SERICEA LESPEDEZA (*LESPEDEZA CUNEATA*): SEED DISPERSAL, MONITORING, AND EFFECT ON SPECIES RICHNESS

by

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B.S. Kansas State University 1977
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Abstract

Sericea lespedeza [*Lespedeza cuneata* (Dumont) G. Don] is a rangeland weed of the tallgrass prairie of Kansas. Experiments were carried out during the 2001-2003 growing seasons (June-November) to examine the relationship between sericea lespedeza and other rangeland species, wildlife use and dispersal of sericea lespedeza propagules, and the relationship between sericea lespedeza stubble height and utilization by livestock. Sericea lespedeza cover was positively correlated with violet lespedeza (r=0.25) [*Lespedeza violacea* (L.) Pers.], heath aster (*Aster ericoides* L.) (r=0.23) and total forb cover (r=0.56). Sericea lespedeza composition was negatively correlated with big bluestem (*Andropogon gerardii* Vitman.) (r=-0.27) and sideoats grama [*Bouteloua curtipendula* (Michx. Torr.)] (r=-0.27) composition and positively correlated with western ragweed (*Ambrosia psilostachya* D.C.) (r=0.21) and violet lespedeza (r=0.36) composition. Sericea lespedeza density was inversely related to forb species richness on all sites. On half the sites, there was also an inverse relationship between grass species richness and sericea lespedeza density. Grazed sites had less difference in grass species richness between high and low levels of sericea lespedeza densities. There was no evidence of an ecological threshold to the detriment of species richness with increasing sericea lespedeza density.

Cattle digestive processes did not affect sericea lespedeza germination. Quail digestive processes enhanced germination of the few seeds that were excreted. Quail diet selection was investigated with a field study. Five out of 49 crops collected contained

seed classified as sericea lespedeza. None of these seeds germinated in the greenhouse. Both cattle and quail could potentially disperse sericea lespedeza seed, but voluntary consumption appears to be low for both species, at least during November when other food is available.

An height-weight table estimating percent utilization for various grazed and ungrazed heights of sericea lespedeza was constructed. Coefficient of determination values were greater than 0.85 between plant height and weight, indicating that the height-weight method was appropriate for estimating sericea lespedeza utilization. Using additional regression analysis, a chart for estimating forage from percent of plants grazed was constructed.

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Introduction

Sericea lespedeza [*Lespedeza cuneata* (Dumont) G. Don] is an undesirable introduced species in Kansas, from a livestock production, wildlife, or ecological perspective, and has been labeled as an "invasive" (BLM 2006) "weed" (Whitson 1996). While sericea lespedeza has been planted for wildlife cover and forage in other states and in other situations (Fire Effects Information System 2006), in Kansas other species fulfil these uses. The dense, single-species stands that develop at high sericea lespedeza densities (Pieters 1939) contrast with a tallgrass ecosystem that is typified by diversity (Towne and Kemp 2003).

Weed species competition can vary in its effect on other plant species (Connolly and Wayne 1996). The correlation between community species richness and introduced species invasiveness was reported as positive by Smith and Knapp (1999) and negative by Naeem et al. (2000). Symstad (2000) reported a negative correlation between grassland invasiveness and plant functional group richness; however, resident species that were functionally similar to invaders had little effect on repelling invasion. The tallgrass species with growth forms that most closely resemble sericea lespedeza are the upright legumes with taproots (Lavorel and Garnier 2002). This group includes the prairie-clovers (*Dalea* spp.), the tickclovers (*Desmodium* spp.), and the lespedezas (*Lespedeza* spp.). There are ten lespedeza species found in Kansas besides sericea lespedeza (Barkley et al.1986). Turnbull et al. (2005) reported that introduced legumes had difficulty establishing within resident legume monocultures. The native slender lespedeza [*Lespedeza virginica* (L.) Britt.], with a growth form nearly identical to the non-native sericea lespedeza, appears to offer little invasive resistance as both frequently grew in close spatial proximity on the study site (personal observation).

Sericea lespedeza reproduces by clonal formation and by seed. Given the immobility of clones, seed dispersal is a possible method by which sericea lespedeza could spread to new sites. Sericea lespedeza dispersal tends to be attributed to animal movement, especially since sericea lespedeza does not seem to preferentially spread adjacent to watercourses. Sericea lespedeza was observed to be absent in areas that were frequently inundated on our study site (personal observation). Sericea lespedeza seed is small and does not have physical attributes such as wings or bladders that would aid dispersal by wind or water.

Animal dispersal depends on how far an animal moves, how long it retains the seed in the digestive tract or adhered to skin, fur or feathers, and how viable the seed is after passing through the digestive tract (Blackshaw and Rose 1991). It is impractical to monitor all animal species that have a potential for ingesting or attaching sericea lespedeza seed. Because large mammals and avian species are conspicuous, they are frequently suspected of transporting seed. Invertebrates and small mammals such as mice, which are less conspicuous, are less often considered agents of dispersal by the general public.

Public opinion is important because it affects how different species are perceived and treated. The animal species studied for their dispersal ability in this dissertation were chosen because they were perceived to be spreading sericea lespedeza, based on questions and comments made to extension personnel (Charles Lee, personal communication 2001). Northern bobwhite are found throughout Kansas and are conspicuous as a game species. Because they are perceived as spreading sericea lespedeza, public opinion favors increased harvesting. Lack of scientific validation does not deter personal action based on tightly-held beliefs.

Monitoring utilization of sericea lespedeza can be done precisely with carefully repeated vegetative measurements, esophageal fistula sampling, and manure collection and analysis. This sampling requires time, experience, labor and economic inputs that are not feasible for most ranchers. A less precise but valid method of estimating utilization can provide objectivity in assessing the success or failure of grazing strategies.

The effects of an invasive species on the surrounding rangeland ecosystem are often difficult to quantify. A typical two-to-three year study may be too short to measure changes in a resilient, perennial rangeland, where normal year-to-year variations in climatic conditions, wildlife populations and management can affect experimental results.

Despite the potential for confounding factors, a need exists to discern to the greatest extent possible the ecological effects of a weed species. The experimental work in this dissertation was undertaken to expand the understanding of sericea lespedeza invasion of the tallgrass prairies of Kansas.

Review of Literature

Morphology and Physiology

Adaptation

Sericea lespedeza was not thought to be suitable for areas with 35" or less rainfall per year (Bailey 1951, Pieters 1939). However, sericea lespedeza has adapted to the tallgrass region of Kansas, where rainfall averages 30-40" of precipitation annually (Goodin et al. 1995).

Utilization by Livestock and Wildlife

Animal grazing can accelerate the displacement of native species with exotic species by preferential grazing of the more palatable native species (Olson 1999). Sericea lespedeza is less palatable and nutritious than native species because of its tannin content (Cope and Burns 1974) and high lignin content at maturity (Hawkins 1955, Hawkins 1959, Hoveland et al.1969). Grazing can also affect sericea lespedeza seed production (Donnelly and Patterson 1969, Ward et al. 1985).

Sericea lespedeza's coarse stems (Hoveland et al. 1969) and high tannin level (Stitt and Clarke 1941, Cope et al.1971) make it unpalatable to cattle (Hoveland et al. 1969) and sheep (Wolf and Dove 1987), but goats (*Capra hircus* L.) find it palatable (Hart 2000). Standing sericea lespedeza stems can also form a thicket difficult to penetrate (Dove and Zipper 1997). Physical impedance could alter forage availability and grazing distribution.

Wildlife use or avoidance of sericea lespedeza in Kansas is not widely documented, but Eddy and Moore (1998) stated that the "grasses and forbs that are replaced by sericea lespedeza are superior in terms of shelter and food resources [for vertebrates]". Invertebrate use of sericea lespedeza was lowest of all plant species studied in one trial (Bugg and Dutcher 1989). Other experiments suggest that sericea lespedeza contains a substance that inhibits corn earworm [*Heliothis zea (Boddie)*] development (Buntin and Wiseman 1990). Menhinick (1967) reported that insect biomass was less on sericea lespedeza than on other vegetation, and ingestion was lower than on native grasses. Earthworm abundance declined where sericea lespedeza detritus accumulated (Knapp and Seastedt 1986).

Eddy (1999) concluded that invertebrate and vertebrate species declined by 73 and 55% respectively in sericea lespedeza sites. High stem density, lack of singing perches, fewer canopy openings and a decrease in the seasonal availability of foliage, flowers, seeds, and prey insects were given as factors in the decline.

Fire Effects

Fire has been an integral component of prairie development in the Kansas Flint Hills (Axelrod 1985) and has influenced vegetative patterns (Stewart 1951). Mid- to late-April burns favored warm-season perennial grasses in the Flint Hills (Anderson and Owensby 1970) and did not appear to alter forb species richness (Abrams and Hulbert 1987). Smith and Knapp (1999) recorded an 80-90% reduction in exotic species richness in tallgrass prairie due to burning.

Burning improved the competitive ability of warm-season grasses, enhancing their ability to inhibit or restrict sericea lespedeza invasion. However, late-spring burns also increased sericea lespedeza densities (Boring et al. 1991, Koger 1996, Fick 2000). This increase in density was attributed to foliar burn injury that resulted in loss of apical dominance and was followed by stem development from crown buds (Koger 1996).

Burning increased sericea lespedeza density regardless of grazing activity; however, burning and grazing together decreased sericea lespedeza biomass, possibly due to improved palatability resulting in increased consumption by cattle (Koger 1996). A hot burn decreased lespedeza germination (Segelquist 1971). Stritzke et al. (2001) reported increased livestock grazing of sericea lespedeza with spring burning and early season double stocking.

Grazing without burning increases sericea lespedeza seedling density and survival; however, grazing with burning increases seedling density but decreases survival (Koger 1996). In view of the confounding effects of grazing and burning on sericea lespedeza survival and growth, the common tallgrass management strategy of late-spring burning and early-summer grazing of Flint Hills grasslands appears, overall, to have little effect on the competitive balance between sericea lespedeza and warm-season grasses. Without additional research to quantify the net effects of grazing and late-spring burning interactions, it is difficult to determine the correct management strategy.

Dove et al. (1997) reported that fall burning suppressed sericea lespedeza. A fall burn that resulted in warm soil temperatures and bare soil enhanced seedling germination but decreased seedling survival over the subsequent winter (Helm and Etheridge 1933, Vogel 1974, Jorgensen and Davis 1983). Hamilton (2003) reported that a September 2 burn decreased sericea lespedeza maximum stem height, maximum stem number, and seedling density. The effect of fall burning on tallgrass production is conflicting (Towne and Kemp 2003, Owensby and Anderson 1967) and may hinge on grazing use and precipitation patterns.

Tallgrass produces copious litter which is detrimental to warm-season grass dominance if the litter is not periodically removed by late-spring burning (Foster and Gross 1998). Warm-season grass litter negatively interfered with sericea lespedeza seedling survival (Koger 1996). Late-spring burns both increased the density of existing sericea lespedeza stems and decreased seedling survival. Late-spring burning appeared to have the same net competitive effect on both sericea lespedeza and warm-season grasses, with some advantage to the grasses because sericea lespedeza seedling survival decreased (Koger 1996).

Sericea lespedeza standing dead detritus was resistant to burning because the woody stems did not produce the continuous fine-texture fuel necessary to carrying a fire (Mooers and Ogden 1935). Sericea lespedeza infestation, by reducing burn extent and intensity, could potentially reduce C_4 grass viability.

Competitive Interactions

Undesirable plants invade through the introduction of a species, with escape and establishment followed by naturalization and spread and ultimately, the recognition of its weed or pest status (Myers and Bzaely 2003). The ability to successfully compete with other local vegetation is important in a weed's ability to establish and spread.

The relative competitive abilities of sericea lespedeza and other species were found to be affected by prior establishment, with competitive advantage for the species with prior establishment (Mooers and Ogden 1935, Bailey 1951, Pieters 1939, Skousen and Call 1987b). Competitive advantage can be reduced or overcome by management practices (Carrier 1921, Bailey 1951, Hoveland et al. 1969, Hoveland and Carden 1971, Vogel 1974, Rothwell 1984, Skousen and Call 1987b, Smith and Calvert 1987, Altom et al. 1992, El Hadj et al. 2000). Weeds compete for nutrients, water, and light and can produce allelochemicals that may inhibit growth and germination (Rice 1984).

Detritus

Sericea lespedeza produces prolific amounts of detritus (Bailey 1951) which is slow to decompose (Wiegert and McGinnis 1975, Rothwell 1984, Dove et al. 1997, Menhinick 1967) and results in litter accumulation of up to 31,750 kg/ha after 9 years of growth (Bailey 1951). This litter and detritus accumulation, both standing dead biomass and organic material on the soil surface, has important implications for competitive interactions of sericea lespedeza and native vegetation. Litter accumulation has been associated with reduced forb establishment and species richness (Foster and Gross 1998). Sericea lespedeza detritus accumulation lowered the capacity of big bluestem to fix CO_2

by up to 32%, reduced symbiotic nitrogen fixation and thus the conversion of inorganic to organic N suitable for plant uptake, reduced earthworm abundance and invertebrate activity, reduced root productivity, and resulted in decreased soil temperature and light energy into the system in a study conducted by Knapp and Seastedt (1986).

Allelopathy

Sericea lespedeza leaf litter suppressed seed germination of other species (Hartley et al. 1989) while providing the ideal germination environment for itself (Pieters 1939). Sericea lespedeza may actively interfere with germination of other species through allelopathic compounds generated in leaf and stem tissue (Adams et al. 1973, Wade 1989, Dudley 1994). Allelopathic compounds found in sericea lespedeza seed are catechin and epicatechin (Buta and Lusby 1986).

Shade

Heavy shading by brush and trees decreased or eliminated sericea lespedeza stands (Watson et al. 1984, Sambeek et al.1986, Brown 1973), but Mays and Bengtson (1985) reported sericea lespedeza in vigorous condition in a pine understory after 9 years and Davison (1941) concluded that sericea lespedeza is tolerant of tree shade.

Light shading, such as that provided by tallgrasses, could increase seedling growth and establishment (Young 2000). Numerous sericea lespedeza seedlings were observed growing in heavy mulch where the range had not been grazed or burned and where shading was the greatest. This is in contrast to earlier observations (Carrier 1921). Intraspecific shading can negatively affect sericea lespedeza seedlings (Pieters 1939) or provide a safe site for germination (Eddy and Moore 1998). Benenati (2000) suggested that dense intraspecific shading could cause a shift in the ratio of chasmogamous:cliestogamous (CH: CL) flowering.

Sericea lespedeza seedlings tolerated interspecific shade in several studies (Pieters 1939, Smith and Calvert 1987, Hoveland et al. 1971). Close intraspecific spacing inhibited sericea lespedeza growth (Cope 1971).

Interspecific competition

Sericea lespedeza competes poorly with weeds (Hoveland and Donnelly 1985, Smith and Calvert 1987, Hoveland et al. 1971, Buchanan and Burns 1969) while having invasive tendencies (Riley 1957, Mooers and Ogden 1935). Numerous studies refer to sericea lespedeza's weak germination and establishment, frequently attributed to weed interference (Mays and Bengtson 1985, Crews 1984, Buchanan and Burns 1969). Sericea lespedeza vigor rapidly increased after establishment (Sambeek et al. 1986, Bengtson and Mays 1978, Mooers and Ogden 1935, Bailey 1951, Davison 1941, Buchanan and Burns 1969, Smith and Calvert 1987, Mays and Bengtson 1985, Vogel 1974). Weak seedling development and slow establishment have also been attributed to the allocation of most plant resources to root development following germination (Joost 1984, Joost and Hoveland 1986, Helm and Etheridge 1933). Sericea lespedeza competed successfully against annual grasses (Hoveland and Carden 1971, Hoveland et al. 1975, Helm and Etheridge 1933) and sweet gum (*Liquidambar styraciflua* L.) (Malik et al. 1997).

Sericea lespedeza stands were adversely affected by competition with warm-season grasses such as bermudagrass (*Cynodon* spp.) (Pieters 1939, Mooers and Ogden

1935, Hoveland et al. 1969, Skousen and Call 1987a, Skousen and Call 1987b). The level of competition provided by bermudagrass was dependent upon management factors such as haying and fertilization (Skousen and Call 1987b, Mooers and Ogden 1935). Rothwell (1984) reported that sericea lespedeza dominated a bermudagrass/annual legume stand, and Carrier (1921) thought that bermudagrass could successfully co-exist with sericea lespedeza. Heavy grass growth during the summer suppressed sericea lespedeza (Hoveland et al. 1971).

Other warm-season grasses that competed successfully with sericea lespedeza are crabgrass (*Digitaria* spp.) (Pieters 1939), carpetgrass (*Axonopus affinis* Chase) (Carrier 1921) and johnsongrass [*Sorghum halepense* (L.) Pers.] (Mooers and Ogden 1935). El Hadj et al. (2000) concluded that sericea lespedeza was compatible with legumes in a mix with perennial warm-season grasses due to its ability to co-exist.

Some cool-season grasses competed well with sericea lespedeza (Altom et al. 1992, Smith and Calvert 1987). Tall fescue [*Festuca arundinacea* Schreb.] reduced sericea lespedeza production (Bailey 1951, Hoveland et al. 1975, Vogel 1974). However, an attempt to interseed fescue into established sericea lespedeza failed (Bailey 1951). Rescuegrass (*Bromus catharticus* Vahl) (Hoveland et al. 1975) also competed successfully against sericea lespedeza.

Other cool-season grasses delayed early spring growth of sericea lespedeza: Abruzzi rye (*Secale cereale* L. cv 'Abruzzi'), rescuegrass, and gulf ryegrass (*Lolium* *multiflorum* Lam. cv 'Gulf') (Hoveland et al. 1975, Hoveland and Carden 1971). Annual winter grasses (small grains) were reported to be competitive with sericea lespedeza (Bailey 1951, Pieters 1939, Carrier 1921) but Hoveland and Carden (1971) reported no adverse effects of small grains on sericea lespedeza stands.

Sweet clover (*Melilotus officinalis* (L.) Lam.), alfalfa (*Medicago sativa* L.), wild winter pea (*Lathyrus hirsutus* L.), and manganese bur clover *(Medicago polymorpha* L.) were found to be competitive with sericea lespedeza (Pieters 1939, Bailey 1951, Riley 1991). Annual legumes were (Mooers and Ogden 1935) and were not (Rothwell 1984) successful in competing with sericea lespedeza. Alfalfa has greater photosynthetic and transpiration rates and greater net productivity than sericea lespedeza at high light and temperature intensities (Brown and Radcliffe 1986). Menhinick (1967) found net community production for a lespedeza stand to be 550 g/m^2/year, comparable to the low end of the range for tallgrass prairie community net production.

Growth form

Sericea lespedeza competes with weeds with its upright (shading) growth form, deep taproot system for exploiting water and nutrient resources unavailable to shallow-rooted weeds, and early greenup with its attendant competitive advantage for light and resources (Stritzke et al 2001, Skousen and Call 1987b, Cope 1966). We observed earlier spring greenup and later fall senescence of sericea lespedeza in comparison with warm-season grasses in the Flint Hills.

Roots and Mycorrhizae

Sericea lespedeza grew a dense, deep root system that was 125 cm long (Koger et. al. 1996, Joost et al. 1989) and accumulated 4535 kg of roots/ha (Hartley et al. 1989, Pieters 1939). Deep root systems can exploit water and nutrients from a large volume of soil. Sericea lespedeza's drought tolerance (Mooers and Ogden 1935) is attributed to its root system (Hartley et al. 1989, Koger et al. 1996, Bailey 1951).

Dense fibrous root systems provide attachment sites for mycorrhizal colonization (Lynd and Ansmna 1993) and are readily colonized by *Rhizobium* spp. (Bender et al. 1988, Wade 1989, Erdman 1950, Rothwell 1984, Lynd and Ansmna 1993, Bender et al. 1989). Rhizobium colonization enhances nitrogen (NO_3) fixation. Nitrogen was a nutrient that limited forage production in tallgrass prairie (Owensby et al.1970). N-sharing between sericea lespedeza and surrounding plants was minimal or non-existent, but sloughed off nodules may provide some N as they decompose (Mkhatshwa 1985, Ward et al. 1985, Gerken and Eller 1983). However, Mays and Bengson (1985) reported that mature sericea lespedeza did supply N to pine trees when grown as a cover crop.

Nodulation was also associated with drought tolerance (Lynd and Ansmna 1993), exploitation of soil nutrients (Lynd and Ansmna 1993), and forage production (Erdman 1950). Nodules comprised as much as one third of the root + nodule dry weight of sericea lespedeza (Lynd and Ansmna 1993). Sericea lespedeza nodulation was suppressed by grass (Danho 1984).

Sericea lespedeza increased acidity in the rhizosphere, resulting in less favorable conditions for surrounding plants (Joost 1987, Joost 1984). Sericea lespedeza also produced root exudates that actively promoted parasitic hasutoria both in sericea lespedeza and surrounding plants (Riopel and Musselman 1979, Steffens et al. 1986). Haustorium formation is associated with parasitism by the native forb gerardia (*Agalinus* spp.*)* (Steffens et al. 1986).

Climatic conditions

Drought-stressed sericea lespedeza exhibited reduced ability to fix N (Mkhatshwa 1985), reduced plant height (Fick 1990), reduced seed production (Ward et al. 1985, Mayo 2002, Donnelly and Patterson 1969), reduced shoot density (Schmidt et al. 1985), reduced emergence and establishment (Koger et al. 2002, Koger 1996, Wright et al.1978), and reduced biomass (Kuenstler et al. 1983, Hoveland et al. 1971). Wiegert and McGinnis (1975) reported that sericea lespedeza mortality was highest in August and September in South Carolina due to the drought conditions prevalent at this time of year.

We observed in this study that late summer drought negatively affected sericea lespedeza seed production. A series of dry years would appear to be detrimental to sericea lespedeza populations. Conversely, a series of wet years, such as the 1990s in Kansas, would tend to increase sericea lespedeza populations. We know that sericea lespedeza populations increased in Kansas during the 1990s. No similar dry period has provided the opportunity to study the ability of sericea lespedeza to persist in a stand of drought-adapted native vegetation. Dry conditions also decrease parasitic webworm populations, altering the competitive ability of this parasite to affect sericea lespedeza (Eddy 2002).

Cope (1966) reported that sericea lespedeza seedlings “begin growth well before the last frost in the spring”; however, Mosjidis (1989) reported cool temperatures decreased seedling growth. Sericea lespedeza plants that germinated late in the growing season were susceptible to winter kill (Joost 1987, Helm and Etheridge 1933). We observed sericea lespedeza greenup late in the spring near the frost-free date.

Soil moisture availability for surrounding plants is reduced by sericea lespedeza. Sericea lespedeza caused higher precipitation runoff than other perennial vegetation (Malik et al. 2000, Cripps and Bates 1993) despite earlier predictions that sericea lespedeza’s root penetration would increase the soil’s capacity for absorbing water (Bailey 1951). Soil moisture was so completely depleted by sericea lespedeza that new sericea lespedeza seedlings could not survive (Bailey 1951).

Reproduction

Sericea lespedeza reproduces both sexually (seed) and asexually (clonal growth). The ability to reproduce via clones increases the invasive potential of a species (Francirkova 2001) by ensuring local persistence as seeds are dispersed into new areas. Francirkova (2001) stated that “for more than 50% of invaders [in]to seminatural habitats, vegetative reproduction is more important than sexual reproduction”. Clonal invaders were more common in natural, less disturbed habitats (Pysek et al. 2001).

Sericea lespedeza reproduces sexually by chasmogamy and cliestogamy (Cope 1966). It does not cross with native lespedezas (Hansom and Cope 1995), but populations in Kansas appear to have adapted rapidly to local conditions and display “considerable” genetic variation (Sundberg et al. 2002). Sexual reproduction was possible during the first season of growth (Pieters 1939). Cliestogomous seed production can be important in the initial stages of weed dispersal because it allows reproduction by a single individual after a long-distance, isolating migration (Bimova et al. 2001).

Chasmogamous (out-crossed) seed production favors adaptation to local conditions. Sericea lespedeza plants located on the periphery of a patch will produce more chasmogamous than cliestogomous seed (Cope 1971, Benenati 2000). Control measures that fail to eliminate all sericea lespedeza have the effect of creating more patches. Plants within these patches are more likely to produce a higher proportion of chasmogamous flowers than before the control treatment. The resulting heterosis could produce more vigorous plants. (Benenati 2000). Chasmogamous seed progeny produce 25% more forage (Donnelly 1955, Cope 1966) and 40% more seed (Donnelly 1955) than cliestogomous seed progeny.

Seed production was affected by management, climatic conditions, and competition with other plants (Adamson and Donnelly 1973). Irrigation increased seed yield 117% over dryland conditions (Adamson and Donnelly 1973). Although a prolific seed producer (Koger et al. 2002), sericea lespedeza has a low germination rate of 10-20% (Pieters 1939). Seed mortality rapidly increased with age (Carrier 1921).

Propagule pressure (Williamson 2001) from a prolific seed producer may overwhelm other species in the seed bank simply by disproportionate numbers. Sericea lespedeza produces up to 1000 seeds/stem (Fechter 2003) and up to 30 stems/plant (Pieters 1939), which could potentially result in massive seedbank accumulations. Sericea lespedeza densities increased with increased seeding rates (Hoveland et al. 1971, Jorgensen and Davis 1983).

Animal Interactions

Dispersal

The mechanisms of sericea lespedeza seed dispersal have not received much attention. The seed, which resembles alfalfa seed in size and shape, has no specialized structures for wind or water dispersal, animal attachment, or animal attractant. One possible method of dispersal could be seed ingestion and subsequent deposition by animals foraging on the leaves of the plant or harvesting seed as a fall and winter food source. Eddy et al. (2003) observed that cattle, birds, and deer disperse sericea lespedeza seed, but the methodology used in that study was not reported.

The role of birds and mammals in seed dispersal has long been recognized (Malo and Suarez 1996). Krefting and Roe (1949) performed recovery and germination tests on a variety of seeds passed through the digestive tract of 10 bird and mammal species, with digestion rates as high as 100% (no recovery). Some of the seed that successfully passed through the digestive tract exhibited enhanced germination, which was attributed to abrasion and to exposure to gastric juices and bacteria.

Numerous studies (Dore amd Raymond 1942, Burton amd Andrews 1948, Harmon amd Keim 1934, Gardener et al. 1993, Blackshaw amd Rose 1991, Brunn and Fritzboger 2002) examined the effects of cattle digestion on seeds. Dore and Raymond (1942) concluded that cattle were the most important dispersal agency for pasture species when compared with wind, water, mechanical, and animal-assisted transport dispersal mechanisms, with a single cow distributing over 900,000 seeds in its manure during the growing season. Janzen (1984) summarized numerous investigations as indicating that livestock, through their seed dispersal activities, could affect species richness and composition. Karl et al. (1994) reported that cattle functioned as transient seed banks, but their depositions resulted in negligible seedling emergence and establishment.

Dispersal attributes of birds have also been examined in previous studies (Krefting and Roe 1949, Harmon and Keim 1934, Traveset et al. 2001, Paulsen and Hogstedt 2002, Kerner et al. 1895 summarized in Collinge 1913). Cole et al. (1993) concluded that game birds, specifically ring-necked pheasant [*Phasianus colchicus* (L.)], were instrumental in spreading native plant species. Krefting and Roe (1949), working with both birds and mammals, considered birds to be more important than mammals in enhancing the germination of ingested seed.

Dispersal effectiveness is dependent on propagule quantity and quality (Schupp 1993). Quantity, the number of seed dispersed, includes not only how much seed is produced by a plant but how much is consumed by an animal. Quality, the probability that a dispersed seed produces a new adult, includes treatment of the seed in the digestive tract and how effectively it is transported.

A seed that is retained longer in the digestive tract gives the animal more time to move away from the point of consumption (Kerner et al. 1895 summarized in Collinge 1913). The majority of seed consumed by cattle passed within 2 days, with lesser quantities excreted for an additional 3 days (Kempski 1906 summarized in Brunn and Fritzboger 2002, Gardener et al. 1993). Passage rate increased in cattle with high forage consumption (Blackshaw and Rose 1991) but decreased with poor forage quality (Vallentine 2001). The late-season tallgrass forage available to foraging animals during sericea lespedeza seed set is high in indigestible components (Heady and Child 1994) and is retained longer in the rumen (Vallentine 2001). Fairbrother and Brink (1989) reported that the digestive rate of sericea lespedeza was lower than that of grasses.

Barnea et al. (1991) reported average seed retention times in birds to be 73 minutes or less. Small spherical seeds passed more rapidly through the intestinal tract and experience more scarification than large seeds, resulting in higher viability (Brunn and Fritzboger 2002).

Gastrointestinal passage rates in bobwhite quail were rapid, with peak recovery rate at 3-4 hours with negligible recovery after 9 hours (Stultz et al. 2001). Rapid passage rates results in a limited travel distance before crop contents are eliminated.

A trade-off between passage time and dispersal range exits (speed and direction of an animal's movements) (Blackshaw and Rose 1991). A slower passage rate potentially increases the area where the seed could be spread as the animal wanders to fresh herbage. On the other hand, a long passage rate seems to correlate strongly with decreased survival of the seed (Gardener et al. 1993). Prolific seed production and massive consumption could partially offset rapid passage through the digestive tract. At least some of the seed might be moving slowly through the digestive tract and be widely dispersed: a small percent of a very large number can still be substantial. Given that cattle movements between fenced areas is fairly regulated, new plant populations in distant locations attributable to animal dispersal indicate either rapid, deliberate relocation of domestic livestock or unregulated movement of wildlife.

Robinson (1957) estimated it would take 12 acres of south-central Kansas rangeland for bobwhite survival during their critical period (winter). Taylor (1997) estimated bobwhite quail home ranges are between 65 and 103 ha in eastern Kansas, depending on site characteristics.

Palatability

Several experiments have verified the reduced digestibility of common sericea lespedeza when compared to other legumes such as low-tannin sericea lespedeza, alfalfa and red clover (Messman et al. 1996, Donnelly et al. 1971). The soluble tannin content of sericea lespedeza forage decreased during the growing season from 16.9% in July to 8.8% in October, while the whole-plant tannin content increased (Cope et al. 1971). The increase in whole plant tannin levels was due to the high tannin content of the ripening seed (Stitt and Clarke 1941). Late-season palatability was reduced by stemmy growth (Helm and Etheridge 1933) and declining protein levels (Donnelly et al. 1971).

Effects of Sericea Lespedeza Presence and Density on Species Richness of Kansas Tallgrass Prairies

Abstract

Sericea lespedeza [*Lespedeza cuneata* (Dumont) G. Don] is a rangeland weed that is reducing species diversity in the Kansas tallgrass prairie. Experiments were undertaken in the Kansas Flint Hills in 2001-2003 to examine the influence of sericea lespedeza presence and density on native rangeland plant species. Species composition and cover were obtained using the step-point method. Quadrats placed along transects were also used to measure the effect of sericea lespedeza presence and density on grass and forb species richness. Correlation and mixed analysis were used to examine relationships between sericea lespedeza and 12 other vegetative species. Sericea lespedeza cover was positively correlated with violet lespedeza [*Lespedeza violacea* (L.) Pers.] (r=0.25), heath aster (*Aster ericoides* L.) (r=0.23) and total forb cover (r=0.56). Sericea lespedeza composition was negatively correlated with big bluestem (*Andropogon gerardii* Vitman.) (r=-0.27) and sideoats grama [*Bouteloua curtipendula* (Michx. Torr.)] (r=-0.27) composition and positively correlated with western ragweed (r=0.21) (*Ambrosia psilostachya* D.C.) and violet lespedeza (r=0.36) composition. Sericea lespedeza density was inversely related to forb species richness on all sites. On half of the sites, there was also an inverse relationship between grass species richness and sericea lespedeza density. Grazed sites had less difference in grass species richness between high and low levels of sericea lespedeza densities. There was no evidence of an

ecological threshold to the detriment of species richness with increasing sericea lespedeza density.

Introduction

During the past century, the sericea lespedeza population in Kansas tallgrass rangelands has increased dramatically. Currently, 263,930 ha of rangeland are considered to be negatively affected by this perennial non-native legume (Scott 2004). Native tallgrass prairie has historically supported livestock grazing, hay production, and wildlife food and habitat. These uses are jeopardized by the continued conversion of species-diverse rangelands to near solid stands of sericea lespedeza.

In native rangelands with substantial sericea lespedeza populations, it is probable that species displacement is occurring. The upright, stemmy growth form of sericea lespedeza provides considerable shading of the understory (Pieters 1939). Plant species intolerant of shading would seem to be most at risk for displacement by sericea lespedeza or other shade tolerant species.

Dominance is defined as “the species having the most influence on community composition and form” (Allaby 1985). Tallgrass prairie in Kansas is characterized by high species richness (Towne and Kemp 2003) but is dominated by four species of warm-season grasses: big bluestem, little bluestem [*Schizachyrium scoparium* (Michx) Nash], indiangrass (*Sorghastrum nutans* (L.) Nash), and switchgrass (*Panicum virgatum* L.) (Netherland 1979, Abrams and Hulbert 1987). Native grass dominance can be reduced by sericea lespedeza ((Stritzke 1999, Koger et al. 2002).

Species richness is the number of species in a community (Myers and Bzaely 2003). Richness includes all species without regard to their frequency or abundance. Invasive species affect a plant community by changing the species diversity or altering how the community functions (Myers and Bzaely 2003) by modifying the processes and mechanisms at the community level (Speroni and deViana 2001). Individual plant species can have significant effects on ecosystem processes (Briske et al. 2005) by the replacement of native species by a non-native species (Stohlgren et al. 1999) or by altering species dominance within the community (Smith and Knapp 1999). For example, tamarisk (*Tamarix ramosissima* Deneb) modifies soil salinity, sedimentation rates, soil moisture availability and water uptake (Planty-Tabacchi et al. 2001). Sericea lespedeza at high densities can cause a reduction in native plant richness of up to 70% and a 92% decrease in aboveground biomass of native species (Eddy 1999).

Plant species composition in this context is the proportional contribution of each species to the total plant population. Management practices (Gibson et al. 1993) such as burning frequency and intensity, herbivore species (livestock) selected, seasons, and intensity affect species composition. Species composition analysis can also detect plant invasions and ecosystem changes over time. Changes in richness may be related to both the presence and density of an invasive species (Olson 1999).

Successional models of rangeland ecosystems distinguish between a climax community and seral (sub-climax) community. These models attribute species composition within seral communities to a specific type and intensity of disturbance. Removal of the disturbance should eventually result in a progression toward a climax community (Westoby 1979).

An alternate model of succession has evolved, generally called state-and-transition. Implicit in this model are the ideas that removing a disturbance (e.g., non-native plants) does not necessarily initiate progress toward climax conditions and that some otherwise non-significant event can trigger a rapid, irreversible change in the plant community if certain conditions are met (Westoby 1979). The new model does not completely discard the old model, but incorporates successional theory as occurring within various stable states; these states are separated from each other by discontinuous and non-reversible transitions (Briske et al. 2005). The point where a combined set of circumstances causes a rapid, irreversible change to occur is called the threshold (Fig. 3.6).

Plant functional groups have been delineated by similar taxonomy, by similar effects on ecosystem functions, or by similar responses to specific levels of environmental resources (Lavorel and Garnier 2002). Plant communities exist as states that vary from each other by relatively large differences in plant functional groups and ecosystem processes and functions (Bestelmeyer et. al 2003, Brown et al. 1999). Plant functional group changes are thought to precede ecosystem process changes (Briske et al. 2005) whereas soil indicators may precede vegetation response (Herrick et al. 2004).

The objectives of the current study were: 1) to describe the species composition of the study site; 2) to compare sericea lespedeza presence and density vs. other community attributes; and 3) to obtain ecological criteria for an ecological threshold in species composition with sericea lespedeza density as the disturbance factor.

Materials and Methods

Data were collected during the 2001-2003 growing seasons on the Otter Creek Ranch in Greenwood County near Eureka, Kansas (N 37^0 39’ 53.8”, W 96^0 21’ 44.9”) on an otherwise healthy native rangeland site with moderate densities of sericea lespedeza. This approximately 162-ha site is located in the southern tallgrass region of Kansas and is dominated by warm-season grasses, including big bluestem, little bluestem, indiangrass, switchgrass, and tall dropseed [*Sporobolus compositus* (Michx. Kunth].

Soils on the site were Clime-Sogn (loamy-skeletal, mixed, superactive, thermic, shallow Typic Haplodurids- loamy, mixed, superactive, mesic Lithic Haplustolls), Eram (fine, mixed, active, thermic Aquic Argiudolls), Kenoma (fine, smectitic, thermic Vertic Argiudolls), Labette-Sogn (fine, mixed, mesic Udic Argiustolls- loamy, mixed, superactive, mesic Lithic Haplustolls), Martin (fine, smectitic, mesic Aquertic Argiudolls), Reading (fine-silty, mixed, superactive, mesic Pachic Argiudolls), and Steedman (fine, smectitic, thermic Udertic Haplustalfs).

Vegetation on the study site was burned between 10:00 AM and 5:00 PM on April 12, 2001. At the beginning of the study, only the exterior fence around all the paddocks was in place. Beginning in 2001, the site was gradually divided into five paddocks of approximately 32 ha each (Fig. 3.1). The existing barb-wire perimeter fence was reinforced with three additional strands of barbed wire to contain the goats (*Capra hircus* L.). Interior electrical wire fences were added as the owner had time and labor. Each paddock was assigned a number. All decisions regarding stocking density, livestock species (cattle and/or goats), and grazing season of each paddock were made by the producer with little experimental input. All sites were grazed by livestock at some point during the growing season.

Experiment 1

To estimate species basal cover, eight modified step-point transects (Evans and Love 1957) comprised of 100 points and each approximately 76 m in length were collected across each 32-ha site in both 2001 and 2003. Only five transects were sampled on Site 5. Transects were systematically placed within each site to ensure that all soil types present within the site were represented proportionally (Fig. 3.2). Sample points every 0.75 m along the transect were observed using a tripod mechanism similar to that described by Owensby (1973). At each location, soil basal cover (plant basal hit, bare soil/litter) and closest plant species within an 180^o arc were recorded. A species' basal cover or any other similar aerial attribute is directly proportional to the probability of recording a hit on that particular species.

Data for each transect were combined into one record per transect (eight per site except Site 5). For each record, species composition and cover was recorded. Species composition and cover were recorded for the seven grass species and five forb species that were most abundant [big bluestem, little bluestem, switchgrass , indiangrass, tall dropseed, sideoats grama, Scribner's panicum [*Dichanthelium oligosanthes* (Schult.)

Gould *var. scriberianum*], western ragweed, sericea lespedeza, fringeleaf ruellia (*Ruellia humilis* Nutt.), violet lespedeza, and heath aster]. Sedges (*Cyperacae* spp.) were also categorized separately. All other species were grouped into "other grasses" and "other forb" categories.

Linear relationships among individual plant species were examined for species composition and cover using correlation analysis (Littell et al., Statistical Analysis Systems Institute, Inc. 1996). A mixed model was used to evaluate soil type and year effects on sericea lespedeza.

Experiment 2

Permanent straight-line transects were established within patches of sericea lespedeza with sufficient spatial extent to allow all transects to be positioned in close proximity to each other. Each transect was oriented so that most quadrats would contain sericea lespedeza plants, and a total of four transects were observed on each site. Two transects of 6.1 m were placed parallel to each other within a 7.3 m circular exclosure constructed of 1.4-m tall cattle panels, steel fence posts, and wire. Two, 30.5-m transects were located outside the exclosure (Fig. 3.3). The end of each transect within the exclosure was marked with flags; whereas outside the exclosure ends were marked with painted rocks to minimize alteration of grazing behavior. Transects were sampled twice each year during 2001-2003, in June and in September, to ensure that both early- and late-emerging species were recorded.

A total of 10 quadrat samples were taken along each transect within the exclosure and 20 quadrat samples were taken along each transect located outside the exclosure in each sampling period. During sampling, a tape measure was positioned between the endpoints. Quadrats were positioned at intervals of 0.6 m inside the exclosure and 1.5 m outside the exclosure in an alternating pattern along both sides of the tape measure using a 0.25 m^2 square frame. All plant species found within each quadrat were recorded. The number of quadrats counted for grasses and forbs differed because during the first sampling period, grass species were not counted; grass species were subsequently recorded in all other sampling periods. There were 153 grass quadrats and 170 forb quadrats included in the analysis. In alternate quadrats, counts were made of each sericea lespedeza stem arising from ground level to estimate sericea lespedeza stem density. Density was sampled only half as often as presence/absence. All density measurements were expressed as counts/m^2 to facilitate comparisons.

Data from site 5 were collected but not included in the statistical analysis because of the extreme differences in management on this site. These differences included broadcast spraying for sericea lespedeza (including the test site), an extra burn, no grazing the second year, and construction of a road across the transects while a watershed dam was being built on this site.

Linear and curvilinear mixed models with year, season, and grazing treatment as strip-plot factors and sericea lespedeza density as covariate were fitted to the data from each site using SAS procedure MIXED. A check for normality was performed using SAS procedure UNIVARIATE. Forb species richness fixed effects were sericea lespedeza density, year, season (spring and fall), grazing treatment, and all interactions. Grass species richness was analyzed with season nested within year because of changes in experimental protocol during the 3 years of the study. During the first spring sampling period, sericea lespedeza density was not recorded for Site 1 but was recorded for all subsequent sites; thus season main effects were analyzed for years 2 and 3 on this site. Also, during the first spring of the study, grass species richness was not recorded for any of the sites. The analysis was changed to reflect these omissions in the data. Fixed effects for grass species richness were sericea lespedeza density, year, season within year, and grazing treatment. Species richness vs. sericea lespedeza density was graphed to visually compare with threshold and successional models.

Results

Experiment 1

Big bluestem and little bluestem together composed approximately 35-45% of the species composition in all sites, emphasizing their important role in tallgrass prairie communities. The narrow range in grass species composition also indicates the vegetative similarity between sites (Table 3.1) despite differences in soils and topography. Sericea lespedeza comprised between 1% and 5% of the species composition across all sites.

Because sericea lespedeza composition was not significantly different across soil types, dates and years, and no soil by year interaction was present ($p > 0.1$), site selection by soil type was unbiased for this study. Sericea lespedeza cover was positively correlated with violet lespedeza and heath aster cover as well as total forb cover (Table 3.2). Sericea lespedeza composition was negatively correlated with big bluestem and sideoats grama composition and positively correlated with western ragweed and violet lespedeza composition. Violet lespedeza was the only species positively correlated with sericea lespedeza for both cover and composition.

Experiment 2

Tests for normality (W, D, W-Sq and A-Sq) were significant for both grasses and forbs (Appendix C). When the data were plotted, the grass data appeared to have near normal distribution (Appendix D). The forb data were less normally distributed but still displayed a bell-shaped distribution. No corrections were made for non-normality of the data in any analysis.

The linearity model showed that on Sites 1, 2, 3, and 4 sericea lespedeza was present in 77, 96, 59, and 79% of the quadrats respectively. Sericea lespedeza was not included in forb species richness. Grass species richness was significantly ($p<0.1$) affected by sericea lespedeza density on Sites 1 and 3 (Table 3.3). There was also a significant ($p<0.1$) interaction between grass species richness, sericea lespedeza density and grazing treatment. The two grazing treatments were grazed and ungrazed. Site 1 was usually grazed by cattle and Site 3 had the heaviest goat grazing.

The slopes for grazing and sericea lespedeza density vs. grass species richness for Sites 1 and 3 are graphed in Fig. 3.4. For purposes of comparison, sericea lespedeza density endpoints were set at 0 and 400 stems/m^2. Grazed sites had less difference in grass species richness between high and low levels of sericea lespedeza densities. On Site 1, without grazing, grass species richness was half as great at the high sericea lespedeza density as at the low density. In contrast, there was little difference in grass species richness at low and high sericea lespedeza densities with grazing. On Site 3, grass species richness dropped by more than 70% when high density sericea lespedeza was ungrazed. In contrast, there was less than a 25% decrease in grass species richness between the two densities of sericea lespedeza with grazing.

The highest sericea lespedeza stem density recorded in this data set was 576 stems/m^2, but there were very few quadrats (0 to 8% on any site) that contained more than 400 stems/m^2. Grass species richness was significantly ($p<0.1$) affected by the interaction between sericea lespedeza density, grazing treatment, season, and year on Site 2 (Table 3.3).

A significant, negative interaction between forb species richness and sericea lespedeza density was present on all four sites ($p<0.1$) (Table 3.4). On Site 3, forb species richness declined at high sericea lespedeza densities regardless of grazing treatment (Fig. 3.4). However, species richness was greater with grazing.

Forb species richness varied by season on Site 4. Spring species richness was greater than fall species richness. A review of the species list for Site 4 did not reveal that any one species was responsible for this difference.

Sericea lespedeza stem density was plotted vs. species richness to visually assess the potential for a species richness threshold at increasing levels of disturbance, in this case sericea lespedeza stem density. Quadrats containing the same number of species at the same sericea lespedeza stem density were identified by a single symbol in the plot. In general, a slight downward trend in the number of grass and forb species was present as sericea lespedeza density increased (Fig. 3.5). This trend was more evident for forbs than for grasses. Few quadrats with very high sericea lespedeza densities (>400 stems/m^2) were present and thus caution must be used when interpreting trends at this end of the scale.

No discernable threshold effect on species richness was evident at sericea lespedeza densities recorded in this study. Very few quadrats contained high levels of sericea lespedeza. It is possible that a threshold may exist at density levels above those in this study. On Site 5, which was omitted from these statistical analyses, sericea lespedeza stem densities reached 944/m^2 and no other grasses or forbs species were present.

Discussion

Experiment 1

The sample size in Experiment 2 was extremely small (2 grazed and 2 ungrazed samples/site). An experiment with more samples, and thus more degrees of freedom, would likely show additional significant relationships.

Olson (1999) stated that severe infestations of noxious weeds usually reduce community productivity, species diversity (relative abundance) and species richness (abundance of species). Tallgrass prairie has high floristic diversity. In the present study, a total of 32 grass species and 90 forb species were encountered within the confines of the quadrats sampled, and a total of 13 grass species and 115 forb species were recorded using the steppoint technique across the entire site. For comparison, Towne and Kemp (2003) recorded a total of 148 species on their study site in the northern Flint Hills tallgrass prairie.

A guild is "a group of species having similar ecological resource requirements and foraging strategies, and therefore having similar roles in the community" (Lincoln and Boxshall 1987). Planty-Tabacchi et al. (2001) reported a significant, positive, linear correlation between species richness of native and non-native guilds, but a negative correlation between species richness of native species and the percentage of non-natives in French riparian systems. Jones (1995) reported that coverage of sericea lespedeza was inversely correlated with native herbaceous and woody coverage. In this study, native forbs and grasses comprised nearly all (greater than 94% on all sites) of the species composition, and observations suggest that sericea lespedeza presence has not facilitated an increase of other non-native species.

Sericea lespedeza was included along with other forbs in calculating species composition. Sericea lespedeza cover was positively correlated with total forb cover, as would be expected. As the sericea lespedeza component of the stand increased, the total forb component increased. This would especially be true if grass cover was being replaced with sericea lespedeza cover. However, in this study, grass cover and sericea lespedeza cover were not negatively correlated. Cover of two native forb species, heath aster and fringed-leaf ruellia, was positively correlated with sericea lespedeza cover.

Sericea lespedeza can alter patterns of dominance by native vegetation (Wade 1989). Dominance, in turn, can alter invasiveness; reduced dominance of C_4 grasses resulted in reduced invasiveness of tallgrass praire by legumes (Smith et al. 2004). No grass species composition was significantly, positively correlated with sericea lespedeza composition in this study. Big bluestem and sideoats grama composition were significantly, negatively correlated with sericea lespedeza composition, suggesting that these two grasses either have a greater negative response to sericea lespedeza or restrict sericea lespedeza invasion more than the other grasses recorded.

Violet lespedeza is a prairie plant with short stature, suggesting shade tolerance. Mid-to-late season sericea lespedeza plants provide considerable shade (Van Sambeek et al. 1986) and understory plants would be best suited to these conditions. The reason for the positive correlation of western ragweed cover with sericea lespedeza cover is difficult to discern. Western ragweed roots extend deeper into the soil than do sericea lespedeza roots which may reduce the competition for water and nutrients between the two species.

Experiment 2

Sericea lespedeza has the potential to form extremely dense stands capable of severely reducing or excluding other plant species (Hartley et al. 1989, Jorgenson and

Craig 1983, Skousen and Call 1987, Jorgenson and Davis 1983, Golley 1965). Pieters (1939) observed 20-30 stems per [lespedeza] plant by the third to fourth year after planting, with a single plant having up to 100 stems. Pieters (1939) counted stem densities of approximately 680-980 stems/m^2 in planted plots, with a maximum of 1880/m^2, which probably represented 25-35 plants. Stands thicken by clonal sprouting and by volunteers from seed.

Working in a tallgrass prairie, Eddy and Moore (1998) recorded sericea lespedeza stem densities of up to 466/m^2 and concluded that surviving forbs in most infested areas have low nutritive value and are associated with tallgrass prairie in fair to poor condition. Eddy (1999) stated that when sericea lespedeza stem counts exceeded 352/m^2, native plant species number declined by 70%.

Stritzke (1999) and Stritzke et al. (2001) reported that grasses were able to tolerate sericea lespedeza stem densities of 22-86/m^2 before responding adversely. No decline in grass species richness was observed in the present study at sericea densities of similar magnitude (Fig. 3.5). The highest density of sericea lespedeza stems recorded in the present study was 944/m^2, and was a monospecific quadrat on Site 5.

Lavorel and Garnier (2002) reported that growth form is the functional grouping that best captures patterns of variation in several important functional traits. The species with the growth form most similar to sericea lespedeza in this study was slender lespedeza [*Lespedeza virginica* (L.) Britt]. Slender lespedeza and sericea lespedeza were observed in close association, especially on Site 1.

Hickman et al. (2004) stated that native plant species diversity, species richness, and growth form diversity were significantly higher in grazed than in ungrazed prairie. On two sites in the present study, species richness was significantly greater at high sericea lespedeza density with grazing. The present study did not compare cattle and goat grazing. Although no data were collected, it was observed that sericea lespedeza was more heavily grazed in pastures stocked with goats. Foliage removal might alter the competitive relationship between sericea lespedeza and native grass and forb species.

Friedel (1991) defined a threshold as a "boundary in space and time between two domains or states which is not reversible on a practical time scale without substantial inputs of energy" (reported in Stringham et al. 2003). The ability of sericea lespedeza to form dense stands capable of excluding other species raises the question of reversability: can a solid stand of sericea lespedeza revert to healthy native prairie without "substantial inputs of energy"? Does a zone of vegetative change exist beyond which a "persistent or irreversible transition" occurs (Stringham et al. 2003) and results in a community with a new equilibrium state (Myers and Bazaely 2003)?

Efforts in the present study to identify a threshold were inconclusive. If such a threshold exists, it apparently occurs at sericea lespedeza density levels above those commonly encountered in this study. From a management perspective, a threshold is crossed when management practices need to shift from maintaining existing processes to reversing degrading processes (Brown et al. 1999).

Repeated chemical treatment, which requires major energy inputs (Stringham et al. 2003), is currently the most, if not only, effective method of reducing sericea lespedeza density. This would tend to support the idea that an ecological threshold exists at some level of sericea lespedeza density. This threshold may differ with range condition. Biological control of sericea lespedeza using moths (Eddy 2002) may reduce seed set but has not conclusively proven effective in reducing stem density. Hart (2000) reported sericea lespedeza stem count reductions using goats, but numerical densities were not given. In the present study goats were observed grazing sericea lespedeza, especially late in the growing season. Grazed plants were stripped to the stem, with all leaves and flowers removed. Goat stocking rate was approximately 12.5 goats/ha for 5 months.

Conclusions

Sericea lespedeza negatively affects species composition and forage production of desirable native grasses (Koger et al. 1996, Koger 1996). The plant species richness of the Greenwood County site used in the present study was comparable to other tallgrass range sites (Towne and Kemp 2003) despite the presence of sericea lespedeza. In diversity investigations, the number of species will be less likely to change than will species diversity which also considers the evenness of the distribution among species (Myers and Bzaely 2003). Evenness was not measured in the present study.

Sericea lespedeza density significantly affected tallgrass prairie species richness in the present study. No evidence of a threshold existed for species richness with sericea lespedeza density as the disturbance factor. Failure to identify a threshold may indicate a lack of data around the threshold or that no threshold exists. A succession-type model may be more appropriate for this species, where species richness gradually declines with increasing sericea lespedeza density. Species richness sampling at specific sericea lespedeza densities would more clearly determine existence or non-existance of a threshold.

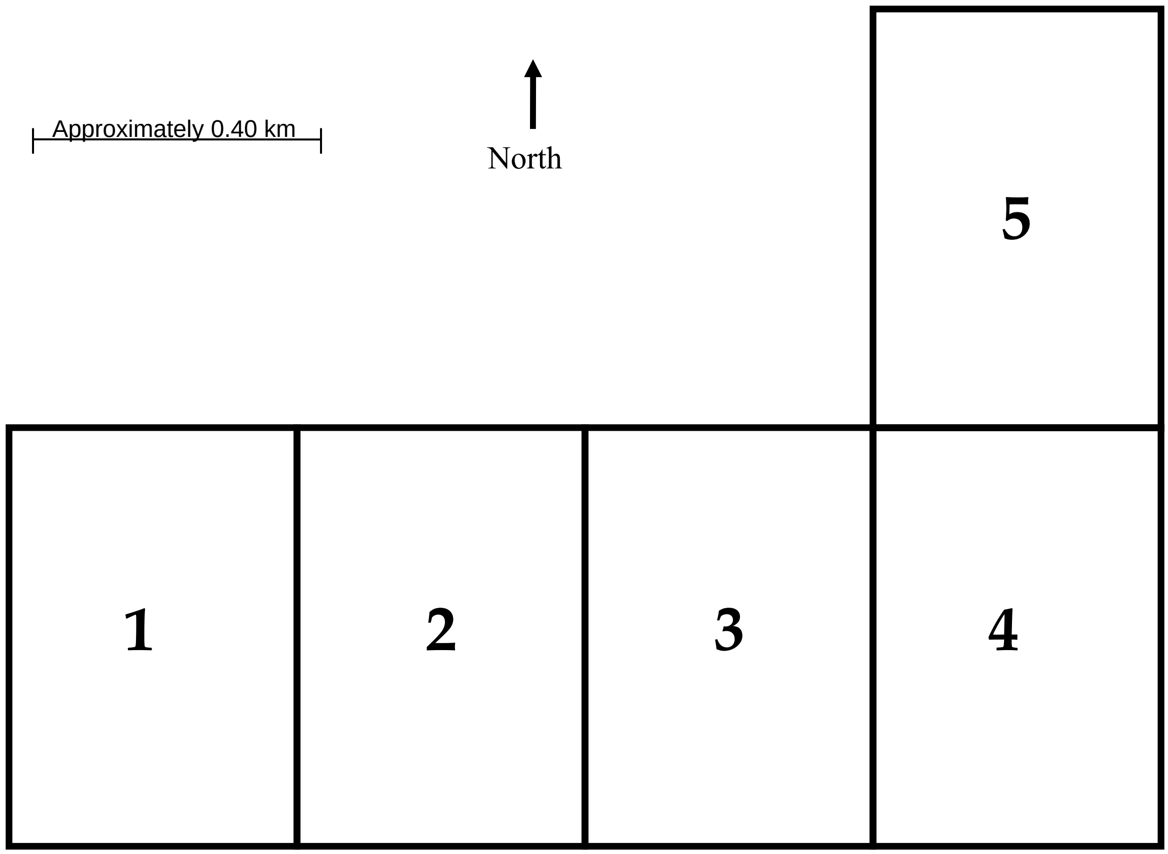


Figure 0.1 Layout of the study site.
The approximately 161.9 ha study site was divided into five approximately 32 ha paddocks.

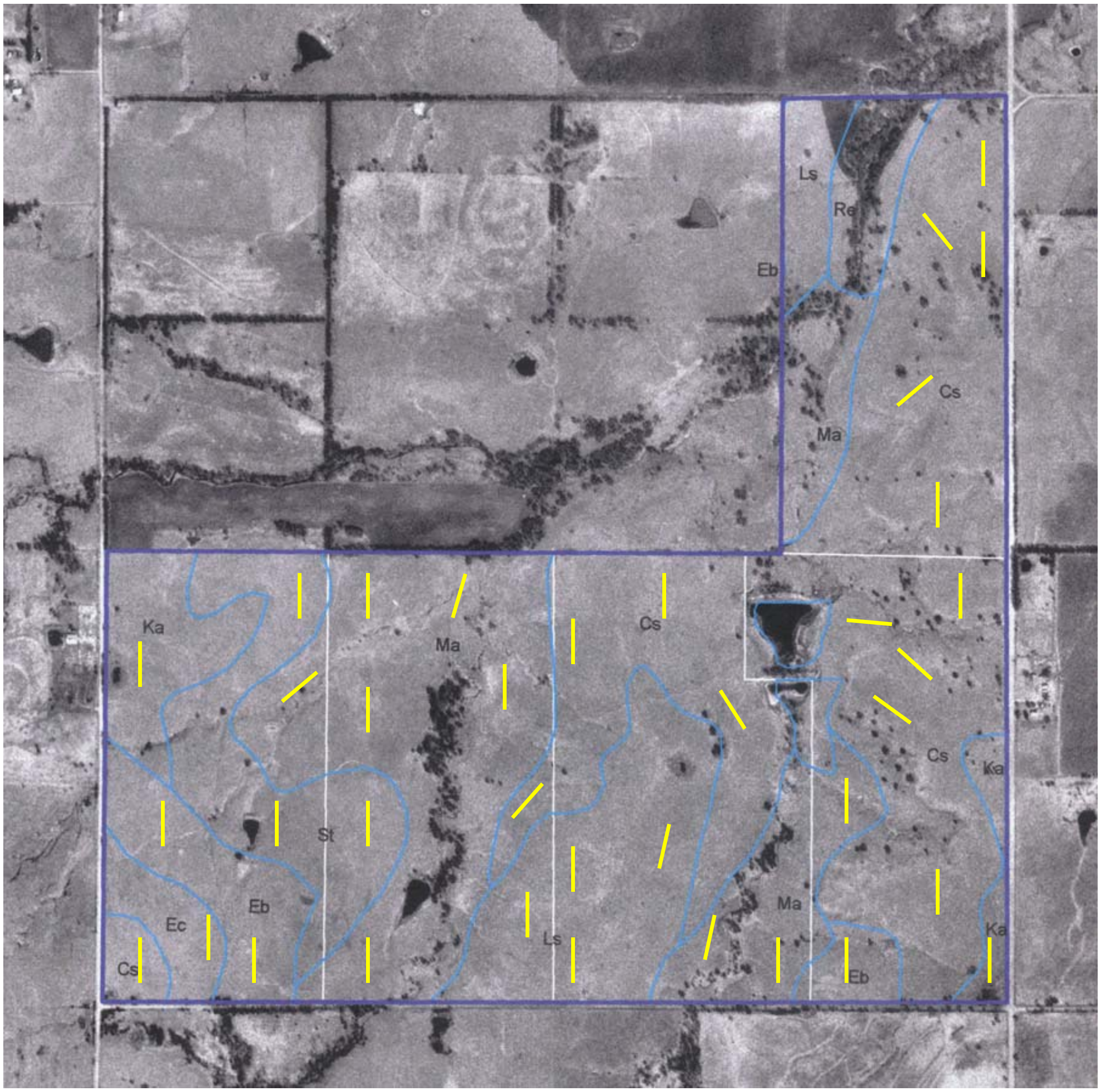


Figure 0.2 Step-point transect locations.

Soil maps[1] were used to obtain the soil type classification within each paddock. Blue lines on the figure above outline soil classes within each paddock. Soils included in these paddocks were Clime-Sogn (CS), Eram (EB and EC), Kenoma (KA), Labette (LS), Martin (MA), and Steedman (ST). Yellow lines on the figure above indicate approximate location of each transect. Because the objective was to collect a representative vegetation sample on each soil type, rather than repeatability, the position of the transects was noted on the map during the first sampling period. During the second sampling period, transects were placed in the same general area but end points would not have been identical.

[1] Forester, J.R., J.T. Neill, and S.C. Ekhart. 1982. Soil survey of Greenwood County, Kansas. USDA-SCS and Kans. Agri. Exp. Sta., Manhattan.

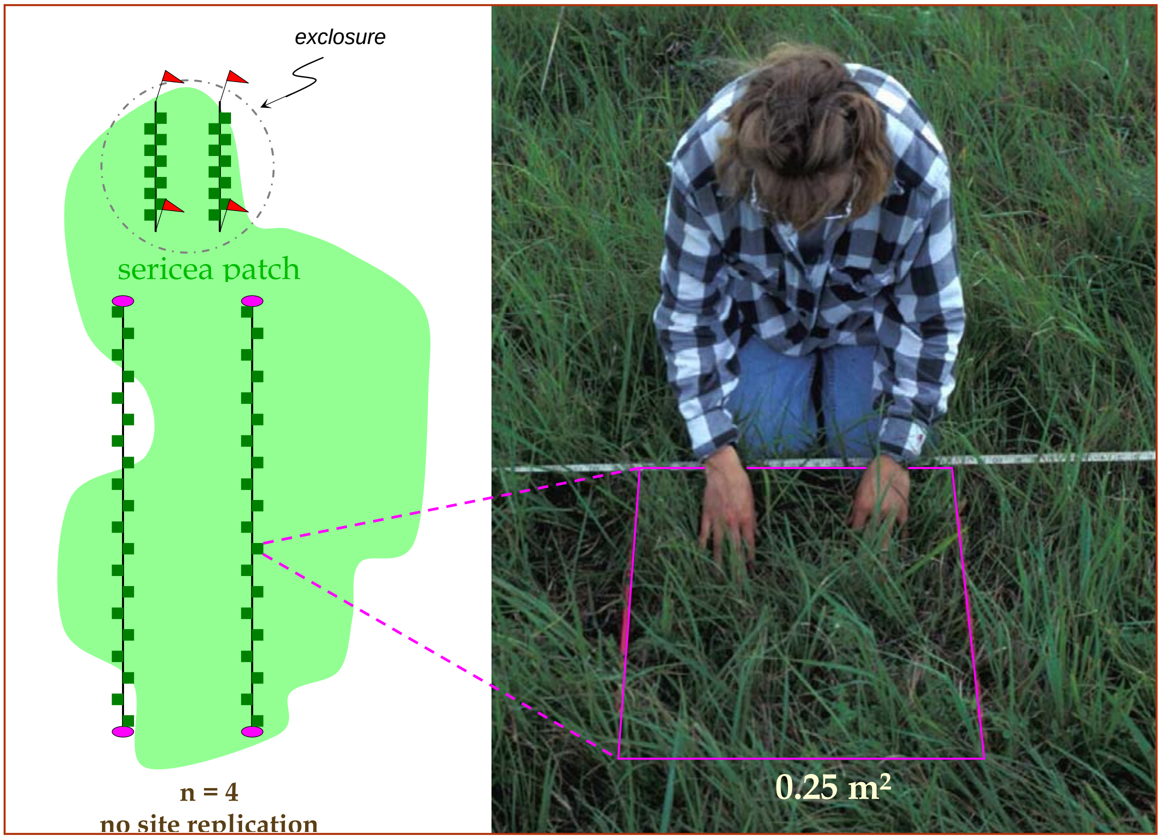


Figure 0.3 Idealized arrangement of transects.

Table 0.1 Vegetative species composition and cover (percent) by site.

	Site 1	Site 2	Site 3	Site 4	Site 5
big bluestem	28	24	23	26	31
little bluestem	14	10	13	9	8
switchgrass	5	4	5	4	6
indiangrass	8	8	6	7	8
tall dropseed	9	11	13	11	10
sideoats grama	7	2	7	9	12
sedge	9	12	9	9	8
scribners panicum	3	4	1	0	2
other grasses	8	8	9	10	6
sericea lespedeza	2	5	3	1	2
western ragweed	2	2	3	2	2
violet lespedeza	1	2	2	3	2
fringed-leaf ruellia	1	1	1	1	1
heath aster	1	1	1	1	1
other forbs	3	4	4	7	4
bare	23	30	28	30	55
litter	69	60	62	57	31
cover	8	9	10	13	14

Table 0.2 Correlation coefficients (r) between sericea lespedeza cover and composition, other species, and cover types.

	sericea lespedeza	
	correlation coefficient	
	cover	composition
big bluestem	-0.5358	-0.2730*
little bluestem	-0.1672	-0.0230
switchgrass	0.1366	-0.0859
indiangrass	-0.0799	-0.0494
tall dropseed	-1.0138	0.0963
sideoats grama	-0.0918	-0.2656*
sedge	0.0309	-0.0357
scribners panicum	-0.0206	0.0492
other grasses	-0.1094	0.0073
western ragweed	0.0000	0.2103*
violet lespedeza	0.2449*	0.3610*
fringed-leaf ruellia	0.1069	-0.1201
heath aster	0.2319*	0.0613
other forbs	-0.0496	-0.0821
total grass cover	-0.1450	
total forb cover	0.5572*	
bare	-0.1692	
litter	0.1588	
total plant cover	0.0456	

Items marked with an asterisk (*) are significantly correlated ($p<0.1$).

Table 0.3 Mixed model analysis of sericea lespedeza density, grazing season, and year effects on grass species richness at four sites.

	Site 1	Site 2	Site 3	Site 4
	P-value	P-value	P-value	P-value
sericea lespedeza density	0.0988*	0.5045	0.0011*	0.7864
year	0.6168	0.8263	0.3788	0.6024
season (year)	0.3902	0.9713	0.2001	0.7599
grazing trt	0.3399	0.4203	0.6506	0.5278
year x trt	0.2980	0.2196	0.2776	0.7568
season x trt(year)	0.4482	0.6387	0.3942	0.4371
sericea x year	0.8671	0.2104	0.1575	0.1504
sericea x season(year)	0.4333	0.5959	0.6081	0.3895
sericea x trt	0.0737*	0.3992	0.0237*	0.4649
sericea x trt x year	0.5254	0.8440	0.8962	0.5775
sericea x season x trt(year)	0.9019	0.0873*	0.3024	0.5017

Items marked with an asterisk (*) are significantly different.

Table 0.4 Mixed model analysis of sericea lespedeza density, grazing, season, and year effects on forb species richness at four sites.

	P-value	P-value	P-value	P-value
sericea lespedeza density	0.0031*	0.0001*	0.0087*	0.0001*
year	0.3155	0.1735	0.6305	0.5550
season	0.1216	0.1354	0.1226	0.0940*
year x season	0.6568	0.3796	0.2282	0.3002
grazing trt	0.1240	0.3173	0.0760*	0.7299
year x trt	0.5699	0.2105	0.4752	0.3214
season x trt	0.2129	0.2286	0.4035	0.4588
year x season x trt	0.6598	0.3483	0.2554	0.6993

Items marked with an astersik (*) are significantly different.

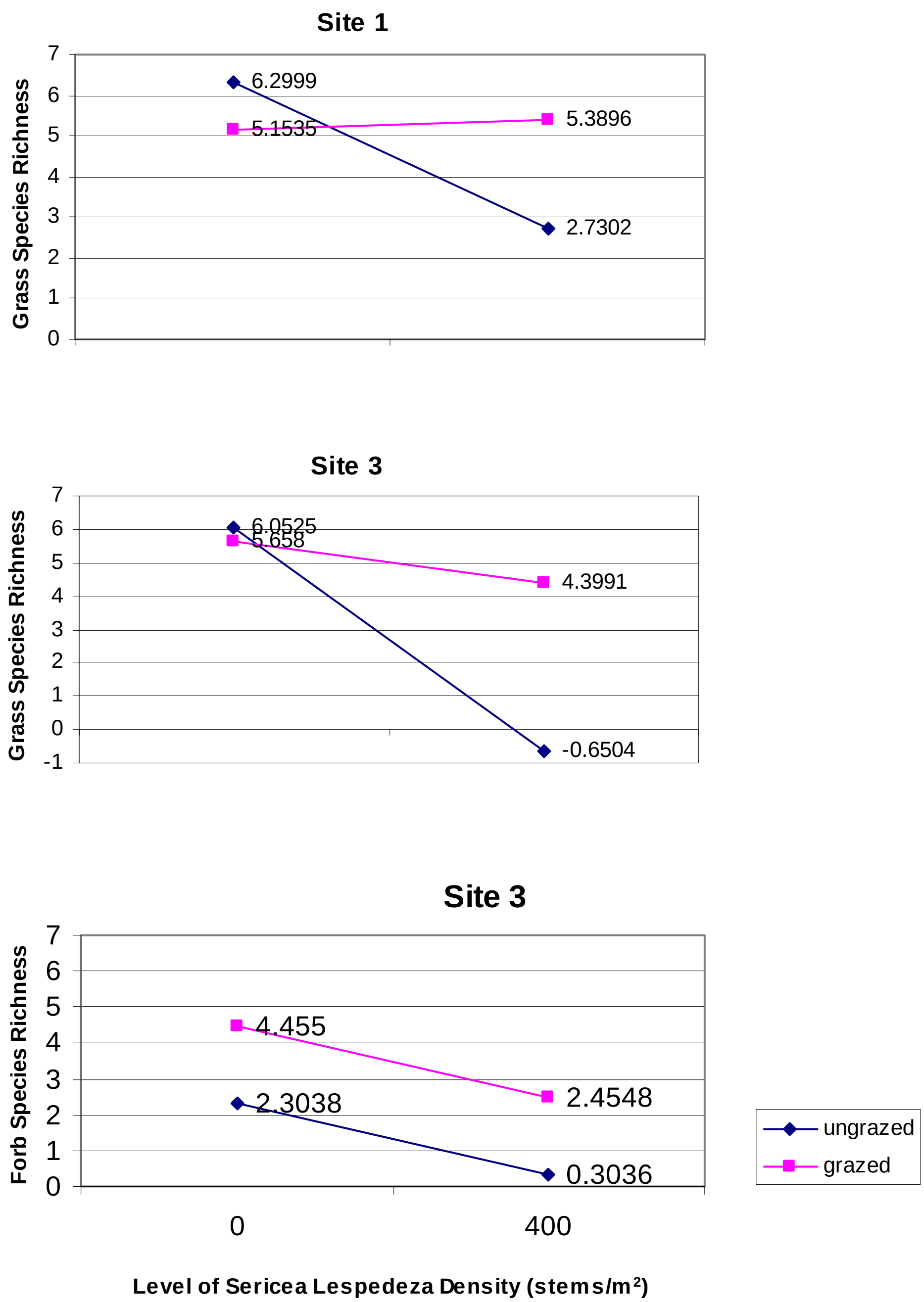


Figure 0.4 Relationship between species richness and sericea lespedeza density with and without grazing.

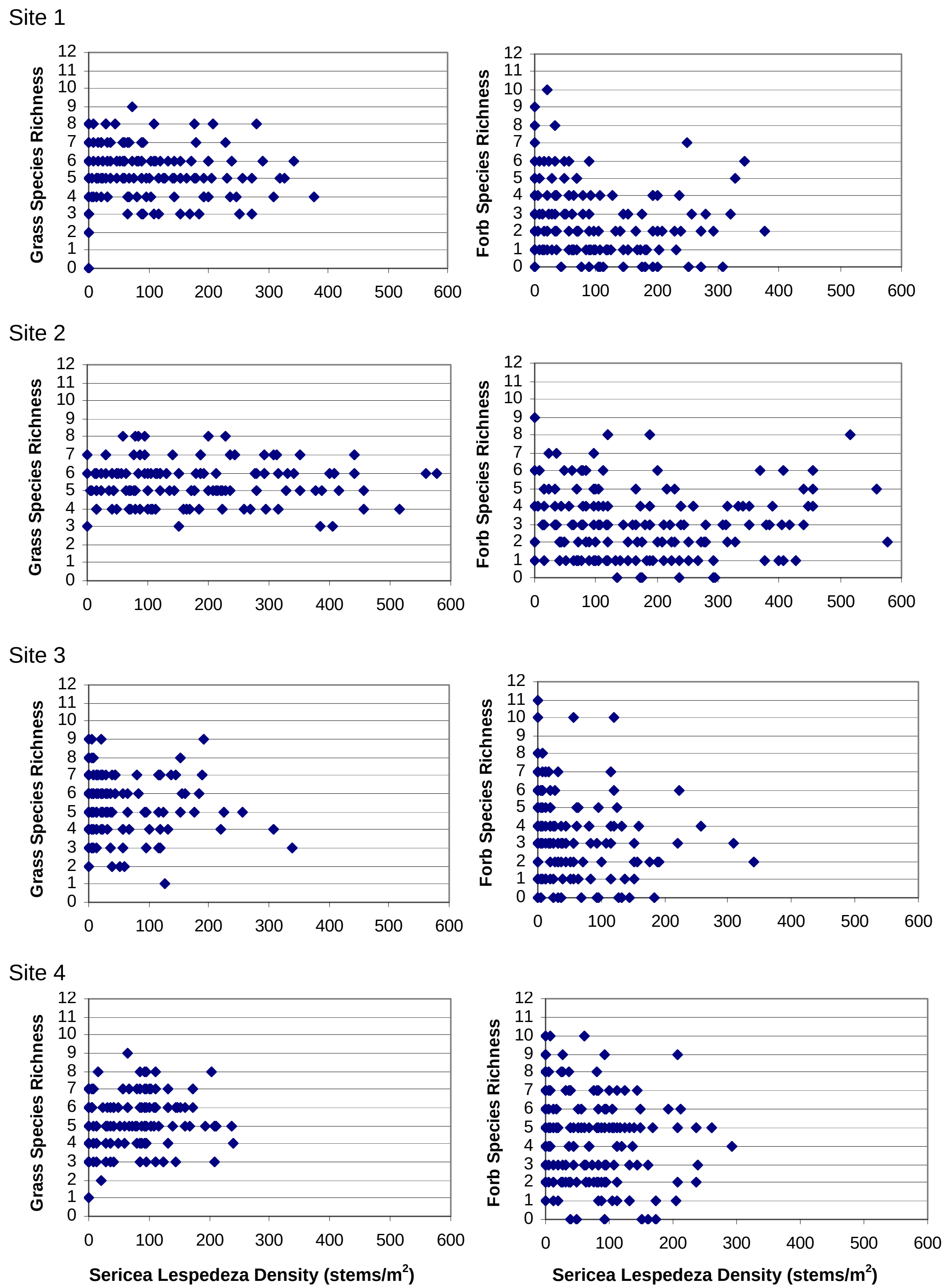


Figure 0.5 Sericea lespedeza density vs. species richness.

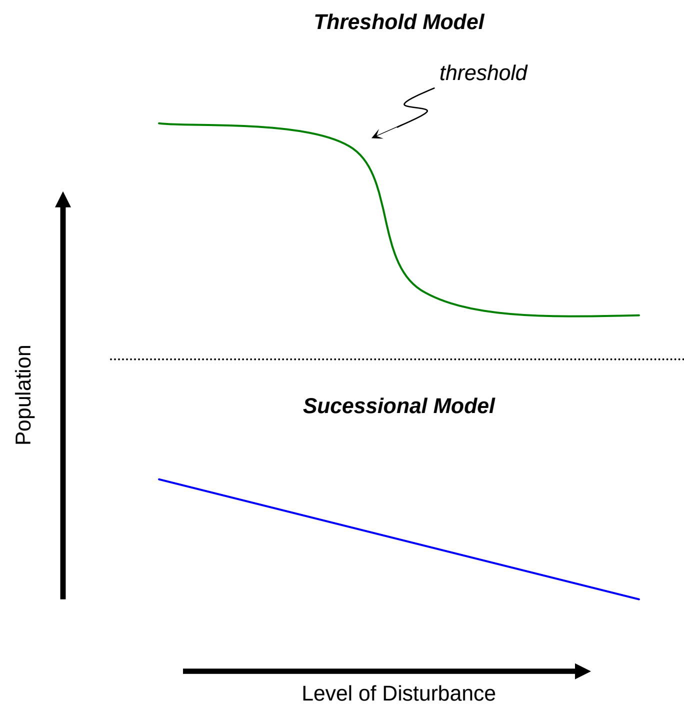


Figure 0.6 Two generalized models of population response to adverse disturbance.

Adapted from: Turner, M.G., R.H. Gardner and R.V. O'Neill. 2001. Landscape ecology in theory and practice. Springer-Verlag, New York.

The Potential for Cattle and Northern Bobwhite Quail to Spread Sericea Lespedeza via Ingestion and Subsequent Deposition

Abstract

Sericea lespedeza [*Lespedeza cuneata* (Dumont) G. Don], a state-listed noxious weed of Kansas rangelands, has spread widely throughout the state. The dispersal modes of sericea lespedeza are unknown. Cattle and quail were investigated as dispersal agents for sericea lespedeza seed. Sericea lespedeza seed was fed to steers and quail in confinement. Feces were collected and sericea lespedeza seed separated out and germinated in Petri dishes. Cattle digestive processes did not affect sericea lespedeza germination. Quail digestive processes enhanced germination. Quail diet selection was investigated with a field study. Five of 49 crops collected contained seed classified as sericea lespedeza. None of these seeds germinated in the greenhouse. Both cattle and quail could potentially disperse sericea lespedeza seed, but voluntary consumption appears to be low with both species. Sericea lespedeza seed has a high tannin content which may discourage consumption by cattle. Further study is needed to ascertain actual consumption of sericea lespedeza seed by cattle under field conditions.

Introduction

Sericea lespedeza [*Lespedeza cuneata* (Dumont) G. Don] is an invasive rangeland weed. Intentionally introduced into the United States from Asia for livestock forage, wildlife cover, and soil stabilization (Pieters 1939, Pieters 1938, Bailey 1951, Hoveland and Donnelly 1985, Isley 1955), it has naturalized and spread into native rangelands across Kansas, Missouri, and Oklahoma. Sericea lespedeza replaces desirable forages in rangelands, lowering carrying capacity (Eddy et al. 2003, Young 2000).

The tannin content of sericea lespedeza may discourage its consumption by livestock (Wilkins et al. 1953). High tannin and phenol concentrations in forages can limit forage intake (Meissner and Paulsmeier 1995). Sericea lespedeza has a tannic acid equivalent (TAE) of 18-28 g TAE kg^{-1} of dry matter, as compared with a TAE of 0.0 for alfalfa and milkvetch (Broderick and Albrecht 1997).

Cattle (*Bos taurus* L.) and northern bobwhite (*Colinus virginianus* L.) were assessed for their potential as dispersal agents of sericea lespedeza in Kansas tallgrass rangelands. Dispersal quality (seed treatment) and dispersal quantity (dietary component) were investigated.

Investigation objectives were: 1) to ascertain if the seed of sericea lespedeza could pass through the bovine or quail digestive tract and remain viable; 2) to compare *in situ* digestion processes and steer digestion processes in their effect on sericea lespedeza germination; and 3) to ascertain if bovine or quail digestive processes enhanced or decreased the rate of germination of sericea lespedeza seed. The objectives of the second investigation were 1) to ascertain if quail were actually consuming sericea lespedeza seed in a native rangeland environment and 2) if excreted seed would germinate on ordinary soil.

Materials and Methods

Experiment 1

Four steers with a rumen fistula and 16 quail were fed a diet of sericea lespedeza seed. The animals were housed at the dairy and poultry barns, respectively, at Kansas State University, Manhattan, Kansas. Sericea lespedeza seed was provided by a commercial seed source located in the southern tallgrass region of Oklahoma (Holman Seed Farms, Inc., Collinsville, Oklahoma). The seed was harvested in the fall of 2001 from a field near Miami, Oklahoma. The seed was cleaned but not otherwise treated. The quail used in this investigation were provided by a local game bird breeder and had been raised in outside cages with minimal handling. The steers were randomly selected from a herd maintained by the Department of Animal Science & Industry at Kansas State University.

Steer and quail experiments were set up in a completely randomized design. All animals were acclimated to their new surroundings for a period of 3 days prior to the start of the experiment. Water was continuously available to all animals throughout the experimental period. For the 24 hours immediately prior to the initiation of the experiment, all animals were fasted. Fecal collections were made every 12 hours after the start of the experiment from fecal collection bags fitted to each steer.

Steers were confined to tie-stalls in the dairy barn. On day 1 of the experiment, the steers were fed a mixture of 0.5 kg sericea lespedeza seed mixed with 0.23 kg corn and 0.23 kg molasses followed by prairie hay. Steers were fed prairie hay equivalent to

2% of their body weight (about 4.5 kg) each of the 4 mornings of the steer experiment.

A nylon 50 micron rumen *in situ* bag (Ankom Technology, Fairport, New York) was filled with 150 g sericea lespedeza seed plus a steel washer (81.7 g average weight) added for weight. The rumen bag was heat sealed and placed in the rumen of each steer. These bags were removed after 2 days. A second set of rumen bags was placed in each rumen for the final 48 hours of the study because two of the first set of rumen bags and one of the second set of bags were ruptured when they were retrieved.

A sub-sample of sericea lespedeza seed from each rumen bag was placed in a F-57 filter bag (Ankom Technology, Fairport, New York) and sealed. These subsamples were incubated in an acid pepsin solution in a Daisy® incubator (ANKOM Ankom Technology, Fairport, New York) for an additional 48 hours to simulate post-ruminal digestion. After completing the simulated post-rumenal digestion, the seed was washed with tap water and placed on paper towels to dry.

The collected fecal material was mixed with water to form a slurry. Each sample was washed over a 24/64 sieve (0.2 mm diameter holes) to remove fines and liquids. The peat moss-like material remaining on the sieve was spread on cotton sheeting laid on aluminum window screening attached to 61 cm x 122 cm wood frames and dried for 24 hours at 38° C in a drying oven. Air drying was not an option because germination would potentially be affected by the time necessary to dry the large quantity of moist fecal material surrounding the seeds.

To remove the sericea lespedeza seed from the surrounding matrix, the dried material was fed through an Almaco belt thresher (Almaco, Nevada, Iowa). The recovered seed was cleaned with a South Dakota seed blower (similar to Seedburo Equipment Co., Chicago, IL) and further sievings to remove as much fecal material and other non-sericea lespedeza seed as possible. There were few seeds from other species present in the fecal material. Sericea lespedeza seed was abundant and easily distinguishable from the few grass and forb seeds the steers had consumed in the prairie hay.

Quail were weighed immediately prior to the experimental period. Quail were individually confined in wire-bottom cages and fed a commercial pelleted bird feed during the acclimation period. Lighting was set for 11 hours on and 13 hours off. Temperature was set at 16°C. Ten grams of grit were provided for each bird. The quail were presented with 20 g sericea lespedeza seed in a feeder attached to the front of their cages on day 1. The quail were not provided with any other food during the entire 48-hour quail trial period. At the end of the trial each bird was re-weighed.

Bird fecal material was collected from trays under each cage every 12 hours using a rubber spatula and placed in paper cups. Any seed not contained within a fecal patty was considered spillage and discarded. The collected fecal material was washed over a 24/64 sieve, the feathers were removed, and the remaining seed was placed on a folded paper towel laid on screening to dry at 24°C.

Sterile petri dishes were fitted with Whatman 42 ashless filter paper disks (Florham Park, New Jersey) and 25 intact seeds added from the quail and 50 intact seeds added from the steers. Seeds from each animal and each collection period were kept separate. Nearly half of the bird samples did not contain 25 seeds; whatever seed was available was used. In one instance, a bird did not excrete a total of 25 seeds during the entire 48 hour trial period. Percent germination was calculated for each bird. Six of the 16 birds had a collection period (first collection or third collection) with no seed excreted; thus, percent germination was calculated from the content of three petri dishes for these birds. The effect of varying seed number on the germination rate is unknown. If a single seed represents more than 2% of the total germination, it may lead to inaccurate germination percentages.

Ten dishes each of control and manually scarified seed were used for comparison. Seed was scarified by rubbing it between corrugated rubber surfaces to dehull it and then scratching it with emery cloth.

Germination trials of steer- and quail-treated seed were conducted separately because of the space limitations of the germination chamber. Each germination trial consisted of animal-treated seed, manually scarified seed and untreated seed. Two ml of tap water were added to each petri dish prior to placement in a germination chamber with a glass door that admitted some ambient light. Dishes were randomly placed on 6 shelves and were checked daily for dryness. Additional water was added as necessary. Each time water was added, dishes were re-randomized on the shelves to minimize chamber effect on germination.

Petri dishes were removed from the germination chamber after 7 days. Each dish was examined for germinated seed; any seed with a visible radicle was considered germinated. All germinated seed were counted and removed from the dish. The dishes were returned to the germination chamber for an additional 7 days, after which newly germinated seeds were counted and then the dish contents discarded.

Data were analyzed as a complete random design. Germination percentages for each animal were calculated; the data were arcsine transformed and analyzed using SAS ANOVA for mean separation.

Experiment 2

Bobwhite quail crops were collected during the first week of the open hunting season in November 2002. The study site was Fort Riley military base, located just west of Manhattan, KS. The base is home to a large variety of native fauna because of the large unbroken expanse of varying habitat types, including rangeland, riparian areas, cropland, wildlife food plots, and brush and timber stands. Sericea lespedeza grows on 1/3 of the base's 40,000 ha as a result of a deliberate planting program in the 1950s.

Hunter stations located around the perimeter of the base are maintained by the U.S. Army to collect harvest information from hunters using the base. At each hunter station, signs were posted asking hunters to donate bobwhite crops. Sealable plastic bags, markers, and an ice-filled bucket were provided at each station to facilitate collection. Hunters were asked to provide sex and age (adult/juvenile) data by writing on the bag. The crops were picked up daily at sunset and refrigerated until the end of the collection period.

Each crop was opened and the contents removed and washed over a 24/64 sieve. Rocks, feathers, and other easily removable debris were picked out of the sample. The remaining material was spread on paper towels in the greenhouse to dry. The contents of each crop were separated by species. In addition to seeds, several crops contained insects and snails. Each quail diet component was counted and weighed.

Because several of the lespedezas, especially sericea lespedeza and slender lespedeza [*Lespedeza virginica* (L.) Britt.], have nearly indistinguishable seed, all seed resembling sericea lespedeza seed was assumed to be sericea lespedeza. All seeds classified as sericea lespedeza seed were planted in 1 cm deep furrows in fumigated soil and germinated for 2 months in the greenhouse. The temperature was maintained between 22^0 C daytime and 13^0 C nighttime with a controller (Acme Engineering and Manufacturing, Muskogee, OK). Two grow lights (Energy Technics Horticultural Lighting, York, PA) were used to extend the day length to 14 hours. The planting was watered as necessary to keep the soil surface damp. The soil surface was mulched with sericea lespedeza litter (dried leaves and fine stems), which was found to enhance germination in prior, unrelated studies (unpublished data). Soil and mulch were used as a germination media instead of Petri dishes and filter paper to more closely mimic field conditions.

Results

Experiment 1

The germination results for each treatment are presented in Table 4.1. The F value for all pairwise comparisons was F=33.28 for the quail and F=99.5 for the steers. Steer-treated seed and *in situ*-treated seed did not differ in germination rate, and steer-treated seed did not differ in germination rate from the control. Scarified seed had significantly higher germination than all other treatments. Quail-treated seed had a significantly higher germination rate (15% more) than the control seed. Scarified seed had significantly higher germination than all other treatments. No comparisons can be made between quail and steer results because each was a separate investigation.

Sericea lespedeza seed was able to withstand the digestive processes of steers and quail and remain viable. Germination rate was enhanced by quail digestive processes but reduced by steer digestive processes. Scarified seed had significantly higher germination rate than either animal-treated seed.

Experiment 2

A total of 49 crops were collected. Five crops contained seed assumed to be sericea lespedeza (Table 4.2). Of the 77 seeds assumed to be sericea lespedeza, only one germinated. It was not sericea lespedeza. The identity of ungerminated seed was undetermined. It appeared that either quail digestive processes partially or completely digested the seed (partially digested seeds of various species were common) rendering it unviable, that quail simply weren't eating sericea lespedeza seed, or that some unknown factor interfered with germination.

Discussion

Experiment 1

Consumption rate of sericea lespedeza seed by both steers and quail was low. Of the 4 steers, one readily consumed the corn/molasses/sericea lespedeza seed mixture; an additional steer consumed the mixture more slowly, but without coaxing. The remaining steers were hand-fed the mixture rubbed onto hay and even then were reluctant to eat the seed.

Of the 8 bags placed in the steer rumens, 3 ruptured before being retrieved. This seed would have been part of the seed recovered in the manure from these animals, which might have affected germination rates since this seed would not have been subjected to mastication.

The quail scattered rather than ate sericea lespedeza seed. None of the birds consumed all of the seed during the trial period, which resulted in a 20% weight loss during the 4 days of the trial period. The low consumption of sericea lespedeza consumption could have been because of its novelty as a food item, social disruption in moving pen-reared birds into individual cages, or low palatability of sericea lespedeza seed.

The ability to choose and select a diet is a general trait of animals foraging native range. Given the reluctance exhibited in this investigation, it appears unlikely that either species (cattle or bobwhite quail) would preferentially choose a diet containing sericea lespedeza seed. However, additional factors, such as prior experience, may have caused a refusal to eat sericea lespedeza seed (Provenza 2003). Although molasses and corn were not novel foods for the steers used in this trial, it is possible that these ingredients could have been used in previous trials to entice consumption of substances that afterwards caused intestinal distress and the steer associated distress with these foods.

The condensed tannin level of the sericea lespedeza seed used in this trial was 12.5% as estimated by commercial lab analysis. Condensed tannin levels above 5-10% reduce voluntary feed intake and digestibility (Min et al. 2001).

The soluble tannin content of sericea lespedeza forage decreases during the growing season from 16.9% in July to around 8.8% in October, while the whole-plant tannin content increases (Cope et al. 1971). The increase in whole plant tannin levels is due to the high tannin content of the ripening seed (Stitt and Clarke 1941). Late-season palatability is reduced by stemmy growth (Helm and Etheridge 1933) and declining protein levels (Donnelly et al. 1971). Bailey (1951) observed that cattle begin grazing sericea lespedeza early in the fall and “graze them [sericea lespedeza] to the ground”, and the author attributed this behavior to declining tannin levels in the forage.

Given that cattle are unlikely to deliberately and specifically eat sericea lespedeza seed due to its high tannin content, seed consumption by cattle would likely be associated with grazing the surrounding foliage. Fecal collection analysis from range-fed animals is needed to confirm sericea seed consumption. A low consumption of whole seeds decreases the chance of cattle acting as a dispersal agent (Gardener et al. 1993).

Seed passage rate also appears to be important. A seed that is retained longer in the digestive tract gives the animal more time to move away from the point of consumption (Kerner et al. 1895 summarized in Collinge 1913). The majority of seed consumed by cattle is passed within 2 days with lesser quantities excreted for an additional three days (Kempski 1906 summarized in Brunn and Fritzboger 2002, Gardener et al. 1993). Barnea et al. (1991) reported seed retention times to be 73 minutes or less for the twleve plant species and two bird species analyzed in his study. Small spherical seeds pass more rapidly through the intestinal tract and experience more scarification than large seeds, resulting in higher viability (Brunn and Fritzboger 2002, Traveset et al. 2001). Passage rate is increased in cattle by increasing forage consumption (Blackshaw and Rose 1991) but decreased by poor forage quality compared to good forage quality (Vallentine 2001). The late-season tallgrass forage that is available during sericea lespedeza seed set tends to be high in indigestible components (Heady and Child 1994) and thus has longer rumen retention times (Vallentine 2001). Fairbrother and Brink (1989) reported that the digestive rate of sericea lespedeza was lower than that of grasses.

A trade-off exists between passage time and dispersal range (speed and direction of an animal's movements) (Blackshaw and Rose 1991). A longer passage rate would potentially increase the area where the seed could be spread as the animal wanders to fresh herbage. On the other hand, a long passage rate seems to correlate strongly with decreased survival of the seed (Gardener et al.1993). Prolific seed production and massive consumption could partially offset rapid passage through the digestive tract. At least some of the seed might move slowly through the digestive tract and be widely dispersed: a small percent of a very large number can still be substantial. Brunn and Fritzboger (2002) state that rare, long-distance events of dispersal are very important for species migration. Given that cattle movements between fenced areas is fairly regulated, new plant populations in distant locations attributable to animal dispersal indicate either rapid, deliberate relocation of domestic livestock or unregulated movement of wildlife.

Quail-treated seed showed an increased germination rate, which suggests that quail have potential for spreading sericea lespedeza seed. The remaining question, given the low consumption rate in this trial, is whether sericea lespedeza seed is part of a quail diet when other choices are available. A second investigation looked at quail diet selection.

Experiment 2

Diet Choice

Northern bobwhite rarely use sericea lespedeza seed if other food sources are available. Numerous studies have shown that sericea lespedeza is either an insignificant

(<0.5%) or non-existent component of quail diets (Robel 1963, Jennings 1941, Eubanks and Dimmick 1974, Davison 1942a, Davison 1945, Jennings 1941, North Carolina Wildlife Resources Comm. 1951, Watson 1944, Hunter 1954, Davison 1946, Robinette et al. 1968, Allen and Pearson 1945, Brunswig and Johnson 1972).

A notable exception was Wilson and Vaughn's (1942) report which concluded that "this lespedeza [sericea lespedeza]...has been an important factor in the maintenance of the present [bobwhite quail] population levels." Wilson and Vaughn's diet study revealed sericea lespedeza seed in 17 of 23 crops collected. The idea that sericea lespedeza is an important bobwhite quail food was apparently confirmed by hunters (Durell 1952). Graham (1941), summarizing previous research and anecdotal evidence, also concluded that sericea lespedeza furnishes food for both northern bobwhite and cottontail.

Publications advocating the use of *Lespedeza* spp. for quail cover and food frequently fail to delineate between species of lespedeza or between quail use of lespedeza for food or cover (Stoddard 1933, Korschgen 1948, Martin 1935, Hankla and Verts 1958, MacNamara 1958, Eubanks and Dimmick 1974, Davison 1941, Moore 1944, Davison 1942b), making interpretation of results problematic with respect to sericea lespedeza as a diet component. Classifying sericea lespedeza seed retrieved from crops to the species level can be difficult (Larimer 1960) and may account for the tendency to pool species into groups.

Diet Quality

Robel et al. (1974) reported that quail, from September to December, had no selection for seeds with high energy content, high efficiency of utilization or high metabolizable energy, and concluded that food consumption by quail was based primarily on availability, not nutritional quality. The availability of sericea lespedeza seed for foraging bobwhite quail was non-controversial in this study. The seed existed in large quantities over a wide spatial scale and it was still attached to the stem. Such a position is ideal for quail use (Robel and Slade 1965). A wide variety of seed sources were available during the study period (early November), and ample opportunity existed for quail to selectively choose their diet. Season is important because it influences what seed is available (Dore and Raymond 1942).

Sericea lespedeza seed has little nutritional value for bobwhite quail (Newlon et al. 1964). In their experiment, quail fed a diet composed exclusively of sericea lespedeza seed consumed very little seed and lost an average of 45.9% of their body weight before dying, with fat strip weight and liver lipid levels also dropping precipitously. Average mean survival period was 14.7 days, the shortest of any of the food sources tested. Although protein content was about 28%, one of the highest of the diets tested, diet quality of sericea lespedeza seed was too low for quail. These researchers concluded that sericea lespedeza seed was an unsatisfactory food for bobwhites.

Tannin content does not seem to provoke the same avoidance behavior response in quail that it does in cattle, with high and low tannin varieties of sericea lespedeza showing similar (low) consumption rates (Robinette et al. 1968).

Rapid debilitation and mortality of quail on a sericea lespedeza diet would seem to decrease the opportunity of bobwhite quail to spread sericea lespedeza across the landscape. Given that weight losses over 35-55% in bobwhite quail are fatal (Errington 1937 summarized in Newlon et al. 1964), northern bobwhite that chose to consume sericea lespedeza seed as the primary part of their diet would not live long.

Dispersal Opportunity

Robinson (1957) estimated it would take 12 acres (4.9ha) of south-central Kansas rangeland for bobwhite survival during their critical period (winter). Taylor (1997) estimated bobwhite quail home range at between 65 ha and 103 ha in eastern Kansas, depending on site characteristics. This is a spatially limited area in which other forms of dispersal such as small rodent transport and seed rain might be as much or more important than quail dispersal.

Gastrointestinal passage rates in bobwhite quail are rapid. Stultz et al. (2001) reported peak recovery rate at 3 to 4 hours, with negligible recovery after 9 hours. Rapid passage rates result in a limited travel distance before crop contents are eliminated.

Animal species that are more tolerant of high tannin content, such as goats, or animals supplemented with substances such as polyethylene glycol that alter tannin tolerance, may be much more likely to eat sericea lespedeza seed and thus more likely to function as seed dispersal agents (Landou et al. 2002).

Conclusions

Sericea lespedeza seed consumed by cattle and quail can remain viable. Sericea lespedeza germination was not significantly different between *in situ* digestion and steer digestion. *In situ* digestion appeared to be an acceptable substitute for *in vivo* digestion in its effect on seed germination. Potential for these animals to disperse sericea lespedeza seed is dependent upon diet selection and animal movement across the landscape. Whereas steers in our study did not display a preference for sericea lespedeza seed, variability within the steer population might include animals with a taste for sericea lespedeza, especially those raised on sericea lespedeza hay in other parts of the country.

Given a distinct preference for other foods over sericea lespedeza, decreased vigor of birds consuming sericea lespedeza seed, limited home ranges, rapid excretion, and overall short life spans (52.1% annual mortality) (Williams 2004), there appears to be limited potential for bobwhite quail to function as a dispersal agent for sericea lespedeza.

Table 0.1 Percent germination of seed passed through the digestive tract of steers and quail.

Treatment	Steer
in situ (rumen bag)	3.8[a]
steer	5.5[ab]
control	10.5[b]
scarified	63.5[c]

	Quail
control	19.6[x]
quail	34.6[y]
scarified	53.4[z]

Values followed by different letters are significant different at the p<0.05 level.

Table 0.2 Number of seeds assumed to be sericea lespedeza.

crop number	seed count
1	1
2	5
3	1
4	29
5	41

Use of the Height-Weight Method for Assessing Sericea Lespedeza Utilization

Abstract

Sericea lespedeza [*Lespedeza cuneata* (Dumont) G. Don] is a rangeland weed in Kansas prairies. Grazing can reduce seed set and result in lowered reproduction. A quick method of determining grazing use would be helpful for managers. The height-weight method has been shown to give a general estimate of forage utilization without extensive sampling and analysis once a utilization chart is constructed. Plants with upright, regular growth forms such as many grasses and sericea lespedeza are most appropriate for this estimation method. Sericea lespedeza plants were measured and collected for two growing seasons on a Greenwood County, KS site. Both cattle and goats grazed portions of the site at various times during the growing season. Ungrazed sericea lespedeza plants were collected and the percent weight each inch contributed to total plant weight was calculated. An height-weight table estimating percent utilization for various grazed and ungrazed heights of sericea lespedeza was constructed. Coefficients of determination were greater than 0.85 for all plant heights, indicating that the height-weight method was appropriate for estimating sericea lespedeza utilization. Using additional regression analysis, a chart for estimating forage utilization from percent of plants grazed was constructed. The table and chart are useful tools for managers needing a rapid, easy method of estimating forage utilization in the field.

Introduction

Sericea lespedeza is an invasive weed of Kansas tallgrass prairies. Clipping sericea lespedeza, either by mowing or grazing, reduces seed production (Ward et al. 1985, Donnelly and Patterson 1969, Hoveland and Donnelly 1985). Reduced seed production is one element of control (Kansas Dept. of Agriculture 2004).

The percent of the plant that has been removed by animals is defined as utilization (Cook and Stubbendieck 1986). The need for a quick and accurate forage utilization method has been a long-time concern of those who use and manage rangelands (Campbell 1937). Quantifying grazing utilization is problematic because the grazed portion of the plant is missing and unavailable for measurement (Heitschmidt 1998).

Detailed and time-consuming assessment methods such as esophageal fistula sampling, which allows objective measurement of consumption, are not practical for a rancher to use in the field (Reid and Pickford 1941). Indirect assessment methods have been developed to measure forage utilization (Cook 1962). Lommasson and Jensen (1943) proposed a grass assessment technique that would convert inches of stubble remaining into percent of weight removed. Plants were clipped into 2" (5.1cm) segments and each segment was weighed. The contribution of each successive inch to the total weight was calculated. The calculations were incorporated into a table and a graphical representation showing the relationship between grazed height and biomass removed (Lomasson and Jenson 1943a,b) for in-the-field assessment of utilization.

The height-weight method has also been applied to sedges (McDougald and Platt 1976, Ried and Pickford 1941) and forbs (Harshman and Forsman 1978). The height-weight method of assessment is based on the assumption of a consistent growth form of the species of interest among years, seasons and sites, and that plant weight is distributed evenly through the plant height (Heady 1949). When the growth form is not constant, using the height-weight method can result in large errors in utilization estimates (Clark 1945).

Sericea lespedeza has an erect, columnar growth form until late in the growing season when it may begin to branch. Grazing apical meristems at stem tips can also cause the plant to branch. Branching alters the growth form of the plant, which is otherwise consistent. The objectives of this study were 1) to ascertain if the height-weight method is suitable for estimating grazing utilization of sericea lespedeza and 2) to ascertain the relationship between percent plants grazed and utilization.

Materials and Methods

Ungrazed sericea lespedeza plants were sampled at 2-week intervals from June through October during 2001and 2002 on a tallgrass prairie site in Greenwood County, KS. The site was grazed by cattle and goats (*Capra hircus* L.) during all or part of the growing season. The site was grazed by cattle and goats during all or part of the growing season. The site was divided into five, 27 ha paddocks. Samples were collected at 5-step intervals along temporary transects in the paddocks where the animals were currently grazing. One hundred plants were measured with a yardstick and designated as grazed and ungrazed in each sampling period and location. Twenty ungrazed plants located along the transects were clipped with hand shears at ground level and placed in paper bags for transport back to the lab. Under closer inspection in the lab, some plants that had been classified as ungrazed showed evidence of grazing. These plants were discarded, and resulted in a total of 429 sericea lespedeza plants used in the regression analysis. Ungrazed plants were air-dried and clipped into 1-inch (2.5cm) segments. Plants dried in a forage drier were too brittle to handle. Fractions of an inch above the penultimate inch were counted as an additional inch. Each segment of each plant was weighed sequentially, beginning with the bottom inch segment (Fig. 5.1).

McArthur's (1951) methodology for calculating height-weight utilization was used (Appendix G). For each plant, all individual segment weights were combined to determine total plant weight. Then, the amount each segment contributed to the total plant weight and to the percent of total plant weight was calculated. The cumulative percent weight of each inch was regressed against plant height using a linear regression model (Excel 2003, Microsoft Corp., Redmond, Wash.) for all samples of the same clipped height, e.g., 11-inch (28cm) plants. The equation for each line was used to calculate the grazed plant height (stubble height) that would remain after a given percentage of the plant (y) was removed.

To calculate the relationship between percent plants grazed and utilization, grazed and ungrazed plant heights were each averaged for each sampling date. The percent of both grazed and ungrazed plants was determined for each sampling date. The average ungrazed plant height for each date was used to choose the appropriate regression equation for that sample; the predicted biomass value was subtracted from 1 to give percent of plant utilized. Percent utilization was multiplied by the percent of plants grazed for each sample date and regressed against the percent of plants grazed.

Results and Conclusions

The height-weight technique is an appropriate choice for estimating sericea lespedeza utilization. Much of the variation in cumulative plant weight was accounted for by the inch of plant height, with r^2 values ranging from 0.86 to 0.99. This indicates that sericea lespedeza has a growth form amenable to height-weight analysis.

The relationship between grazed plant height and forage utilization appears to be nearly linear, with each successive inch of plant removed increasing forage utilization by nearly the same amount. This relationship was consistent for all plant heights, despite the tendency of large plants to branch near the base. Since branches generally formed in the bottom 2 to 3 inches (5 to 7.5cm), their weight would be included with the inch weight taken at that height. For a 16-inch plant, each incremental 10% of forage utilization was accompanied by a 1.44 inch or 1.45 inch (3.6 cm) reduction in plant height, except for the first 10% of forage dry matter grazed from the top of the plant, which accounted for 2.33 inches (5.9 cm) of plant height removed (Table 5.1). The apex of the sericea lespedeza plants had smaller stem diameters and had less fibrous structure than the caudex, resulting in lower dried weights per inch than samples taken lower on the plant.

To use the chart, the average grazed and ungrazed plant height are estimated by measuring the heights of numerous plants calculating the average for each type. At the left edge of the chart, the plant height closest to the average ungrazed height is chosen. Moving directly to the right into the chart, stop at the plant height closest to the average grazed height. Move towards the top of the chart to read the percent utilization. This is the estimated percent of the plant part that has been removed by grazing. For example, if the ungrazed height is about 16 inches and the grazed height is a little over 9 inches, about 40% of the plant (by weight) has been grazed (utilized).

Fig. 5.2 was constructed by additional simplification of the relationship between sericea lespedeza height and forage utilization. In this chart, only the number of grazed plants is considered, not the height. This reduces the amount of time and effort needed to collect samples, but also reduces the accuracy of the utilization estimate. A simple estimate of utilization allows rapid monitoring of large areas (Coulloudon et al. 1999) where lack of resources preclude more precise methodology.

A rough estimate of sericea lespedeza utilization (proportion of biomass removed by grazing) can be made using Fig. 5.2. A utilization estimate is based on percent of plants grazed regardless of height. For example, 40 sericea lespedeza plants have been grazed in a 100-sample plant survey in a given paddock or area. This estimates that 40% of sericea lespedeza plants have been grazed. On the x axis, starting at 40%, move directly towards the top of the chart until the trendline is encountered. Moving to the left, read the estimated percent of sericea lespedeza utilization on the y axis. In this example, sericea lespedeza utilization is about 8%. While less precise than the chart presented in Table 5.1, this graph is easier to use in the field.

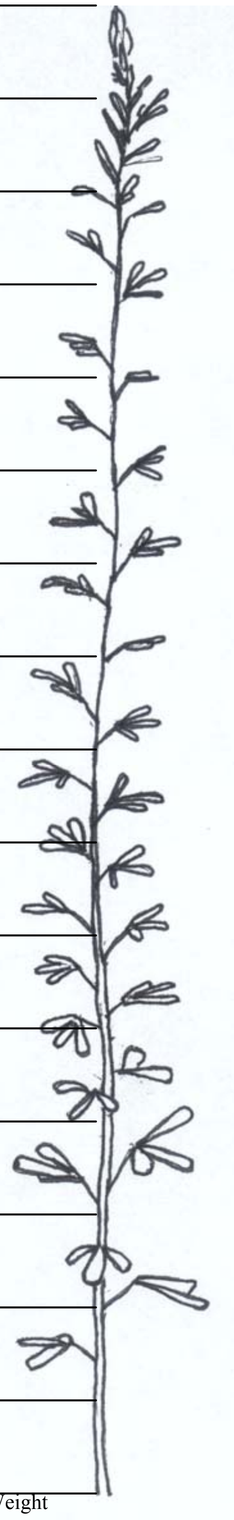
Since each branch will produce flowers, light cattle grazing early in the season may stimulate branching and result in increased seed production. Intense grazing by goats removes both foliage and flowers. The height-weight technique does not distinguish between intensity of grazing other than by plant height, and may fail to accurately reflect the amount of seed produced. A 16-inch plant with the top inch removed may have multiple branches each producing seeds, or it may be a stalk with no foliage or flowers remaining.

All methods of estimating animal consumption, except for fistula collections, make assumptions about how much of a particular forage was consumed during grazing. Height-weight forage utilization estimates are based on the height of ungrazed plants, which may not accurately reflect the height of plants which were grazed.

Near the end of the grazing season, it was observed that nearly all sericea lespedeza plants had sustained at least some grazing. Plants with tips missing were found within the exclosures; this grazing was attributed to grasshoppers. No estimate of non-livestock utilization was made. Despite extensive searching, it was difficult to find 20 ungrazed plants on each site; frequently the only ungrazed plants that could be found were within the exclosures.

The height-weight method provides a rapid, simple tool for determining sericea lespedeza utilization in the field. It should be remembered that assessments made during the growing season do not reflect total utilization, which can only be assessed at the end of the growing season (Laycock 1998), nor is utilization the only factor to be considered when developing a sericea lespedeza control strategy. It is important to use principles of good range management along with any assessment tool.

Inch Weights (g)	Cumulative Weights (g)	Cumulative Weight (%)
0.03	1.68	100
0.16	1.65	98
0.10	1.49	89
0.10	1.39	83
0.20	1.29	77
0.16	1.09	64
0.12	0.93	55
0.13	0.81	48
0.14	0.68	41
0.09	0.54	33
0.08	0.45	27
0.06	0.37	22
0.06	0.31	19
0.09	0.25	15
0.08	0.16	10
0.08	0.08	05



Total Plant Height
16” (40.64 cm)

Figure 0.1 Clipped plant segmentation.

Table 0.1 Percent utilization of sericea lespedeza as a function of stubble height (inches).

	Forage Utilization (%)								n=429
	10%	20%	30%	40%	50%	60%	70%	80%	90%
Ungrazed Plant Height (inches)	Grazed Plant Height (inches)								
5	*4.12*	*3.65*	*3.18*	*2.71*	*2.24*	*1.78*	*1.31*	*0.84*	*0.37*
6	*4.99*	*4.45*	*3.91*	*3.37*	*2.83*	*2.29*	*1.75*	*1.21*	*0.67*
7	*6.14*	*5.52*	*4.90*	*4.28*	*3.66*	*3.04*	*2.42*	*1.80*	*1.18*
8	*7.06*	*6.31*	*5.56*	*4.82*	*4.07*	*3.33*	*2.58*	*1.83*	*1.09*
9	*7.87*	*6.98*	*6.09*	*5.20*	*4.30*	*3.41*	*2.52*	*1.63*	*0.74*
10	*8.77*	*7.85*	*6.93*	*6.01*	*5.09*	*4.18*	*3.26*	*2.34*	*1.42*
11	*9.51*	*8.49*	*7.47*	*6.45*	*5.43*	*4.41*	*3.39*	*2.37*	*1.35*
12	*10.37*	*9.24*	*8.10*	*6.97*	*5.83*	*4.70*	*3.56*	*2.43*	*1.29*
13	*11.25*	*10.06*	*8.87*	*7.68*	*6.49*	*5.30*	*4.12*	*2.93*	*1.74*
14	*12.17*	*10.88*	*9.60*	*8.32*	*7.04*	*5.76*	*4.48*	*3.20*	*1.92*
15	*13.01*	*11.63*	*10.25*	*8.86*	*7.48*	*6.10*	*4.72*	*3.34*	*1.96*
16	*13.67*	*12.22*	*10.77*	*9.33*	*7.88*	*6.43*	*4.99*	*3.54*	*2.09*
17	*14.76*	*13.20*	*11.64*	*10.07*	*8.51*	*6.95*	*5.39*	*3.82*	*2.26*
18	*15.64*	*13.99*	*12.33*	*10.68*	*9.02*	*7.37*	*5.71*	*4.05*	*2.40*
19	*16.10*	*14.36*	*12.62*	*10.88*	*9.14*	*7.41*	*5.67*	*3.93*	*2.19*
20	*16.94*	*15.13*	*13.33*	*11.52*	*9.71*	*7.90*	*6.09*	*4.28*	*2.48*
21	*17.94*	*16.00*	*14.05*	*12.11*	*10.17*	*8.23*	*6.29*	*4.35*	*2.40*
22	*19.47*	*17.44*	*15.42*	*13.39*	*11.37*	*9.34*	*7.32*	*5.30*	*3.27*
23	*19.21*	*17.11*	*15.01*	*12.92*	*10.82*	*8.73*	*6.63*	*4.53*	*2.44*
24	*22.02*	*19.61*	*17.21*	*14.81*	*12.40*	*10.00*	*7.59*	*5.19*	*2.79*
25	*22.84*	*20.46*	*18.07*	*15.68*	*13.30*	*10.91*	*8.53*	*6.14*	*3.75*
26	*21.96*	*19.56*	*17.16*	*14.76*	*12.37*	*9.97*	*7.57*	*5.17*	*2.77*
27	*23.61*	*21.13*	*18.66*	*16.18*	*13.71*	*11.23*	*8.76*	*6.28*	*3.81*
28	*24.65*	*22.07*	*19.48*	*16.90*	*14.32*	*11.73*	*9.15*	*6.56*	*3.98*
29	*26.31*	*23.35*	*20.39*	*17.43*	*14.47*	*11.51*	*8.56*	*5.60*	*2.64*
30	*27.19*	*24.27*	*21.35*	*18.42*	*15.50*	*12.57*	*9.65*	*6.73*	*3.80*
31	*28.71*	*25.64*	*22.57*	*19.50*	*16.44*	*13.37*	*10.30*	*7.23*	*4.17*
32	*29.20*	*26.11*	*23.01*	*19.92*	*16.82*	*13.72*	*10.63*	*7.53*	*4.44*
33	*29.44*	*26.42*	*23.40*	*20.38*	*17.36*	*14.34*	*11.31*	*8.29*	*5.27*
34	*31.29*	*27.82*	*24.34*	*20.87*	*17.40*	*13.93*	*10.45*	*6.98*	*3.51*

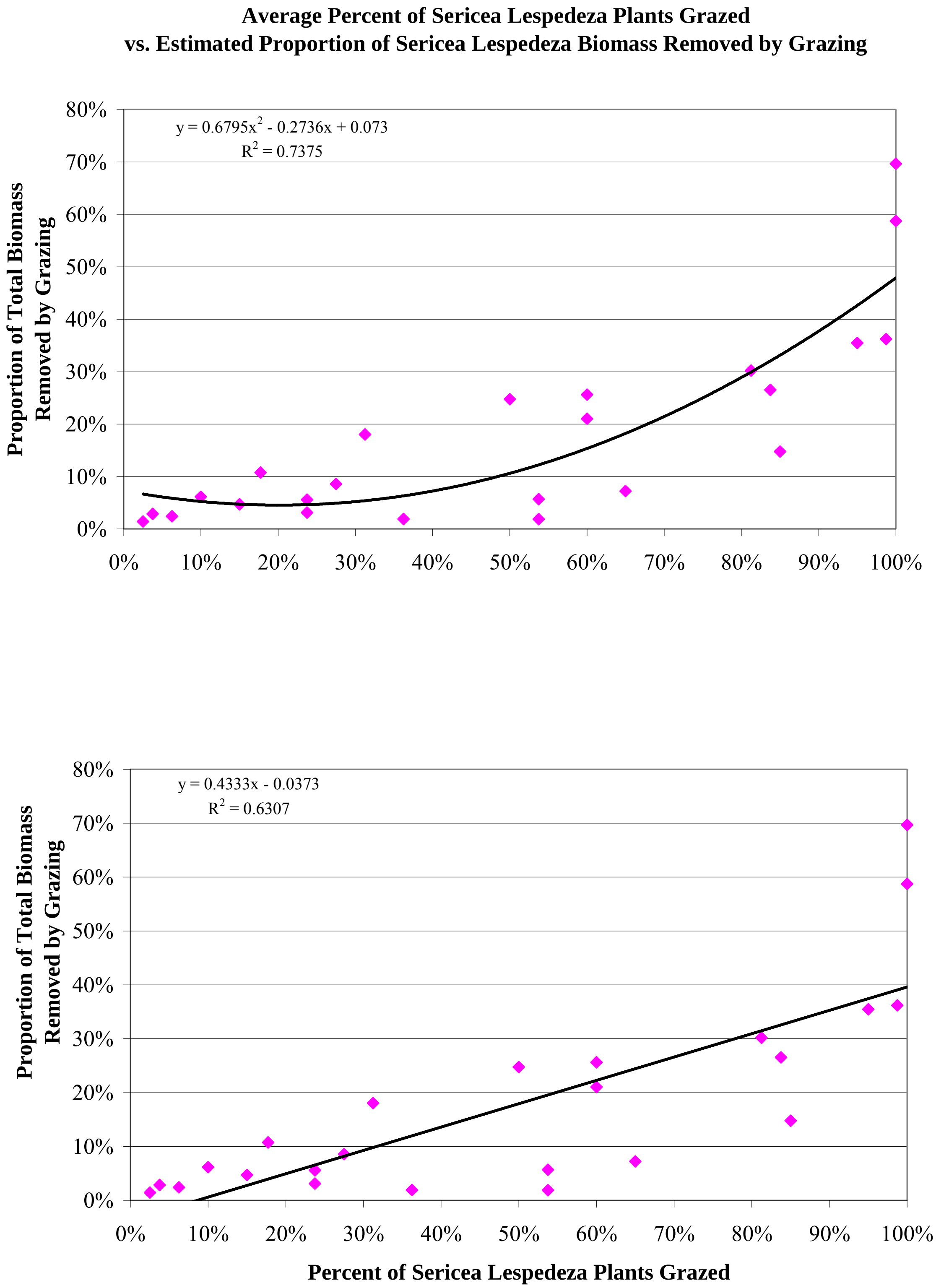


Figure 0.2 Grazing utilization charts for estimating sericea lespedeza biomass removed by percent of plants grazed.

Related Observations

The largest sericea lespedeza plants observed, and in the most dense stand, were in ungrazed “waste” areas. It is wrong to assume that cattle don’t ever readily graze sericea lespedeza. Twice during the past five years cattle have been observed to have heavily grazed sericea lespedeza when other forage which would be considered more palatable was available. During the final year of the species composition study reported in this dissertation, heifers turned into an ungrazed pasture in July at a double-stocked rate ate sericea lespedeza at the same rate as palatable grass and forb species. In Douglas County in September, a pasture that had been grazed by an unknown class of cattle were observed to have grazed sericea lespedeza to a height of less than four inches despite the presence of seemingly more palatable forage (personal observation). The reason for this grazing activity is unknown. Other ranchers have also reported cattle actively grazing sericea lespedeza at various times of the year (various personal communications). This suggests that either some cattle have a predilection for sericea lespedeza or that at some life stage sericea lespedeza is more palatable. Both options are worth considering. Shaik et al. (2006) reported that sericea lespedeza is useful for controlling gastrointestinal worms in goats (*Capra hircus* L.). If this were true for cattle too, it might indicate self-medication.

Exploiting differences in cattle genetics and training (by others in the herd) for sericea lespedeza control has been suggested (*Dale Kirkham, personal communication*).

There is enough genetic variation within the *Bos taurus* species that differences in diet preference exist. Animals that have been raised on sericea lespedeza, including the low-tannin variety, would find the taste familiar, which can positively influence grazing preference. Individual differences in diet selection and rumen microflora could account for differences in sericea lespedeza preference. Animals adapted to a sericea lespedeza diet could react to the tannin by either adjusting their diet or possessing digestive microflora that were better able to adapt to higher tannin levels.

Cattle raised on sericea lespedeza would most likely be found in the southeastern U.S. where sericea lespedeza is still promoted as a forage. Ranchers who purchase stocker animals could purposely select for exposure to sericea lespedeza forage. Identifying these animals would take effort. Cows with a history of sericea lespedeza grazing could be expected not only to continue to graze it, but by demonstration to spread the practice among others in the herd, especially to young animals. Cows that eat sericea lespedeza would need to be retained in the herd to capture this genetic trait.

Goat grazing was used for sericea lespedeza control on the Eureka site. Goats stocked at a rate sufficient to control sericea lespedeza (12 animals/ha) impacted the prairie by close grazing, denuding resting areas, establishing numerous trails, and uprooting plants. Supplemental feeding, which was continued throughout the summer, resulted in large denuded patches around the feeder. Goats were observed pulling up grasses by the roots, which occurs much more rarely with cattle. The bare areas resulting from goat grazing were colonized by annuals.

Goats were protected with guard animals, a llama (*Lama glama*) and a specially trained dog (*Canis lupus* familiaris). Both were initially effective in averting predation, but by the third year coyotes (*Canis latrans* Say) were hunting in packs. Several coyotes would distract the guard animals while the others attacked the goats (*Harold Garner, personal communication*). Coyote predation was great enough for this producer to abandon goat grazing as a sericea lespedeza control strategy.

Biological control methods based on grazing appear favorable to chemical control methods. Chemicals used to control sericea lespedeza kill many non-target forbs (*personal observation*). Where chemical has been applied for several years, few forbs remain. On a step-point transect through a chemically treated area of tallgrass prairie, the closest forb was over 6 m from the point.

Chemicals are also often used to control plants which ranchers erroneously perceive as sericea lespedeza (*Jeff Davidson, personal communication*). This misperception, in addition to marketing efforts by chemical companies to convince ranchers that all forbs are weeds, has resulted in unwarranted chemical treatment of many acres of rangeland.

Introducing plant species that are competitive with sericea lespedeza could be a viable method of control. Plant introductions would need to be done judiciously to prevent new weed problems. Introduced plant competition could control sericea lespedeza without the non-target species damage evident with chemical control.

Two common species, alfalfa (*Medicago sativa* L.) and smooth brome (*Bromus inermis* Leyss.) suggest themselves as good competitors with sericea lespedeza. Both are widespread throughout the Kansas tallgrass prairie region and would not be novel plant introductions. Alfalfa, as a similarly sized legume, would appear to offer the greatest competition to sericea lespedeza. Alfalfa seed could be used to saturate the seedbank in sericea lespedeza patches. Because alfalfa begins growth earlier in the spring than sericea lespedeza (*personal observation*), sericea lespedeza would experience shading as it emerged. With similar root systems, alfalfa and sericea lespedeza would appear to compete in water and nutrient extraction.

Fecal material from both cattle and goats was collected at bi-weekly intervals during the growing season all three years of the study. This material was frozen and has not been analyzed. Microhistological analysis would provide information about sericea lespedeza consumption throughout the grazing season.

Soil cores were collected each spring along transects. These were screened and seed identified as sericea lespedeza was counted. The validity of these counts is questionable and they were not included in the dissertation. Slender lespedeza [*Lespedeza virginica* (L.) Britt] is widespread on the site. In a side-by-side comparison of dehulled sericea lespedeza and slender lespedeza seed, it was impossible to distinguish between the seed.

Grazing exclosures installed as part of the experimental work were scheduled to be removed at the end of the study period. The landowners requested that the exclosures be left to help them monitor their rangeland. It was rewarding to see an increased awareness of the effects of management on rangeland.

Rangeland is an easily destroyed vegetative complex that is impossible to replace within a human lifetime. Effort spent to understand and improve management of this resource is effort well spent.

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Conclusion

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Appendices

Appendix A

Sky Conditions	Visibility	Weather Type	Dry Bulb Temp (F)	Dry Bulb Temp (C)	Wet Bulb Temp (F)	Wet Bulb Temp (C)	Dew Point Temp (F)	Dew Point Temp (C)	Rel Humd %	Wind Speed knt	Wind Dir Deg	Wind Char Gusts	Val. for Wind Char	Station Pressure	Press Tend	Level Pressure	Report Type	Precip Total
SCT018 BKN027	9SM	-	-	-	-	-	-	-		4	250	-	0		-		SP	-
FEW018 BKN036 OVC042	9SM	-	-	-	-	-	-	-		4	240	-	0		-		SP	-
BKN022 BKN035 OVC042	9SM	-	47	8.3	46	7.8	45	7.2	93	5	250	-	0	28.37	-	34	AA	-
BKN015 OVC022	5SM	-RA BR	50	10	49	9.4	48	8.9	93	8	290	-	0	28.37	-	33	AA	T
BKN013 BKN019 OVC024	7SM	-	-	-	-	-	-	-		17	300	G	20		-		SP	-
OVC011	10SM	-	49	9.4	47	8.3	45	7.2	86	20	300	G	25	28.4	3	44	AA	T
OVC013	10SM	-	47	8.3	45	7.2	43	6.1	86	18	300	G	23	28.43	-	54	AA	-
OVC015	10SM	-	-	-	-	-	-	-		14	310	G	21		-		SP	-
OVC015	8SM	-RA	46	7.8	44	6.5	41	5	83	18	290	G	24	28.44	-	62	AA	T
BKN021 OVC043	10SM	-	45	7.2	42	5.7	39	3.9	80	18	300	G	25	28.46	1	67	AA	T
OVC027	10SM	-	45	7.2	41	5.2	37	2.8	74	19	290	G	26	28.47	-	73	AA	-
FEW023	10SM	-	45	7.2	41	5	36	2.2	71	20	310	G	24	28.48	-	80	AA	-
BKN023	10SM	-	-	-	-	-	-	-		16	290	G	22		-		SP	-
BKN023	10SM	-	46	7.8	42	5.5	37	2.8	71	17	290	G	22	28.49	3	85	AA	-
OVC023	10SM	-	46	7.8	41	5.3	36	2.2	68	18	310	-	0	28.52	-	95	AA	-
OVC027	10SM	-	47	8.3	42	5.5	36	2.2	66	18	290	G	21	28.53	-	101	AA	-
OVC029	10SM	-	49	9.4	43	6.3	37	2.8	64	21	280	G	25	28.53	0	99	AA	-
OVC031	10SM	-	-	-	-	-	-	-		18	300	-	0		-		SP	-
OVC031	10SM	-	50	10	44	6.6	37	2.8	61	15	300	G	24	28.53	-	100	AA	-
OVC033	10SM	-	51	10.6	45	7.1	38	3.3	61	15	290	G	22	28.54	-	101	AA	-
OVC033	8SM	-	51	10.6	45	7.4	39	3.9	64	15	290	G	20	28.55	3	102	AA	-
BKN037	10SM	-	53	11.7	46	7.9	39	3.9	59	15	290	-	0	28.55	-	103	AA	-
BKN035	10SM	-	52	11.1	46	7.9	40	4.4	64	13	310	-	0	28.56	-	109	AA	-
OVC033	8SM	-	52	11.1	47	8.1	41	5	66	11	330	-	0	28.58	3	114	AA	-
FEW039 BKN050	10SM	-	50	10	46	7.9	42	5.6	74	6	320	-	0	28.59	-	117	AA	T
SCT022 OVC037	10SM	-	49	9.4	46	7.6	42	5.6	77	13	330	-	0	28.61	-	128	AA	-
OVC055	10SM	-	49	9.4	46	7.6	42	5.6	77	8	330	-	0	28.61	1	127	AA	-
BKN028	10SM	-	-	-	-	-	-	-		8	350	-	0		-		SP	-
OVC028	10SM	-	49	9.4	46	7.8	43	6.1	80	7	340	-	0	28.62	-	130	AA	-
OVC030	10SM	-	-	-	-	-	-	-		7	330	-	0		-		SP	-
SCT024 OVC032	10SM	-	49	9.4	46	7.8	43	6.1	80	5	310	-	0	28.64	-	135	AA	-
SCT030 OVC035	10SM	-	49	9.4	46	7.8	43	6.1	80	6	310	-	0	28.64	1	136	AA	-

Station Name: **WICHITA MID-CONTINENT AIRPORT Call Sign: ICT**

Day	Time	Station Type	Maint Indic	Sky Conditions	Visibility	Weather Type	Dry Bulb Temp (F)	Dry Bulb Temp (C)	Wet Bulb Temp (F)	Wet Bulb Temp (C)	Dew Point Temp (F)	Dew Point Temp (C)	Rel Humd %	Wind Speed knt	Wind Dir Deg	Wind Char Gusts	Val. for Wind Char	Station Pressure	Press Tend	Level Pressure	Report Type
12	56	AO2	-	OVC026	10SM	-	49	9.4	46	7.8	43	6.1	80	16	310	G	23	28.31	-	61	AA
12	131	AO2	-	FEW024 OVC038	10SM	-RA	-	-	-	-	-	-		15	310	-	0		-		SP
12	156	AO2	-	BKN026 BKN040	10SM	-	47	8.3	44	6.7	41	5	80	17	310	-	0	28.32	-	64	AA
12	235	AO2	-	SCT028 BKN044 OVC100	10SM	-	-	-	-	-	-	-		15	330	-	0		-		SP
12	256	AO2	-	FEW055 BKN095 OVC110	10SM	-	46	7.8	43	6.2	40	4.4	79	16	330	-	0	28.33	1	70	AA
12	356	AO2	-	BKN032	10SM	-	45	7.2	42	5.4	38	3.3	77	19	320	-	0	28.36	-	81	AA
12	456	AO2	-	SCT032	10SM	-	43	6.1	40	4.4	36	2.2	76	15	310	-	0	28.39	-	92	AA
12	556	AO2	-	CLR	10SM	-	42	5.6	39	3.9	35	1.7	76	14	320	-	0	28.39	1	94	AA
12	656	AO2	-	SCT100	10SM	-	43	6.1	40	4.4	36	2.2	76	14	310	-	0	28.39	-	98	AA
12	756	AO2	-	CLR	10SM	-	47	8.3	42	5.8	37	2.8	69	16	300	G	21	28.4	-	99	AA
12	856	AO2	-	FEW120	10SM	-	51	10.6	44	6.9	37	2.8	59	22	300	G	29	28.41	1	100	AA
12	956	AO2	-	FEW120	10SM	-	55	12.8	46	8	37	2.8	51	18	310	G	28	28.42	-	102	AA
12	1056	AO2	-	FEW047	10SM	-	58	14.4	47	8.3	35	1.7	42	24	320	G	31	28.42	-	103	AA
12	1156	AO2	-	FEW046	10SM	-	60	15.6	49	9.5	38	3.3	44	23	320	G	30	28.41	0	99	AA
12	1256	AO2	-	BKN049	10SM	-	60	15.6	49	9.5	38	3.3	44	22	320	G	30	28.41	-	97	AA
12	1356	AO2	-	BKN055	10SM	-	61	16.1	50	10	39	3.9	44	17	320	-	0	28.42	-	102	AA
12	1456	AO2	-	BKN044 BKN250	10SM	-	58	14.4	49	9.7	41	5	54	18	340	G	23	28.43	3	107	AA
12	1556	AO2	-	SCT038 BKN250	10SM	-	58	14.4	49	9.4	40	4.4	51	19	340	G	24	28.44	-	109	AA
12	1656	AO2	-	FEW039 SCT200	10SM	-	57	13.9	49	9.2	40	4.4	53	15	340	G	22	28.45	-	114	AA
12	1756	AO2	-	FEW039 SCT200	10SM	-	56	13.3	48	8.7	39	3.9	53	15	340	G	23	28.46	3	117	AA
12	1856	AO2	-	FEW060 SCT200	10SM	-	54	12.2	48	8.6	41	5	62	8	350	-	0	28.47	-	122	AA
12	1956	AO2	-	SCT200	10SM	-	52	11.1	47	8.1	41	5	66	7	340	-	0	28.49	-	127	AA
12	2056	AO2	-	SCT200	10SM	-	48	8.9	45	7	41	5	77	6	320	-	0	28.5	1	130	AA
12	2156	AO2	-	SCT200	10SM	-	47	8.3	45	7	42	5.6	83	8	320	-	0	28.5	-	133	AA
12	2256	AO2	-	CLR	10SM	-	46	7.8	44	6.5	41	5	83	7	320	-	0	28.52	-	137	AA
12	2356	AO2	-	CLR	10SM	-	46	7.8	44	6.5	41	5	83	9	330	-	0	28.52	1	139	AA

Figure 0.1 Climatic detail for April 12, 2001, Emporia, Kansas
Source: Kansas Weather Data Library, Kansas State University

Appendix B

Figure 0.2 Sericea lespedeza litter left after burning.

Appendix C

Table 0.1 Univariate tests for normality.

Test	***Statistic***	***Site 1***		***Site 2***		***Site 3***		***Site 4***	
		Grass	***Forb***	***Grass***	***Forb***	***Grass***	***Forb***	***Grass***	***Forb***
Shapiro-Wilk	W	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0002
Kolmogorov-Smirnov	D	<0.0100	<0.0100	<0.0100	<0.0100	<0.0100	<0.0100	<0.0100	<0.0100
Cramer-von Mises	W-Sq	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Anderson-Darling	A-Sq	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050

Appendix D

Figure 0.3 Data distribution graphs

D.1.a. Plots of grass data distribution. Data appear to have near normal distribution despite significant normality test values (Appendix B).

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-------------------------------------------- site=1 ---------------------------------
                                   The UNIVARIATE Procedure
                                       Variable:  GRASS

             Stem Leaf                                          #             Boxplot
                9 0                                             1                |
                8                                                                |
                8 00000000000                                  11                |
                7                                                                |
                7 000000000000000000                           18                |
                6                                                                |
                6 00000000000000000000000000000000000000000    41             +-----+
                5                                                             |     |
                5 000000000000000000000000000000000000000      39             *--+--*
                4                                                             |     |
                4 000000000000000000000000                     24             +-----+
                3                                                                |
                3 000000000000000                              15                |
                2                                                                |
                2 00                                            2                |
                1
                1
                0
                0 00                                            2                0
                  ----+----+----+----+----+----+----+----+-
-------------------------------------------- site=2 ---------------------------------

                                   The UNIVARIATE Procedure
                                       Variable:  GRASS

                                Histogram              #             Boxplot
                      8.1+***                          6                0
                         .
                         .
                         .
                         .
                      7.1+********                    16                |
                         .                                              |
                         .                                              |
                         .                                              |
                         .                                              |
                      6.1+*************************   50             +-----+
                         .                                           |     |
                         .                                           |     |
                         .                                           |  +  |
                         .                                           |     |
                      5.1+*******************         38             +-----+
                         .                                              |
                         .                                              |
                         .                                              |
                         .                                              |
                      4.1+************                24                |
                         .
                         .
                         .
                         .
                      3.1+**                           4                0
                          ----+----+----+----+----+
                          * may represent up to 2 counts
```

```
------------------------------------------ site=3 -----------------------------------

                                The UNIVARIATE Procedure
                                   Variable:  GRASS

Stem Leaf                                                 #          Boxplot
   9 0000                                                 4             0
   8
   8 000000                                               6             0
   7
   7 0000000000000000000000000000000                     31             |
   6                                                                    |
   6 000000000000000000000000000000000000000000000000    48          +-----+
   5                                                                 |  +  |
   5 0000000000000000000000000000000000000000000         43          +-----+
   4                                                                    |
   4 00000000000000000000000000                          26             |
   3
   3 00000000000                                         11             0
   2
   2 0000                                                 4             0
   1
   1 0                                                    1             *
     ----+----+----+----+----+----+----+----+----+---

------------------------------------------- site=4 ----------------------------------

                                The UNIVARIATE Procedure
                                   Variable:  GRASS

     Stem Leaf                                        #          Boxplot
        9 0                                           1             |
        8                                                           |
        8 000000                                      6             |
        7                                                           |
        7 0000000000000000000                        19             |
        6                                                           |
        6 00000000000000000000000000000000000000     38          +-----+
        5                                                        |     |
        5 000000000000000000000000000000000000       36          *--+--*
        4                                                        |     |
        4 00000000000000000000000                    23          +-----+
        3                                                           |
        3 0000000000000000000000                     22             |
        2                                                           |
        2 0                                           1             |
        1                                                           |
        1 0                                           1             |
          ----+----+----+----+----+----+----+---
```

D.1.b. Plots of forb data distribution. Data appear to have near normal distribution despite significant normality test values (Appendix B).

```
------------------------------------------ site=1 ----------------------------------

                                 The UNIVARIATE Procedure
                                     Variable:  forb

               Stem Leaf                                      #             Boxplot
                 10 0                                         1                0
                  9
                  9 0                                         1                0
                  8
                  8 00                                        2                |
                  7                                                            |
                  7 00                                        2                |
                  6                                                            |
                  6 000000000                                 9                |
                  5                                                            |
                  5 00000000000                              11                |
                  4                                                            |
                  4 00000000000000000000000                  23             +-----+
                  3                                                         |     |
                  3 000000000000000000000000000              27             |     |
                  2                                                         |  +  |
                  2 0000000000000000000000000000             28             *-----*
                  1                                                         |     |
                  1 00000000000000000000000000000000000000   38             +-----+
                  0                                                            |
                  0 00000000000000000                        17                |
                    ----+----+----+----+----+----+----+---
```

```
------------------------------------------ site=2 ----------------------------------

                                 The UNIVARIATE Procedure
                                     Variable:  forb

               Stem Leaf                                     #             Boxplot
                  9 0                                        1                0
                  8
                  8 0000                                     4                |
                  7                                                           |
                  7 000                                      3                |
                  6                                                           |
                  6 000000000000                            12                |
                  5                                                           |
                  5 00000000000000                          14                |
                  4                                                           |
                  4 000000000000000000000000000             27             +-----+
                  3                                                        |     |
                  3 0000000000000000000000000000000000000   37             *--+--*
                  2                                                        |     |
                  2 0000000000000000000000000000            28             |     |
                  1                                                        |     |
                  1 0000000000000000000000000000000000000   37             +-----+
                  0                                                           |
                  0 0000000                                  7                |
                    ----+----+----+----+----+----+----+--
```

```
------------------------------------------- site=3 ---------------------------------

                       The UNIVARIATE Procedure
                           Variable:  forb

                Histogram                  #             Boxplot
   11.25+*                                 1                0
        .
        .**                                3                0
        .
        .
        .
        .***                               5                |
        .                                                   |
        .*******                          14                |
        .                                                   |
        .*********                        17                |
    5.75+                                                   |
        .***********                      22             +-----+
        .                                                |     |
        .********************             39             |     |
        .                                                |  +  |
        .**************************       51             *-----*
        .                                                |     |
        .************                     24             +-----+
        .                                                   |
        .************                     24                |
        .                                                   |
    0.25+*******                          13                |
         ----+----+----+----+----+-
         * may represent up to 2 counts
```

```
------------------------------------------- site=4 ---------------------------------

                       The UNIVARIATE Procedure
                           Variable:  forb

              Stem Leaf                                  #           Boxplot
                10 000                                   3              |
                 9                                                      |
                 9 000000                                6              |
                 8                                                      |
                 8 0000000000                           10              |
                 7                                                      |
                 7 00000000000000000                    17              |
                 6                                                      |
                 6 00000000000000000000                 20           +-----+
                 5                                                   |     |
                 5 0000000000000000000000000000000000   34           |     |
                 4                                                   |     |
                 4 00000000000000000                    17           *--+--*
                 3                                                   |     |
                 3 0000000000000000000000000000         28           |     |
                 2                                                   |     |
                 2 00000000000000000000000000000        29           +-----+
                 1                                                      |
                 1 00000000000                          11              |
                 0                                                      |
                 0 000000                                6              |
                   ----+----+----+----+----+----+----
```

Appendix E

Table 0.2 Test results for curvilinearity.
E.1.a. Test results for curvilinearity (grass).

The SAS System 14:25 Thursday, September

The Mixed Procedure

-- site=1 ---------------------------------

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
sericea	1	113	0.00	0.9560
SSQ	1	113	0.03	0.8687
year	2	1	0.85	0.6093
season	1	1	0.94	0.5094
year*season	1	1	0.11	0.7934
trt	1	1	1.37	0.4502
year*trt	2	1	1.76	0.4705
season*trt	1	1	0.23	0.7161
year*season*trt	1	1	0.71	0.5535
sericea*year	2	113	0.23	0.7962
sericea*season	1	113	0.00	0.9547
sericea*year*season	1	113	0.04	0.8384
sericea*trt	1	113	0.48	0.4907
sericea*year*trt	2	113	0.73	0.4859
sericea*season*trt	1	113	0.09	0.7643
seric*year*seaso*trt	1	113	0.14	0.7067
SSQ*year	2	113	0.24	0.7834
SSQ*season	1	113	0.02	0.8834
SSQ*year*season	1	113	0.00	0.9888
SSQ*trt	1	113	0.08	0.7794
SSQ*year*trt	2	113	0.39	0.6758
SSQ*season*trt	1	113	0.10	0.7491
SSQ*year*season*trt	1	113	0.17	0.6785

-- site=2 ---------------------------------

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
sericea	1	98	0.01	0.9406
SSQ	1	98	0.00	0.9529
year	2	1	1.67	0.4796
season	1	1	0.95	0.5076
year*season	1	1	0.01	0.9498
trt	1	1	1.51	0.4347
year*trt	2	1	0.26	0.8131
season*trt	1	1	0.20	0.7313
year*season*trt	1	1	0.69	0.5577
sericea*year	2	98	2.41	0.0952
sericea*season	1	98	1.45	0.2307
sericea*year*season	1	98	0.06	0.8084
sericea*trt	1	98	0.98	0.3257
sericea*year*trt	2	98	0.55	0.5806
sericea*season*trt	1	98	0.12	0.7275
seric*year*seaso*trt	1	98	0.06	0.8049
SSQ*year	2	98	1.90	0.1553
SSQ*season	1	98	1.79	0.1839
SSQ*year*season	1	98	0.14	0.7086
SSQ*trt	1	98	0.35	0.5551

SSQ*year*trt	2	98	0.81	0.4460
SSQ*season*trt	1	98	0.93	0.3376
SSQ*year*season*trt	1	98	0.00	0.9836

--- site=3 ---------------------------------

The Mixed Procedure

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
sericea	1	135	6.20	0.0140
SSQ	1	135	3.80	0.0534
year	2	1	1.84	0.4623
season	1	1	7.80	0.2189
year*season	1	1	6.29	0.2415
trt	1	1	0.04	0.8790
year*trt	2	1	3.12	0.3716
season*trt	1	1	1.58	0.4280
year*season*trt	1	1	0.56	0.5904
sericea*year	2	135	1.95	0.1469
sericea*season	1	135	0.65	0.4225
sericea*year*season	1	135	3.13	0.0791
sericea*trt	1	135	1.24	0.2679
sericea*year*trt	2	135	1.35	0.2639
sericea*season*trt	1	135	0.63	0.4305
seric*year*seaso*trt	1	135	1.05	0.3071
SSQ*year	2	135	1.73	0.1810
SSQ*season	1	135	0.02	0.8955
SSQ*year*season	1	135	1.56	0.2141
SSQ*trt	1	135	2.00	0.1594
SSQ*year*trt	2	135	1.58	0.2105
SSQ*season*trt	1	135	0.00	0.9573
SSQ*year*season*trt	1	135	0.74	0.3906

--- site=4 ---------------------------------

The Mixed Procedure

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
sericea	1	108	1.58	0.2118
SSQ	1	108	1.68	0.1972
year	2	1	0.98	0.5819
season	1	1	0.03	0.8843
year*season	1	1	0.05	0.8595
trt	1	1	0.78	0.5402
year*trt	2	1	0.06	0.9442
season*trt	1	1	0.40	0.6404
year*season*trt	1	1	0.58	0.5867
sericea*year	2	108	1.38	0.2568
sericea*season	1	108	0.03	0.8536
sericea*year*season	1	108	0.09	0.7668
sericea*trt	1	108	2.21	0.1400
sericea*year*trt	2	108	1.05	0.3523
sericea*season*trt	1	108	0.31	0.5787
seric*year*seaso*trt	1	108	0.12	0.7345
SSQ*year	2	108	1.18	0.3106
SSQ*season	1	108	0.47	0.4964
SSQ*year*season	1	108	0.28	0.5952
SSQ*trt	1	108	1.82	0.1798
SSQ*year*trt	2	108	1.14	0.3241
SSQ*season*trt	1	108	0.54	0.4647
SSQ*year*season*trt	1	108	0.11	0.7453

E.1.b. Test results for curvilinearity (forb).

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The Mixed Procedure

-- site=1 ---------------------------------

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
sericea	1	101	3.80	0.0541
SSQ	1	101	1.11	0.2943
year	1	1	1.34	0.4537
season	1	1	5.49	0.2567
year*season	1	1	0.10	0.8049
trt	1	1	0.61	0.5787
year*trt	1	1	0.11	0.7955
season*trt	1	1	0.40	0.6405
year*season*trt	1	1	0.11	0.7944
sericea*year	1	101	0.01	0.9342
sericea*season	1	101	0.00	0.9672
sericea*year*season	1	101	0.15	0.7016
sericea*trt	1	101	0.84	0.3605
sericea*year*trt	1	101	0.23	0.6295
sericea*season*trt	1	101	0.10	0.7516
seric*year*seaso*trt	1	101	0.02	0.8960
SSQ*year	1	101	0.00	0.9977
SSQ*season	1	101	0.01	0.9375
SSQ*year*season	1	101	0.30	0.5857
SSQ*trt	1	101	0.27	0.6054
SSQ*year*trt	1	101	0.04	0.8401
SSQ*season*trt	1	101	0.02	0.8899
SSQ*year*season*trt	1	101	0.04	0.8505

-- site=2 ---------------------------------

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
sericea	1	122	7.69	0.0064
SSQ	1	122	3.27	0.0730
year	2	2	2.52	0.2837
season	1	1	7.64	0.2210
year*season	2	2	0.32	0.7582
trt	1	1	0.20	0.7298
year*trt	2	2	1.41	0.4149
season*trt	1	1	0.97	0.5056
year*season*trt	2	2	1.49	0.4023
sericea*year	2	122	0.24	0.7908
sericea*season	1	122	0.37	0.5437
sericea*year*season	2	122	1.31	0.2741
sericea*trt	1	122	3.21	0.0759
sericea*year*trt	2	122	0.48	0.6183
sericea*season*trt	1	122	0.09	0.7670
seric*year*seaso*trt	2	122	0.44	0.6450
SSQ*year	2	122	0.26	0.7706
SSQ*season	1	122	0.09	0.7677

SSQ*year*season	2	122	1.20	0.3048
SSQ*trt	1	122	3.92	0.0499
SSQ*year*trt	2	122	0.41	0.6636
SSQ*season*trt	1	122	0.48	0.4918
SSQ*year*season*trt	2	122	0.17	0.8414

-- site=3 ---------------------------------

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
sericea	1	166	0.01	0.9027
SSQ	1	166	0.00	0.9676
year	2	1	0.40	0.7461
season	1	1	10.60	0.1897
year*season	2	1	3.22	0.3664
trt	1	1	43.45	0.0958
year*trt	2	1	0.31	0.7846
season*trt	1	1	3.02	0.3325
year*season*trt	2	1	2.18	0.4318
sericea*year	2	166	0.01	0.9866
sericea*season	1	166	0.11	0.7385
sericea*year*season	2	166	0.02	0.9808
sericea*trt	1	166	0.23	0.6334
sericea*year*trt	2	166	0.31	0.7345
sericea*season*trt	1	166	0.87	0.3528
seric*year*seaso*trt	2	166	1.19	0.3054
SSQ*year	2	166	0.04	0.9635
SSQ*season	1	166	0.36	0.5487
SSQ*year*season	2	166	0.09	0.9119
SSQ*trt	1	166	0.04	0.8475
SSQ*year*trt	2	166	0.11	0.8931
SSQ*season*trt	1	166	0.79	0.3767
SSQ*year*season*trt	2	166	0.61	0.5426

-- site=4 ---------------------------------

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
sericea	1	134	0.37	0.5467
SSQ	1	134	1.10	0.2951
year	2	1	2.80	0.3892
season	1	1	9.80	0.1969
year*season	2	1	1.12	0.5559
trt	1	1	0.30	0.6816
year*trt	2	1	3.57	0.3504
season*trt	1	1	0.09	0.8179
year*season*trt	2	1	2.28	0.4244
sericea*year	2	134	2.83	0.0626
sericea*season	1	134	1.30	0.2562
sericea*year*season	2	134	0.69	0.5050
sericea*trt	1	134	0.73	0.3941
sericea*year*trt	2	134	0.67	0.5138
sericea*season*trt	1	134	0.59	0.4447
seric*year*seaso*trt	2	134	0.52	0.5975
SSQ*year	2	134	2.07	0.1299
SSQ*season	1	134	1.19	0.2773
SSQ*year*season	2	134	0.75	0.4762
SSQ*trt	1	134	0.96	0.3300
SSQ*year*trt	2	134	0.57	0.5642
SSQ*season*trt	1	134	0.97	0.3276
SSQ*year*season*trt	2	134	0.83	0.4393

Appendix F

Table 0.3 Quail weights (g) by sex prior to and following consumption of sericea lespedeza seed.

		19 Nov	22 Nov	trial	trial	25 Nov	
quail							
#	sex	wt. begin trial	wt. end trial	gain(loss) (g)	% gain(loss)	wt. return	
1	F	225.1	182.5	-42.6	-18.92%	197.4	
2	F	204.0	177.5	-26.5	-12.99%	191.8	
4	F	222.6	170.2	-52.4	-23.54%	186.2	
7	F	193.7	161.5	-32.2	-16.62%	181.3	
9	F	192.4	155.0	-37.4	-19.44%	170.4	
12	F	225.5	174.5	-51.0	-22.62%	191.9	
15	F	209.6	172.9	-36.7	-17.51%	183.6	
				-39.8	-18.8%		mean
3	M	218.9	178.3	-40.6	-18.55%	189.4	
5	M	209.0	152.4	-56.6	-27.08%	169.5	
6	M	211.1	169.1	-42.0	-19.90%	173.7	
8	M	217.4	172.6	-44.8	-20.61%	173.0	
10	M	200.0	146.9	-53.1	-26.55%	159.3	
11	M	218.8	182.2	-36.6	-16.73%	189.9	
13	M	200.3	157.2	-43.1	-21.52%	171.3	
14	M	210.0	160.6	-49.4	-23.52%	175.8	
16	M	220.3	194.7	-25.6	-11.62%	206.5	
				-43.5	-20.67%		mean

Appendix G

Figure 0.4 Calculations used to determine the height-weight table.

Each ungrazed plant was divided into 1-inch segments. Each segment was weighed individually. The highlighted segment of this table shows the inch weights for one plant as well as the cumulative weight at each inch of plant height, beginning at the base of the plant.

date	site	sample	inch	inch wt	wt lab	ht lab	percent cumulative wt
10	1	80	14	0.06	1.30	16	0.9615
10	1	80	15	0.04	1.30	16	0.9923
10	1	80	16	0.01	1.30	16	1.0000
11	3	10	1	0.08	1.94	16	0.0412
11	3	10	2	0.07	1.94	16	0.0773
11	3	10	3	0.1	1.94	16	0.1289
11	3	10	4	0.09	1.94	16	0.1753
11	3	10	5	0.09	1.94	16	0.2216
11	3	10	6	0.11	1.94	16	0.2784
11	3	10	7	0.14	1.94	16	0.3505
11	3	10	8	0.13	1.94	16	0.4175
11	3	10	9	0.21	1.94	16	0.5258
11	3	10	10	0.13	1.94	16	0.5928
11	3	10	11	0.17	1.94	16	0.6804
11	3	10	12	0.17	1.94	16	0.7680
11	3	10	13	0.17	1.94	16	0.8557
11	3	10	14	0.14	1.94	16	0.9278
11	3	10	15	0.06	1.94	16	0.9588
11	3	10	16	0.08	1.94	16	1.0000
11	3	25	1	0.14	3.17	16	0.0442
11	3	25	2	0.13	3.17	16	0.0852
11	3	25	3	0.12	3.17	16	0.1230

Using Excel (Microsoft), a single regression analysis was run on all plants of the same height. The regression shows the relationship between the plant weight and plant height. For example, the regression below indicates that a 16-inch plant has its weight fairly evenly distributed (r^2=0.96) between each inch segment; i.e.; each plant segment contributes approximately the same amount to plant weight, regardless of where the segment is located on the plant. This relationship can be use to provide an estimate of how much plant weight would be removed with each inch of plant grazed.

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.9807984
R Square	0.9619655
Adjusted R Square	0.9618517
Standard Error	0.0636103
Observations	336

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	34.18095	34.18095	8447.5125	3.45E-239
Residual	334	1.3514555	0.0040463		
Total	335	35.532406			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-0.0445752	0.0072792	-6.1236257	2.568E-09	-0.058894	-0.0302563	-0.058894	-0.0302563
slope	0.0691899	0.0007528	91.91035	3.45E-239	0.0677091	0.0706708	0.0677091	0.0706708

The average percent of total plant weight represented by each inch of plant height for a 16-inch plant (and all other plant height classes) was calculated using the x and intercept values from the regression analysis. These values were compiled into Table 2.

formula	remaining height of plant at 10% utilization increments	
=(0.9-(-0.0445))/0.0691	13.67	10% utilization
=(0.8-(-0.0445))/0.0691	12.22	20% utilization
=(0.7-(-0.0445))/0.0691	10.77	30% utilization
=(0.6-(-0.0445))/0.0691	9.33	40% utilization
=(0.5-(-0.0445))/0.0691	7.88	50% utilization
=(0.4-(-0.0445))/0.0691	6.43	60% utilization
=(0.3-(-0.0445))/0.0691	4.99	70% utilization
=(0.2-(-0.0445))/0.0691	3.54	80% utilization
=(0.1-(-0.0445))/0.0691	2.09	90% utilization

For each date and site sampled, 100 plants were measured and their heights recorded. An ungrazed plant was selected for each fifth sample (in blue), clipped, and used for the height-weight inch analysis. Green numbers represent the plants encountered that were grazed. This data sheet is from early in the season, and relatively few plants have been grazed. These data were collected for two growing seasons in each paddock that contained grazing animals on the sample date.

Site 4	height		height		height		height
1	13.5	26	11.5	51	12	76	7
2	11	27	10.5	52	9	77	11.5
3	10.5	28	9	53	9	78	8
4	8.5	29	11.5	54	14	79	4
5	11	30	12	55	13.5	80	13.5
6	12	31	12	56	8.5	81	6
7	9	32	11	57	6	82	11.5
8	10	33	9	58	4.5	83	10
9	9	34	6	59	6	84	8.5
10	16	35	10	60	8	85	9.5
11	11	36	9	61	8.5	86	11
12	9	37	11.5	62	9	87	10
13	7	38	10.5	63	15.5	88	12
14	11.5	39	10	64	9	89	6
15	9	40	10	65	8	90	7
16	10	41	11	66	4	91	7
17	9	42	8.5	67	10	92	11
18	11	43	10	68	18	93	9.5
19	13	44	13.5	69	15	94	6.5
20	13	45	12	70	8	95	6
21	12	46	9	71	4	96	7
22	10.5	47	17	72	9.5	97	6
23	9.5	48	10	73	7.5	98	10
24	12	49	10.5	74	3	99	5
25	9	50	11	75	10	100	9

The average height was calculated for clipped, grazed, and ungrazed plants for each transect. Since by definition clipped plants were not grazed, they were not included in calculating the percent of plants grazed. Thus, out of each 100 plant transect, only 80 plants were included in the average percent ungrazed calculation. This example is for a transect where the averaged grazed height rounded up to 10 inches.

Average Percent Grazed (n=80)

	clipped	grazed	ungrazed
average plant height	10.28	9.21	9.85
number of plants sampled	20	29	51
percent grazed		0.3625	

A chart was constructed showing the slopes and intercepts for each plant height.

plant height	intercept	slope
5	0.021154	0.213462
6	-0.02466	0.185262
7	-0.08939	0.161098
8	-0.04557	0.13399
9	0.016635	0.112348
10	-0.05431	0.108856
11	-0.03284	0.098136
12	-0.01404	0.088196
13	-0.04617	0.084185
14	-0.05016	0.078174
15	-0.04182	0.072498
16	-0.04458	0.06919
17	-0.04479	0.064026
18	-0.04498	0.060452
19	-0.02584	0.057555
20	-0.03694	0.055377
21	-0.02382	0.051566
22	-0.06161	0.049484
23	-0.01624	0.047754
24	-0.01592	0.041618
25	-0.05722	0.0419
26	-0.01572	0.041734
27	-0.0539	0.040403
28	-0.05409	0.038754
29	0.01083	0.033845
30	-0.03004	0.034277
31	-0.03584	0.032654
32	-0.0433	0.032306
33	-0.07452	0.033112
34	-0.00115	0.028817

The intercept and slope for the average grazed plant height, rounding up, were selected and used in the following formula:

Proportion of sericea lespedeza biomass not grazed = ((slope)*(average grazed height)) + intercept

Percent of sericea lespedeza not grazed = ((0.108856)*(9.21)) + (-0.05431)

Percent of sericea lespedeza not grazed = 0.94741

To find the percentage of sericea lespedeza biomass that was grazed (utilized), the following formula was used:

Percent of sericea lespedeza utilization = 1 – (percent of sericea lespedeza not grazed)

Percent of sericea lespedeza utilization = 1 – (0.94741)

Percent of sericea lespedeza utilization = 0.05259

To estimate the percentage of total sericea lespedeza biomass utilized at a given percentage of plants grazed, the following formula was used:

Percent utilization at a given grazed rate = (percent utilization) * (percent of plants grazed)

Percent utilization at a given grazed rate = (0.05259) * (0.3625)

Percent utilization at a given grazed rate = 0.019064

This process was repeated for each sampling site each date it was sampled. n = 24

Values for the Percent Sericea Lespedeza Utilization as Estimated by Percent of Plants Grazed graph (Fig. 2) were the percent of plants grazed (x-axis) and the percent utilization at a given grazed rate (y-axis). Values were changed to percentages.

Thus, one point on the graph would be:

(0.3625), (0.019064) or
(36.25%), (1.9064%)