
Metsulfuron-methyl[b]	0.0126	129 a-c	7 e	3 f
Triclopyr[c]	0.28	106 c-e	3 e	3 f
Triclopyr[c]	0.56	119 a-d	1 e	0 f
No-herbicide	——	118 a-d	121 a	104 a
Mow June and August herbicides				
Metsulfuron-methyl[b]	0.0042	97 e	0 e	0 f
Metsulfuron-methyl[b]	0.0126	115 a-d	0 e	0 f
Triclopyr[c]	0.28	126 a-c	17 e	4 f
Triclopyr[c]	0.56	87 e	4 e	0 f
No-herbicide	——	118 a-d	101 b	90 ab
LSD (0.05)		24	17	22

[a] Means within a column followed by the same letter are not statistically different according to Fishers Protected LSD test at P = 0.05.

[b] Metsulfuron-methyl treatments received 0.25% v/v X-77 surfactant.

[c] Triclopyr treatments are butoxyethyl formulations.

Table 7. Effects of June mowing and herbicide treatments applied in June, July, and August of 1997 and dry weather conditions in the summer of 1998 on density of sericea lespedeza seedlings in June and September 1998 at Stillwater location.[a]

Treatment	Rate	Seedling density June 1998	Seedling density September 1998
	(kg/ha)	—— seedlings per m^2 ——	
No-mow and June herbicides			
Metsulfuron-methyl[b]	0.0042	1 d	0 c
Metsulfuron-methyl[b]	0.0126	0 d	0 c
Triclopyr[c]	0.28	2 d	0 c
Triclopyr[c]	0.56	1 d	0 c
No-herbicide	——	13 d	0 c
No-mow and July herbicides			
Metsulfuron-methyl[b]	0.0042	3 d	0 c
Metsulfuron-methyl[b]	0.0126	3 d	1 c
Triclopyr[c]	0.28	9 d	1 c
Triclopyr[c]	0.56	5 d	0 c
No-herbicide	——	11 d	0 c
No-mow and August herbicides			
Metsulfuron-methyl[b]	0.0042	15 d	0 c
Metsulfuron-methyl[b]	0.0126	10 d	2 c
Triclopyr[c]	0.28	2 d	0 c
Triclopyr[c]	0.56	1 d	0 c
No-herbicide	——	13 d	0 c
Mow June and July herbicides			
Metsulfuron-methyl[b]	0.0042	91 b	2 c
Metsulfuron-methyl[b]	0.0126	122 ab	7 a
Triclopyr[c]	0.28	158 a	7 a
Triclopyr[c]	0.56	103 b	4 b
No-herbicide	——	117 b	0 c
Mow June and August herbicides			
Metsulfuron-methyl[b]	0.0042	54 c	8 a
Metsulfuron-methyl[b]	0.0126	25 cd	8 a
Triclopyr[c]	0.28	27 cd	4 b
Triclopyr[c]	0.56	27 cd	1 c
No-herbicide	——	104 b	0 c
LSD (0.05)		36	3

[a] Means within a column followed by the same letter are not statistically different according to Fishers Protected LSD test at P = 0.05.

[b] Metsulfuron-methyl treatments received 0.25% v/v X-77 surfactant.

[c] Triclopyr treatments are butoxyethyl formulations.

Table 8. Effects of June mowing and herbicide treatments applied in June, July, and August of 1997 and dry weather conditions in the summer of 1998 on remaining density of sericea lespdeza seedlings in September 1998 at Stillwater location.[ab]

Treatment	Rate	Seedlings remaining September 1998
	(kg/ha)	—— % ——
No-mow and June herbicides		
Metsulfuron-methyl[c]	0.0042	0 a
Metsulfuron-methyl[c]	0.0126	0 a
Triclopyr[d]	0.28	10 a
Triclopyr[d]	0.56	12 a
No-herbicide	——	4 a
No-mow and July herbicides		
Metsulfuron-methyl[c]	0.0042	0 a
Metsulfuron-methyl[c]	0.0126	5 a
Triclopyr[d]	0.28	13 a
Triclopyr[d]	0.56	0 a
No-herbicide	——	0 a
No-mow and August herbicides		
Metsulfuron-methyl[c]	0.0042	0 a
Metsulfuron-methyl[c]	0.0126	7 a
Triclopyr[d]	0.28	2 a
Triclopyr[d]	0.56	0 a
No-herbicide	——	0 a
Mow June and July herbicides		
Metsulfuron-methyl[c]	0.0042	1 a
Metsulfuron-methyl[c]	0.0126	9 a
Triclopyr[d]	0.28	5 a
Triclopyr[d]	0.56	7 a
No-herbicide	——	0 a
Mow June and August herbicides		
Metsulfuron-methyl[c]	0.0042	15 a
Metsulfuron-methyl[c]	0.0126	7 a
Triclopyr[d]	0.28	5 a
Triclopyr[d]	0.56	2 a
No-herbicide	——	0 a
LSD (0.05)		16

[a] Means followed by the same letter are not statistically different at P = 0.05 according to Fishers Protected LSD test at P = 0.05.

[b] Percent remaining values were calculated using an arcsin conversion of the June and September seedling densities.

[c] Metsulfuron-methyl treatments received 0.25% v/v X-77 surfactant.

[d] Triclopyr treatments are butoxyethyl formulations.

Table 9. Pooled effects of herbicide treatments applied in June, July, and August of 1997 and dry weather conditions in the summer of 1998 on remaining sericea lespedeza stem density in June and late-summer 1998 and seedling density in June 1998 at Fairfax and Roff locations.[abc]

Treatment	Rate	Application date	Remaining stem density: June 1998	Remaining stem density: Late summer 1998	Seedling density: June 1998
	(kg/ha)		%	%	seedlings per m^2
Metsulfuron-methyl[d]	0.0042	late June	60 ab	58 a	19 b-d
Metsulfuron-methyl[d]	0.0084	late June	44 bc	31 b	16 b-e
Metsulfuron-methyl[d]	0.0126	late June	40 b-d	22 bc	11 b-e
Triclopyr[e]	0.28	late June	40 b-d	15 c-e	24 b
Triclopyr[e]	0.56	late June	1 f	1 e	8 c-e
Metsulfuron-methyl[d]	0.0042	late July	61 ab	47 a	15 b-e
Metsulfuron-methyl[d]	0.0084	late July	25 c-e	20 b-d	22 bc
Metsulfuron-methyl[d]	0.0126	late July	11 ef	9 c-e	20 b-d
Triclopyr[e]	0.28	late July	12 ef	4 e	11 b-e
Triclopyr[e]	0.56	late July	8 ef	2 e	9 b-e
Metsulfuron-methyl[d]	0.0042	late August	12 ef	11 c-e	22 bc
Metsulfuron-methyl[d]	0.0084	late August	7 ef	2 e	13 b-e
Metsulfuron-methyl[d]	0.0126	late August	2 f	4 e	6 de
Triclopyr[e]	0.28	late August	18 d-f	12 c-e	19 b-d
Triclopyr[e]	0.56	late August	5 ef	2 e	20 e
No-herbicide	———	———	69 a	60 a	43 a
LSD (0.05)			22	15	16

[a] Late summer stem counts were taken on August 27, 1998 at Fairfax and September 10, 1998 at Roff.

[b] Means within a column followed by the same letter are not statistically different according to Fishers Protected LSD test at P = 0.05.

[c] Percent remaining values were calculated using an arcsin conversion of the June 1998 and Late Summer 1998 stem density.

[d] Metsulfuron-methyl treatments received 0.25% v/v X-77 surfactant.

[e] Triclopyr treatments are butoxyethyl formulations.

Table 10. Effects of herbicide treatments applied in June, July, and August of 1997 and dry weather conditions in the summer of 1998 on stem density of sericea lespedeza seedlings in June and September 1998 and the percent of seedling density remaining in September 1998 at Roff location.[a]

Treatment	Rate	Application date	Density of sericea lespedeza seedlings June 1998	Sept. 1998	% Remaining Sept. 1998
	(kg/ha)		seedlings per m^2		%
Metsulfuron-methyl[b]	0.0042	19 June	9 bc	0	0
Metsulfuron-methyl[b]	0.0084	19 June	18 bc	0	0
Metsulfuron-methyl[b]	0.0126	19 June	7 bc	0	0
Triclopyr[c]	0.28	19 June	17 bc	0	0
Triclopyr[c]	0.56	19 June	15 bc	0	0
Metsulfuron-methyl[b]	0.0042	23 July	19 bc	0	0
Metsulfuron-methyl[b]	0.0084	23 July	20 a-c	0	0
Metsulfuron-methyl[b]	0.0126	23 July	30 ab	0	0
Triclopyr[c]	0.28	23 July	16 bc	0	0
Triclopyr[c]	0.56	23 July	10 bc	0	0
Metsulfuron-methyl[b]	0.0042	30 August	23 a-c	0	0
Metsulfuron-methyl[b]	0.0084	30 August	3 bc	0	0
Metsulfuron-methyl[b]	0.0126	30 August	1 c	0	0
Triclopyr[c]	0.28	30 August	15 bc	0	0
Triclopyr[c]	0.56	30 August	3 c	0	0
No-herbicide	——	——	46 a	0	0
LSD (0.05)			26		

[a] Means within a column followed by the same letter are not statistically different according to Fishers Protected LSD test at P = 0.05.
[b] Metsulfuron-methyl treatments received 0.25% v/v X-77 surfactant.
[c] Triclopyr treatments are butoxyethyl formulations.

Table 11. Effects of herbicide treatments applied in June, July, and August of 1997 and dry weather conditions in the summer of 1998 on density of sericea lespedeza seedlings in June and August 1998 and calculation of the mean remaining seedling densityys in August 1998 at Fairfax locations.[ab]

Treatment	Rate	Application date	Density of sericea lespedeza seedlings June 1998	Density of sericea lespedeza seedlings August 1998	% Remaining August 1998
	(kg/ha)		seedlings per m^2	seedlings per m^2	%
Metsulfuron-methyl[c]	0.0042	25 June	47 ab	30 ab	62 ab
Metsulfuron-methyl[c]	0.0084	25 June	28 c-g	13 b-e	40 a-d
Metsulfuron-methyl[c]	0.0126	25 June	33 b-e	15 b-e	46 a-c
Triclopyr[d]	0.28	25 June	43 a-c	29 a-c	61 a-c
Triclopyr[d]	0.56	25 June	14 fg	1 e	1 e
Metsulfuron-methyl[c]	0.0042	26 July	29 b-g	11 c-e	34 b-e
Metsulfuron-methyl[c]	0.0084	26 July	38 b-e	23 a-d	60 a-c
Metsulfuron-methyl[c]	0.0126	26 July	30 b-f	10 de	30 b-e
Triclopyr[d]	0.28	26 July	20 e-g	6 de	28 c-e
Triclopyr[d]	0.56	26 July	25 d-g	8 de	37 a-d
Metsulfuron-methyl[c]	0.0042	28 August	35 b-e	21 a-d	61 a-c
Metsulfuron-methyl[c]	0.0084	28 August	41 a-d	23 a-d	47 a-c
Metsulfuron-methyl[c]	0.0126	28 August	26 c-g	8 de	37 a-d
Triclopyr[d]	0.28	28 August	36 b-e	22 a-d	60 a-c
Triclopyr[bd]	0.56	28 August	12 g	1 e	8 de
No-herbicide	———	———	57 a	38 a	69 a
LSD (0.05)			18	17	34

[a] Means within a column followed by the same letter are not statistically different according to Fishers Protected LSD test at P = 0.05.
[b] Percent remaining values were calculated using an arcsin conversion of the June 1998 and August 1998 stem density .
[c] Metsulfuron-methyl treatments received 0.25% v/v X-77 surfactant.
[d] Triclopyr treatments are butoxyethyl formulations.

CHAPTER IV

INFLUENCE OF MOWING AND METSULFURON-METHYL UNDER DIFFERENT GRAZING SYSTEMS ON TOTAL NONSTRUCTURAL CARBOHYDRATE LEVELS IN ROOTS OF SERICEA LESPEDEZA

Influence of Mowing and Metsulfuron-Methyl Under Different Grazing Systems on Total Non-Structural Carbohydrate Levels in Roots of Sericea Lespedeza

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Abstract: Field experiments were established at three locations to determine seasonal fluctuations in root TNC reserves and effects of mowing and metsulfuron-methyl on root TNC levels of established sericea lespedeza plants growing under different grazing systems. Root TNC levels for untreated plants in July and August at both grazed locations and plants not mowed were higher compared to June levels, however decreased by October. Mowing in June reduced root TNC levels in July, August, and October. Root TNC levels in June for plants that were burned in the spring and continuously grazed at high stocking densities through mid-summer were much lower, compared to root TNC levels for plants not burned but grazed with a season-long rotational grazing system. Root TNC levels in August for plants treated with metsulfuron-methyl in June at the grazed locations had decreased from root TNC levels in June. At the continuously grazed site, root TNC levels in October were reduced with August applications of metsulfuron-methyl. Root TNC levels for untreated plants at all three sites increased between June and August sampling dates and decreased between August and October. This decrease is attributed to an increase in energy requirements for flowering and seed development.

Nomenclature: metsulfuron-methyl, methyl 2-[[[[(4-metoxy-6-methyl-1,3,5-triazin-2-yl)amino]carbonyl]amino]sulfonyl] benzoate; sericea lespedeza, *Lespedeza cuneata* (Dumont) G. Don. # LESCU.
Additional index words: Herbicide.
Abbreviations: TNC, total nonstructural carbohydrate.

INTRODUCTION

Sericea lespedeza is a perennial, warm season, herbaceous, leguminous species that is becoming a major weed problem in grazing lands of Oklahoma and Kansas. It is a deep-rooted drought tolerant species capable of producing roots 125 cm in length (Ball et al. 1991), and can survive in excess of 20 years (Lynd and Ansman 1993). Because the ability of a perennial plant to re-grow and persist is dependant upon its capability to store and produce root carbohydrate reserves [Buwai and Trlica 1977; and McIlvanie 1942], it is important to know what the seasonal root carbohydrate levels are for sericea lespedeza. Little is known about the effects of season, environment, and herbage removal on total nonstructural carbohydrate (TNC) levels in roots of sericea lespedeza plants. However, much is known of TNC levels in roots of alfalfa, a perennial leguminous species that is used for haying and grazing purposes. Starch and sugars (glucose, fructose, and sucrose) comprise the TNC components in roots of alfalfa plants during the growing season, with starch comprising 90% and sugars 10% of the TNC found in alfalfa roots [Olson and Wallander 1997; Smith and Marten 1970; and Ueno and Smith 1970]. However, sucrose becomes the major carbohydrate component in alfalfa roots during drought, onset of cold hardening, and early spring re-growth following winter dormancy (Nelson and Smith 1968). Most TNC storage occurs in the upper 10 cm segment of alfalfa roots and less progressively downward (Escalada and Smith 1972).

Little is known of seasonal fluctuations and the effects of control options such as mowing, grazing, and herbicides on carbohydrate levels in roots of sericea lespedeza plants that are growing in association with tallgrass prairies and improved foraged species. However, TNC levels in roots of uncut alfalfa plants typically decrease in the spring as vegetative growth is initiated from crown buds. This growth is supported by TNC located in the roots until leaf growth is sufficient to sustain photosynthetic carbon assimilation (Heichel et al. 1988). Root TNC reserves increase once carbon is assimilated by photosynthetic pathways in aboveground tissue of alfalfa plants, with maximum concentrations in the roots occurring at 10% flower and full bloom (Cooper and Watson 1968; and Reynolds and Smith 1962). Typically there is a slight decrease in root TNC concentrations with fruit development in perennial plants. Heichel et al. (1988) reported a 10% decrease in TNC of alfalfa roots with the initiation of fruit development.

Frequency and height of clipping affects root carbohydrate levels of established sericea lespedeza plants that are grown for haying purposes. Hoveland et al. (1972) reported root TNC levels as a percent of biomass dryweight for plants clipped two times during the growing season at a 3.5 cm height were 15% compared to 6% for plants clipped four times. Plants clipped four times during the growing season at a 12.5 cm cutting height contained 12% root carbohydrate levels compared to 6% for roots of plants clipped at a 3.5 cm cutting height (Hoveland et al. 1975). However, work conducted by Koger and Stritzke (1997) found that mowing once in June had no significant affect on stem density of established plants of sericea lespedeza compared to stem density for plants not mowed.

Little is known about the sink sources of TNC following harvest of above ground biomass of sericea lespedeza. However, Brown et al. (1972) reported that 25% of the reserve root TNC consumed following harvest of alfalfa plants were lost in root respiration, 39 to 45% lost in respiration by the crowns and shoots, and 30 to 36% were incorporated into shoot growth. Close grazing of sericea lespedeza plants also affects root carbohydrate levels. Ball et al. (1991) and Hoveland and Donnelly (1985) documented that sericea lespedeza plants grown for grazing use should not be grazed lower than 10.0 cm in height. They also reported that plants should not be grazed late in the growing season, as this is a period when plants are storing food reserves in the roots. Again, little is known about fluctuating TNC levels in roots of sericea lespedeza plants. However, as temperatures decrease in the fall, aboveground growth of alfalfa slows and TNC accumulation in roots increase (Heichel et al. 1988). This accumulation continues until first frost, when aboveground growth dies back until the next spring.

Better control of troublesome perennial weed species can be achieved by applying control options such as: mechanical and chemical inputs when plants are storing root reserves, rather than relocating reserves to aboveground portions of the plant [Becker and Fawcett 1998; Olson and Wallander 1997; Pakeman and Marrs 1994; Buchache et al. 1993; Otzen and Koridon 1970; Ilnicki and Fertig 1962; Gerhardt 1929; and Welton et al. 1929]. Perennial plants typically translocate carbohydrates from aboveground tissue to roots for storage at flowering stage to leaf senescence [Becker and Fawcett 1998; MacIsaac and Bewely 1992; and Heichel et al. 1988]. Becker and Fawcett (1998) recommended control of hemp dogbane (*Apocynum cannabinum*), a perennial weed species whose large reserves of root carbohydrates likely contribute to its aggressiveness and persistence, with herbicide application after mid- to late-flowering stage through leaf senescence. Leafy spurge (*Euphorbia esula* L.) a perennial Eurasian forb with a deep rhizomatous root system that is invading grazing lands of the north central United States, is very difficult to control with herbicides partly because of large quantities of root carbohydrate reserves during the summer months (Whitson et al. 1996). Carbohydrate levels in the roots of leafy spurge plants fluctuate significantly during the growing season, with accumulations occurring after seed dispersal in the fall until top growth dies back in the winter and a decline in the spring as buds emerge (MacIsaac and Bewely 1992). Control (40 to 95% by 1 YAT) of leafy spurge with picloram, imazethapyr, imazaquin, and nicosulfuron typically occurs in the fall when plants are translocating storage reserves to the roots (Christianson et al. 1992). Knowing seasonal fluctuations in root carbohydrate levels of sericea lespedeza could help in considering possible control options for this troublesome perennial weed.

The objectives of this research were to determine seasonal fluctuations in root TNC levels of sericea lespedeza and to determine the effects of mowing and low application rates of metsulfuron-methyl on root TNC levels for plants growing under different grazing systems.

MATERIALS AND METHODS

Three experiments were established in 1997 at locations that contain dense populations of sericea lespedeza near Stillwater, Fairfax, and Roff Oklahoma. The Stillwater location (Zaneis-Huska loam soil) is a decadent "Jose" tall wheatgrass pasture that has become a solid stand of sericea lespedeza, and is not burned or grazed. The Fairfax location (Kiomatia loamy fine sand soil) is a tallgrass prairie that is burned each spring and double stocked annually with stocker cattle at 1.25 head/ha from April 1 to July 15. The Roff site (Fitzhugh loam soil) is a tallgrass prairie that is not burned and grazed with stocker cattle at 5 head/ha for 4 days followed by 44 days of rest from April to October.

A two factorial-randomized complete block design experiment was initiated in June of 1997 at the Stillwater location. One factor was no-mow and mow in June of 1997, and the second factor was applications of metsulfuron-methyl at 0.0042 kg ai ha^{-1} applied in June, July, and August of 1997. Treatment combinations and dates of applications are listed in Table 1. Plot size was 2.1- by 9.1-m with four replications of each treatment. One randomized complete block design experiment with four herbicide treatments was established in early June of 1997 at the Fairfax and Roff locations. Treatments and dates of applications for the Fairfax and Roff locations are listed in Tables 3 and 4. Plot size was 2.1- by 9.1-m with four replications of each treatment.

Root collection and preparation: Roots of established sericea lespedeza plants that were treated and not treated with metsulfuron-methyl were collected at four stages of plant maturity during the summer and early fall of 1997 from all three locations. Lateral roots growing from the main taproot were collected and analyzed for total non-structural carbohydrate levels. Root collection dates and plant heights at time of collection for all sites are listed in Table 1. For each of the four collection dates, above ground biomass and the root system of five established sericea lespedeza plants were collected with a narrow blade shovel in all four replicated plots of each treatment. Four lateral roots from each of the five plants collected from each plot were clipped from the plant crown with a sharp knife. The top 4 cm (closest to plant crown) of each root was clipped and placed on ice in a ziploc bag in a cooler for transport to the laboratory. Preparation of root samples (20 roots per sample) in laboratory consisted of removing root sample from ziploc bag, rinsing under cool tap water to remove soil, and then blotting dry with paper towels. Samples were then oven dried at 60°C for 72 hours and ground to pass through a 1mm sieve. Ground samples were stored in a freezer at –20°C until all root collections were completed.

Laboratory procedures for TNC analysis: A 2-day procedure was followed to measure TNC in the roots of sericea lespedeza plants. Spectroscopy was used according to the Nelson (1944) procedure to determine TNC levels. Glucose standards of 0, 50, 150, 300, and 450 ug/ml solution were used to calibrate the assay.

Fifty mg of ground root sample and 5 ml of 1M NaOH buffer reagent (Ph 4.5) was placed in 13- by 100-mm test tubes. Each test tube was vortexed, covered with a marble and placed in a boiling water bath (≈100°C) for 20 minutes. Test tubes were cooled in a running water bath for 10 minutes. 500 ul invertase enzyme solution (Sigma chemical Co., #19523 @ 44 units ml^{-1})was added to each test tube, followed by vortexing. 500 ul of amyloglucosidase enzyme solution (Sigma chemical Co., #A3042 @ 58 units ml^{-1}) was added, again followed by vortexing. Test tubes were incubated for 24 hours at 45°C in an oven to complete hydrolytic conversion of starch. Following incubation, test tubes were vortexed and 1 ml of digested sample was added to a 2 ml microcentrifuge tube and centrifuged for 5 minutes to pellet solids. The top 0.4 ml of centrifuged sample was placed in a fresh 2-ml microcentrifuge tube and diluted with 1.6 ml de-ionized water. Then 0.2-ml of diluted sample along with 0.2-ml Copper reagent (0.645M) was placed in a fresh microcentrifuge tube. Three reps of each glucose standard were analyzed by adding 0.2 ml glucose solution and 0.2 ml copper reagent in a 2 ml microcentrifuge tube. All microcentrifuge tubes were then boiled (≈100°C) for 10 minutes, followed by cooling for 5 minutes in a running water bath. Then 0.1 ml arsenomolybdate (0.52M) - sodium arsenate (0.38M) reagent and 1 ml de-ionized water was added to each microcentrifuge tube, followed by vortexing. TNC for each root and glucose standard sample was spectroscopically measured at 520 nm against a blank sample.

ANOVA procedures were used to test for effects of mowing and low application rates of metsulfuron-methyl and for interactions between treatment combinations on TNC levels in roots of sericea lespedeza plants. Appropriate treatment or treatment combinations means were separated using Fisher's Protected LSD. All tests were conducted at the 0.05 level. (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

Stillwater location: Seasonal fluctuations in root TNC levels for plants of sericea lespedeza not mowed or treated with metsulfuron-methyl followed a trend similar to results reported by Heichel et al. (1988) for roots of alfalfa plants. Root TNC levels increased to 12.2 and 12.8 umol glocose/gm root dry weight for the July and August sampling dates from 10.8 on the June sampling date (Table 2). However, root TNC levels decreased slightly by the October sampling date to 11.0 umol glocose/gm root dry weight, respectively. The decrease in root TNC levels is possibly attributed to the development of fruiting structure, as plants of sericea lespedeza were developing fruit when roots were collected in October.

Root TNC levels for plants mowed in June followed a different trend when compared to levels for roots of plants not mowed. Root TNC levels for plants mowed and not mowed (10.6 and 10.8) were not significantly different ($P>0.05$) at the June sampling date. However, root TNC levels in July for plants mowed in June (8.4) were significantly lower ($P<0.05$) when compared to levels in roots of plants not mowed (12.2). The lower root TNC levels for mowed plants is possibly attributed to additional energy (carbohydrates) required of mowed plants to initiate above-ground growth from carbohydrates found in the roots. Root TNC levels for plants mowed in June decreased between the July and August sampling dates from 8.4 to 7.7. This decrease is different from results for plants not mowed, which showed a slight increase in root TNC levels between the July and August sampling dates. Apparently the plants had not recovered from mowing in June, as root TNC levels in August for plants mowed in June (7.7) were significantly lower ($P<0.05$) when compared to levels for plants not mowed (12.8). Root

TNC levels in October for plants mowed in June increased slightly to 8.1 umol glucose/gm root dry weight and was significantly lower ($P<0.05$) compared to levels for plants not mowed (11.0). The energy required to facilitate re-growth after June mowing appeared to cause a delay in flowering and seed development for plants mowed in June, which may have attributed to slightly higher root TNC levels in October compared to August levels

Applications of metsulfuron-methyl had no significant effect ($P<0.05$) on TNC levels in roots of sericea lespedeza plants not mowed at any of the four collection dates. Root TNC levels ranged from 9.5 for roots collected in October from plants treated in August with metsulfuron-methyl to 12.5 for roots collected in July from plants not yet treated (Table 1). Root TNC levels in July, August, and October for plants that were mowed in June and treated with metsulfuron-methyl in July and August were lower, compared to levels for plants treated with herbicide and not mowed. The lower root TNC levels in roots of plants mowed in June and treated with metsulfuron-methyl were attributed to the mowing treatment as discussed previously. Mowing in June resulted in lower TNC levels throughout the sampling period, however previous work conducted by Koger and Stritzke (1997) has shown that mowing in June does not effect stem density of established plants of sericea lespedeza. Therefore, mowing does not appear to be an affective control option with regards to root TNC levels. Applications of metsulfuron-methyl in June ,July, and August to plants that were mowed in June and July and August applications to plants not mowed had no affect on TNC levels in roots of established sericea lespedeza plants at any sampling date.

Fairfax and Roff locations: Root TNC levels in plants not treated with herbicide at the Fairfax location decreased between the August and October sampling dates (Table 3). This is similar to results for the Stillwater location, with the decrease attributed to an increased energy requirement for flowering and seed development. TNC levels in roots of sericea lespedeza plants in June from the Fairfax location were much lower (3.5 to 4.8 umol glucose/gm plant dry weight) than levels at Stillwater location. This is probably attributed to heavy utilization of sericea lespedeza plants after the spring burning at the Fairfax location, with shorter plants reported for the Fairfax location (Table 1). However, there was good recovery in root TNC levels by the July 24 sampling date, with significantly higher ($P<0.05$) root TNC levels in untreated plants in July (12.8) when compared to June levels(4.8).

Applications of mestulfuron-methyl in June had no significant affect ($P>0.05$) on root TNC levels in July, with root TNC levels for treated and untreated plants of 13.1 and 12.8 umol glucose/gm root dry weight, respectively. Root TNC levels in August for plants treated with metsulfuron-methyl in June were significantly lower ($p<0.05$) than levels for untreated plants (7.5 for treated vs. 12.3 umol glucose/gm root dry weight for untreated). However, root TNC levels for plants treated in June had recovered by October, with no significant difference ($P>0.05$) in root TNC levels for treated and untreated plants. Similar to the Stillwater location, metsulfuron-methyl had little affect on root TNC levels for established plants of sericea lespedeza at the Fairfax location.

Trends in TNC levels in roots of sericea lespedeza plants not treated with metsulfuron-methyl at the Roff location (Table 4) were similar to results from the Fairfax location. Root TNC levels in July (12.7) were significantly higher ($P<0.05$) when compared to root TNC levels in June (9.2). Root TNC levels for untreated plants significantly increased ($P<0.05$) from 12.7 in July to 15.9 by August. Also, root TNC levels in October for untreated plants (12.6) significantly decresed ($P<0.05$) from levels reported in August. This is similar to results reported for the Fairfax and Stillwater locations, where decreases in root TNC levels late in the growing season are possibly attributed to additional energy requirements need for fruit and seed development.

Applications of metsulfuron-methyl in June resulted in significant ($P<0.05$) root TNC reduction by August, with 12.3 umol glucose/gm root dry weight for treated plants compared to 15.9 for untreated plants. This root TNC reduction is similar to results reported for the Fairfax location. Root TNC levels in October for plants treated with metsulfuron-methyl in June and July (13.6 and 14.5) recovered to levels not significantly different ($P>0.05$) from levels for untreated plants (12.6).

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Table 1. Root collection dates and stem height of sericea lespedeza plants at time of collection at Fairfax, Roff, and Stillwater OK. 1997.

Location	Root collection date	Stem height of sericea lespedeza	
		—— cm ——	
Fairfax			
	June 25	25±19	
	July 24	36±21	
	August 28	47±26	
	October 3	53±28	
Roff			
	June 19	36±16	
	July 23	48±24	
	August 30	52±27	
	September 30	57±29	
Stillwater		not mowed	mowed
		cm	
	June 13	23±3	5
	July 22	35±10	16±6
	August 26	55±23	23±8
	October 7	59±24	27±9

Table 2. Effects of June mowing and metsulfuron-methyl applied in June, July, and August of 1997 on total nonstructural carbohydrate levels in roots of established sericea lespedeza plants at Stillwater, OK.[a]

Treatment	Application date	Collection date			
		June 13	July 22	August 26	October 7
No-mow		——— umol glucose/gm root wt. ———			
Metsulfuron-methyl[b]	June 16	11.9 ab	13.3 a	10.7 a-d	11.1 a-c
Metsulfuron-methyl[b]	July 22	11.1 a-c	12.5 a	11.0 a-c	11.6 a-c
Metsulfuron-methyl[b]	August 26	12.1 ab	11.1 a-c	12.1 ab	9.5 b-f
No-herbicide	———	10.8 a-d	12.2 ab	12.8 a	11.0 a-d
Mow June 13					
Metsulfuron-methyl[b]	July 22	12.0 a	8.4 d-f	7.2 f	8.7 c-f
Metsulfuron-methyl[b]	August 26	13.4 a	8.2 d-f	7.4 f	7.3 f
No-herbicide	———	10.6 a-e	8.4 d-f	7.7 ef	8.1 d-f

[a] Means followed by the same letter are not statistically different at P = 0.05 according to Fishers Protected LSD test. LSD (0.05) = 2.9.

[b] Metsulfuron-methyl was applied at a rate of 0.0042 kg ai ha^{-1} and received 0.25% v/v X-77 surfactant.

Table 3. Effects of metsulfuron-methyl on total nonstructural carbohydrate levels in roots of established sericea lespedeza plants collected June 25, July 24, August 28, and October 3, 1997 at Fairfax, OK.[a]

Treatment	Application date	Collection date			
		June 25	July 24	August 28	October 3
		umol glucose/gm root wt.			
Metsulfuron-methyl[b]	June 25	3.9 e	13.1 a	7.5 c-e	8.7 b-d
Metsulfuron-methyl[b]	July 24	3.9 e	11.0 a-c	9.0 a-d	11.0 a-c
Metsulfuron-methyl[b]	August 28	3.4 e	11.3 a-c	11.3 a-c	8.5 b-d
No-Herbicide	———	4.8 de	12.8 ab	12.3 ab	10.9 a-c

[a] Means followed by the same letter are not statistically different at P = 0.05 according to Fishers Protected LSD test. LSD (0.05) = 4.2.
[b] Metsulfuron-methyl was applied at a rate of 0.0042 kg ai ha^{-1} and received 0.25% v/v X-77 surfactant.

Table 4. Effects of metsulfuron-methyl on total nonstructural carbohydrate levels in roots of established sericea lespedeza plants collected June 19, July 23, August 30, and October 1, 1997 at Roff, OK.[a]

Treatment	Application date	Collection date			
		June 19	July 23	August 30	October 1
		umol glucose/gm root wt.			
Metsulfuron-methyl[b]	June 19	9.4 e	12.8 cd	12.3 cd	13.6 bc
Metsulfuron-methyl[b]	July 23	9.5 e	12.6 cd	12.7 cd	15.5 ab
Metsulfuron-methyl[b]	August 30	9.6 e	12.8 cd	15.6 ab	11.0 de
No-Herbicide	———	9.2 e	12.7 cd	15.9 a	12.6 cd

[a] Means followed by the same letter are not statistically different at P = 0.05 according to Fishers Protected LSD test. LSD (0.05) = 2.1.
[b] Metsulfuron-methyl was applied at a rate of 0.0042 kg ai ha^{-1} and received 0.25% v/v X-77 surfactant.

APPENDIX

Appendix A. Effects of herbicide treatments applied in June, July, and August of 1997 and dry weather conditions in the summer of 1998 on stem density of established sericea lespedeza plants in June 1997 and June and August 1998 and calculation of the mean remaining stem density in June and August 1998 at Fairfax location.[a,b]

Treatment	Rate	Application Date	Stem density of established plants June 1997	Stem density of established plants June 1998	Stem density of established plants August 1998	% Remaining June 1998	% Remaining August 1998
	(kg/ha)		stems per m²			%	
Metsulfuron-methyl[c]	0.0042	25 June	136 a-c	72 a	69 b	67 ab	64 ab
Metsulfuron-methyl[c]	0.0084	25 June	92 a-c	52 ab	38 c	49 ab	44 bc
Metsulfuron-methyl[c]	0.0126	25 June	124 a-c	69 a	34 cd	66 ab	30 cd
Triclopyr[d]	0.28	25 June	147 a-c	40 a-c	25 c-f	39 b-d	29 a-c
Triclopyr[d]	0.56	25 June	48 c	1 d	1 fg	0 e	15 de
Metsulfuron-methyl[c]	0.0042	26 July	66 bc	49 ab	32 cd	80 a	1 e
Metsulfuron-methyl[c]	0.0084	26 July	125 a-c	20 b-d	26 c-e	16 c-e	51 a-c
Metsulfuron-methyl[c]	0.0126	26 July	110 a-c	2 cd	9 d-g	3 e	21 de
Triclopyr[d]	0.28	26 July	140 ab	2 cd	1 e-g	1 e	15 de
Triclopyr[d]	0.56	26 July	157 ab	0 d	0 g	0 e	1 e
Metsulfuron-methyl[c]	0.0042	28 August	167 a-c	26 cd	28 cd	13 de	0 e
Metsulfuron-methyl[c]	0.0084	28 August	133 a-c	3 cd	2 e-g	2 e	12 de
Metsulfuron-methyl[c]	0.0126	28 August	109 a-c	1 cd	11 d-g	1 e	0 e
Triclopyr[d]	0.28	28 August	113 a-c	6 cd	28 cd	8 de	7 e
Triclopyr[d]	0.56	28 August	104 a-c	15 cd	9 d-g	9 de	21 de
No-herbicide	———	———	165 ab	68 a	95 a	45 bc	7 de
LSD (0.05)			99	39	25	31	22

[a] Means within a column followed by the same letter are not statistically different according to Fishers Protected LSD test at P = 0.05.

[b] Percent remaining values were calculated using an arcsin conversion of the June 1997, June 1998, and August 1998 stem density.

[c] Metsulfuron-methyl treatments received 0.25% v/v X-77 surfactant.

[d] Triclopyr treatments are butoxyethyl formulations.

Appendix B. Effects of herbicide treatments applied in June, July, and August of 1997 and dry weather conditions in the summer of 1998 on stem density of established sericea lespedeza plants in June 1997 and June and September 1998 and calculation of the mean remaining stem density in June and September 1998 at Roff location.[a,b]

Treatment	Rate	Application Date	Stem density of established plants: June 1997	Stem density of established plants: June 1998	Stem density of established plants: Sept. 1998	% Remaining: June 1998	% Remaining: Sept. 1998
	(kg/ha)		stems per m^2	stems per m^2	stems per m^2	%	%
Metsulfuron-methyl[c]	0.0042	19 June	55 d	28 b-d	28 b	52 b	52 a
Metsulfuron-methyl[c]	0.0084	19 June	56 cd	27 b-e	12 b-d	38 b-e	17 b
Metsulfuron-methyl[c]	0.0126	19 June	70 a-d	10 d-f	13 b-d	14 e-h	15 b
Triclopyr[d]	0.28	19 June	96 ab	35 bc	20 bc	41 b-d	14 b
Triclopyr[d]	0.56	19 June	86 a-d	1 f	1 d	0 h	0 b
Metsulfuron-methyl[c]	0.0042	23 July	87 a-d	43 b	27 b	42 b-d	44 a
Metsulfuron-methyl[c]	0.0084	23 July	104 a	37 bc	17 b-d	35 b-f	18 b
Metsulfuron-methyl[c]	0.0126	23 July	77 a-d	16 c-f	14 b-d	18 c-h	15 b
Triclopyr[d]	0.28	23 July	90 a-d	22 c-f	6 cd	23 c-h	7 b
Triclopyr[d]	0.56	23 July	105 a	20 c-f	6 g	17 d-h	5 b
Metsulfuron-methyl[c]	0.0042	30 August	90 a-d	8 d-f	7 cd	10 f-h	11 b
Metsulfuron-methyl[c]	0.0084	30 August	90 a-d	7 d-f	2 d	13 e-h	4 b
Metsulfuron-methyl[c]	0.0126	30 August	59 b-d	1 f	0 d	3 gh	1 b
Triclopyr[d]	0.28	30 August	97 ab	29 b-d	18 b-d	28 b-g	18 b
Triclopyr[d]	0.56	30 August	94 a-c	3 ef	6 cd	2 h	6 b
No-herbicide	———	———	92 a-d	84 a	48 a	92 a	52 a
LSD (0.05)			38	24	17	25	21

[a] Means within a column followed by the same letter are not statistically different according to Fishers Protected LSD test at $P = 0.05$.

[b] Percent remaining values were calculated using an arcsin conversion of the June 1997, June 1998, and September 1998 stem density.

[c] Metsulfuron-methyl treatments received 0.25% v/v X-77 surfactant.

[d] Triclopyr treatments are butoxyethyl formulations.

VITA

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Master of Science

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