AN ABSTRACT OF THE THESIS OF

Milan L. Piva for the Master of Science

in Biology presented February 5, 2016

Title: The Impact of Fuel Load and Fire Season on the Control of Sericea Lespedeza, *Lespedeza cuneata*

Abstract approved: ____________________

Sericea lespedeza, *Lespedeza cuneata*, is an invasive species of legume introduced to North America in the 1800s. Since its introduction, it has become wide spread throughout the Midwest, having detrimental effects on tallgrass prairies by outcompeting native plant species and reducing forage production. Sericea lespedeza is also costly for range managers and landowners to control as current methods have had little success. I investigated a unique combination of control strategies at a plot size that replicates fire behavior seen in pasture-scale burns. These treatments included variations in fire season (spring or fall) coupled with treatments of herbicide, mowing, and fuel (litter) addition. I hypothesized that the subplots that received fuel load additions within the fall fire plots would have the greatest reduction on sericea lespedeza density, without affecting the productivity of native tallgrass prairie plant species compared to that of the herbicide, mowing, and spring burn treatments. In response to these treatment methods, I measured sericea lespedeza desnity and grassland system biomass to evaluate treatment effectiveness. This study was conducted at the Marais des Cygnes National Wildlife Refuge, Pleasanton, KS, a 25 year old tallgrass prairie restoration, operated by the U.S. Fish and Wildlife Service. Total standing biomass increased from 2014 to 2015, however, this is likely from the substantial increase in precipitation in 2015. Fall fire combined with mowing significantly decreases sericea lespedeza standing biomass.

THE IMPACT OF FUEL LOAD AND FIRE SEASON ON THE CONTROL OF SERICEA LESPEDEZA, *Lespedeza cuneata*

A Thesis

Presented to the Department of Biology

EMPORIA STATE UNIVERSITY

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

---

by

Milan L. Piva

May 2016

Approved by Major Advisor
Dr. Brenda Koerner

Approved by Committee Member
Dr. William Jensen

Approved by Committee Member
Dr. Marshall Sundberg

Approved by the Department Chair
Dr. Yixin Yang

Approved by the Dean of the Graduate School
and Distance Education
Dr. Kathy Ermler

ACKNOWLEDGMENTS

I would like to thank my advisor Dr. Koerner for all of her time and energy spent on this project. Tim Menard, Patrick Martin, and the rest of the staff at Marias Des Cygnes Wildlife Refuge for helping with the application of treatments at the site. Also, to Dave Berglund for providing his time, equipment, and hay for the fuel load additions. I'd like to think all those who helped with data collection and analysis (Erin Lingenfelter, Alaina Buchanan, Jill Cole, Jessica Edmunds, Brittany Miller, Andrew Baker, Sarah Noller, and Wenji Wang). Partial funding for this research was provided by Emporia State University, the National Institute of Food and Agriculture, U.S. Department of Agriculture, through the North Central Region SARE program under subaward number LNC15-372, and by Zeta Tau Alpha Fraternity.

PREFACE

This thesis was prepared following the publication style of Transactions of Kansas Academy of Science.

TABLE OF CONTENTS

LIST OF TABLES

Page

LIST OF FIGURES

Page

INTRODUCTION

In recent years, the influence of invasive plants on native plant communities has become a topic of great concern (Keeley et al. 2003). Invasive plants are described as those introduced into an area where they are not native and successfully expand (Rejmanek 2000; Richardson et al. 2000; Wong et al. 2012). These species threaten native vegetation by out-competing natives for resources, such as light, and changing abiotic factors such as soil chemistry (Zedler and Kercher 2004; Cummings et al.b 2007). Sericea lespedeza (*Lespedeza cuneata)* is one such invasive plant that has severely impacted tallgrass prairies in the Midwest (Price and Weltzin 2003; Brandon et al. 2004). In the late 1800s, sericea lespedeza was introduced to North America from eastern Asia for erosion control and forage production, and then by the 1930s it had been introduced in the Midwest US (Allred et al 2010) (Figure 1). Due to the strong competitive nature of the plant, its rapid succession, and high tolerance of varying conditions, its expansion threatens native and restored tallgrass prairies in Kansas (Vermeire et al. 1998; Allred et al. 2010). Currently, sericea lespedeza is listed as a noxious weed in Kansas, and is identified as an invasive plant in Missouri (Eddy et al. 2003). Sericea lespedeza is detrimental to native species because it forms dense stands that completely shade out most native species and its prolific seed production bolsters the soil seed bank allowing for new growth for many years (Cummings et al. 2007b; Allred et al. 2010; USDA 2011). Additionally, sericea lespedeza is allelopathic, releasing chemicals into the soil that are detrimental to surrounding native plants (Kalburtji et al. 2001). Unfortunately, Schutzenhofer et al. (2009), determined that there is significantly less herbivory on sericea lespedeza compared to that of the native species *Lespedeza virginica*, supporting the idea that there is no co-evolved natural enemy to sericea lespedeza in the Midwest to stop its invasion. Allowing for rapid distribution and increase in abundance (Crawley 1997, Maron and Vila 2001, Keane and Crawley 2002) inSericea lespedeza expansion also has severe economic impacts for the ranching industry because it is unpalatable to most livestock and reduces the biodiversity and productivity of the prairie (Cope and Burns 1971).

Currently, ranchers and land managers control sericea lespedeza with herbicides that are costly and, when applied pasture-wide, kill non-target native species with little success in decreasing sericea lespedeza long-term (Koger et al. 2002). Typical herbicides applied, such as triclopyr and metsulfuron-methyl, do not provide permanent eradication because of the large reservoir of seeds in the soil seed bank; thus, repeated application of herbicide is required (Cummings et al. 2007b). Mechanically removing sericea lespedeza with repeat mowing during the late growing season has shown to decrease its density, but not eradicate sericea lespedeza and can also causes damage to native plant species (Cummings et al. 2007a).

Fire and grazing by large ungulates are historically natural disturbances in tallgrass prairies (Mack 1989; D'Antonio 2000; Anderson 2006). Fire and grazing together have been shown to reduce the rate of sericea lespedeza expansion when using a patch burning technique where a portion of the infested pasture is burned, allowing cattle to selectively graze on the new growth in that area while unburned areas accumulate fuel to be burned the following year (Fuhlendorf and Engle 2004, Cummings et al. 2007a). The use of this practice creates a shifting mosaic that increases grassland heterogeneity, which is crucial in conserving many plant and animal grassland species (Fuhlendorf and Engle 2004).

Unfortunately, only 4% of the original tallgrass prairie remains and over 620,000 acres of that prairie in Kansas are infested with sericea lespedeza, with few successful management techniques, a great need exists for more sustainable management practices to be implemented (Samson and Knopf 1996; KSDA 2011).

One goal of this study was to target the plant's most vulnerable life stages, which include seed germination, seedling development, and seed production (Wong et al. 2012). It has been shown that fire temperatures reaching 225º C significantly decreased sericea lespedeza seed viability, and full morality occurred when seeds were exposed at 250º C for two minutes (Bell and Koerner 2009). In addition, greater litter loads, such as those found under patch-burn grazing management significantly increase field fire temperatures (Bell 2012). Currently, prescribed burns are typically applied in the spring, which has little effect on decreasing sericea lespedeza seed germination and may enhance it (Ohlenbusch et al. 2001, Stevens 2002, Cummings et al. 2007a). If rangelands are burned in fall prior to seed maturation, prescribed burns, especially with additional fuel loads, have the potential to eliminate that year's seed production and considerably reduce sericea lespedeza stem counts (Hamilton 2003).

This experiment manipulates fire season with secondary treatments of herbicide, mowing, and fuel load addition supplementation in hopes to provide land managers with a tool to control sericea lespedeza while preserving the integrity of tallgrass prairie ecosystems. By showing that prescribed fire has the potential to reduce abundance of sericea lespedeza through targeted burning in the fall season rather than the spring, it could reduce the environmental impact and economic cost of herbicide use, and lead to greater biodiversity and rangeland health. Sericea lespedeza stem density and standing biomass was determined, as well as the total standing biomass to ensure that native species were not compromised. I hypothesized that the plots burned in the fall would show the greatest decrease in sericea lespedeza because both the existing plants and the seeds from that growing season would be killed, ensuring that seeds were not incorporated into the soil over winter and allowed to germinate the following year. This would require fire temperatures of at least 250º C, so subplots that received fuel load additions would have the greatest fire temperatures, thus largest reduction of sericea density without reducing total standing biomass and grass standing biomass.

MATERIALS AND METHODS

Study Site

The study site is located at the Marais des Cygnes National Wildlife Refuge operated by the U.S. Fish and Wildlife Service near Pleasanton, Kansas (38.2250° N, 94.6500° W) (Figure 2). The site is a well-established, 25-year-old prairie restoration with a dense (up to 350 stems/m^2) and evenly dispersed infestation of sericea lespedeza. A weather station 5.6 km away from the field site recorded climate data (Table 1). Prior to beginning this experiment, a baseline burn was administered in March 2014 to the entire site to ensure uniform management across the site. Plots (50 m x 50 m) were randomly assigned burn season of either spring annual, fall annual, or no burn. Spring burns were administered late March-April, while fall burns occurred in October. Each of these burn treatments had four replicates for a total of 12 plots. Each burn plot was divided into four subplots (25 m x 25 m), to test secondary treatments of fuel load addition, herbicide addition, mid-summer mowing, and burn only in combination within burn season (Figure 3). An herbicide treatment of triclopyr was broadcast with a boom sprayer in mid-summer 2014 to subplots receiving an herbicide addition. The mowing treatment was applied annually during late June-July. Fuel load addition subplots received half a round prairie hay bale that was hand spread across the plot at least 1 week prior to the fire treatment (approximately 230 kg [500lbs] per subplot). Although subplots of fuel load addition (litter) and fire only secondary treatments were randomly assigned to the unburned plots, these subplots did not receive any secondary treatment and were left untouched creating untreated subplots within the unburned plots. However, plots designated as unburned did receiving mowing and herbicide application.

Sericea Lespedeza Density

Sericea lespedeza density was measured in all plots in 2014 (pre-burn), prior to fall burn from August-October. Sericea lespedeza density was remeasured in 2015 (post-burn) from August-October. Permanent markers (poles) placed approximately 5 m inward at all four corners of each subplot (Figure 3). A 1 m^2 quadrat was placed at each permanent marker with the pole located at the south west corner of the quadrat. Stem density was measured by counting the number of stems within the four 1 m^2 quadrats in each subplot. Stem density was measured at the same location each year.

Grassland Productivity

Total standing biomass of all plants was measured by clipping biomass in September-October in 2014 (pre-burn), prior to fall prescribed burn and again in 2015 (post-burn) from September-October. Systematically placing four 0.25 m^2 quadrats within each experimental subplot, plants were cut at ground level within that quadrat (Figure 3). The quadrats were placed within 1 m of the stem density sampling location so that clippings would not interfere with sericea lespedeza stem density measurements. The quadrats were not placed in the same location each year to minimize clipping effects. The clippings were placed in brown paper bags and labeled with plot, subplot, and quadrat identifiers. Samples were immediately placed in a drying cabinet and stored until sorted. The biomass clippings were sorted by hand into three vegetation types: grasses, forbs, and sericea lespedeza. The sorted biomass was dried at 70º C for 48 hours and weighed. All treatment samples were collected prior to the fall burn.

Statistical Analysis

Stem density and percent difference of stem density were analyzed using a split-plot analysis of variance to determine significant differences in stem densities between the year, fire season, and secondary treatment as well as interactions between the three classifications. A split-plot anova was also used to test for differences in total productivity, grass productivity, forb productivity, serciea productivity among year, fire season, and secondary treatment as well as interactions between theses classifications. A least-significant means separation test with Tukey conservative adjustment was used to determine the significant effects of fire season and secondary treatment. A significant level of $\alpha = 0.05$ for ANOVAs and least-significant means separations was used. All split-pot tests were performed using a generalized linear mixed model (Proc GLIMMIX). Least-signficiant means separations tests were done with a general linear model (PROC GLM) in SAS 9.1 (SAS Institute Inc. Cary, NC).

RESULTS

Stem Density

Stem density of sericea lespedeza showed no significant difference between years (*P*= 0.0797), or in response to fire season (*P*= 0.7915). Stem density ranged from 1 to 353 stems/m^2. Treating with herbicide significantly reduces sericea lespedeza stem in the unburned plots compared to mowing. No significant difference in sericea lespedeza stem density between mowing and no treatment within the unburned plots. Herbicide application significantly decreases sericea lespedeza stem density compared to fuel load addition (litter) and fire only, but not mowing. Mowing combined with fall fire does not significantly decrease sericea lespedeza stem density compared to fuel load addition (litter) and fire only. Compared to fire only in the spring, herbicide application also significantly decreases sericea lespedeza stem density. No significant difference in sericea lespedeza stem density was seen between mowing, fuel load addition (litter), and fire only in the spring burn (Table 1).

There was no significant difference in change in sericea lespedeza stem density among fire seasons, however secondary treatment significantly affected change in stem density (*P*= 0.0086). All treatments, regardless of fire season, showed positive changes in stem density. A significant interaction between fire season and secondary treatment (*P*= 0.0160) affected the change in stem density. Unburned and spring plots showed no significant difference in change in sericea lespedeza stem density in any of the secondary treatments. Fall burn combined with herbicide had a significantly higher change in sericea lespedeza stem density than mowing, fuel load addition (litter), and fire only (Figure 8).

Total Standing Biomass

Total standing biomass increased significantly from 2014 (pre-burn) to 2015 (post-burn) (*P*= 0.0203), and showed a significant interaction between year and fire season (*P*= 0.0002), and year and secondary treatment (*P*= 0.0026). Although no significant interaction occurred between year, fire season, and secondary treatment, a trend existed between them (*P*= 0.0736). Total standing biomass was significantly different for fire season in the absence of secondary treatments with the unburned plots having higher total standing biomass than both fall (*P*= 0.0447) and spring burn treatments (*P*= 0.0150). Significantly more total standing biomass was found in unburned plots than in plots receiving fall fire and mow treatments. The total standing biomass was significantly lower in the spring burn herbicide plots than the unburned herbicide plots. Treating with herbicide or mowing reduces total biomass compared to no addition of secondary treatment. Burning in the fall with a fuel load addition (litter) resulted in greater total standing biomass than herbicide and mowing treatments, but not fire only. Spring burning with additional fuel load (litter) also resulted in greater total standing biomass than burning in combination with herbicide or mowing, but not burning only (Figure 4).

Grass Standing Biomass

The grass portion of standing biomass was significantly lower in 2015 than 2014 (*P*= 0.0004), and showed a significant interaction between year and fire season (*P*= 0.0038). Although no significant interaction occurred between fire season and secondary treatment, a trend existed between them (*P*= 0.0641). There was no significant interaction between year and secondary treatment, or year, fire season, and secondary treatment. Although fire season was not significant, secondary treatments significantly affected standing grass biomass (*P*< 0.0001). The only significant fire effect on grass standing biomass occurred within the herbicide treatment with spring fire resulting in significantly lower standing grass biomass than absence of fire, but fall burning was not significantly higher than spring burning or lower than absence of fire. In the absence of fire (unburned), the herbicide treatments significantly increased standing grass biomass compared to mowing and no treatment. Herbicide treatment in combination with fall fire resulted in significantly higher standing grass biomass compared to mowing, fuel load addition, or fire only. Mowing in combination with fall fire significantly reduced standing grass biomass compared to the other treatments. Herbicide treatment in combination with spring fire resulted in higher standing grass biomass than spring fire with mowing, fuel load addition, or fire only (Figure 5).

Forb Standing Biomass

Standing forb biomass excluded standing sericea lespedeza biomass, which was analyzed as a separate vegetative group. Standing forb biomass was not significantly different between years nor was there a significant interaction between year and fire season. However, a significant interaction existed between year and secondary treatment (P= 0.0427), and between year, fire season, and secondary treatment (P= 0.0339). Fire season also significantly affected standing forb biomass when secondary treatment was not taken into account (P=0.0145). No significant difference in forb standing biomass was seen in secondary treatment within any of the fire seasons (Figure 6).

Sericea Lespedeza Standing Biomass

Standing sericea lespedeza biomass was significantly higher in 2015 than 2014 (P< 0.0001), and showed a significant interaction between year and secondary treatment (P< 0.0001), year and fire season (P=0.0420), and fire season and secondary treatment (P=

0.0043). Both fire season and secondary treatment effects were significant ($P= 0.0307$, $P< 0.0001$).Within the mowing treatment, the fall fire significantly reduced standing sericea lespedeza biomass compared to spring fire and not burning. Fall and spring burning only resulted in significantly lower standing sericea lespedeza biomass compared to the unburned plots. In the absence of fire, herbicide treatment significantly decreased standing sericea lespedeza biomass compared to no treatment (litter and fire only designations), but not mowing. Fuel load addition (litter) in combination with fall fire resulted in higher standing sericea lespedeza biomass than mowing or herbicide treatment, but not with fire only. Herbicide addition with fall fire had significantly less standing sericea lespedeza biomass compared to fuel load addition (litter) and fire only, but not mowing. Fuel load addition (litter) with spring fire also resulted in significantly higher standing sericea lespedeza biomass than mowing, herbicide, and fire only treatments. Herbicide, mowing, and fire only treatments did not differ in standing sericea lespedeza biomass when burned in spring (Figure 7).

DISCUSSION

Combining fire season with a secondary treatment of mowing, herbicide, or fuel load addition (litter) may be a useful management tool for landowners with an infestation of sericea lespedeza. Shifting to fall burns rather than spring burns may reduce sericea lespedza while maintaining native forbs and grasses. Overall, prescribed spring or fall burns with no secondary treatment showed a significant reduction of sericea lespedeza compared to unburned plots. However, current management practices primarily utilize spring prescribed burns to control sericea lespedeza with little success (Ohlenbusch et al. 2001, Stevens 2002, Cummings et al. 2007a.). Maintaining native grasses is vital and this study found that standing grass biomass was not negatively affected by burning in the fall compared to spring burning, making an argument for a shift to fall burns. This suggestion is also supported with the findings that standing sericea lespedeza biomass was significantly reduced in fall fire plots that received a mowing and herbicide secondary treatments compared to the spring plots.

Mowing combined with fall fire significantly decreased standing sericea lespedeza biomass compared to the spring burn. This combination of mowing and fall fire did not negatively affect grass standing biomass compared to the spring burn. Suggesting that mowing and burning in the fall may be a practical and less expensive management tool for landowners. Herbicide application has short-term success in reducing sericea lespedeza, but requires repeated application and becomes costly for landowners. Combining herbicide application with prescribed burning results in significantly lower standing sericea lespedeza biomass, but also decreases standing grass biomass significantly compared to applying herbicide in unburned plots. However, herbicide application significantly increased standing grass biomass compared to mowing, fuel load addition, and fire only secondary treatments within fall, spring, and unburned plots. Fuel load addition, in combination with both fall and spring burns, significantly increased standing sericea lespedeza biomass. By visual observation, the fires in the fuel load addition subplots burned more evenly compared to the other subplots receiving herbicide, mowing, or fire only. These thorough burns may have allowed sericea lespedeza to take advantage of the barren ground with no competition from native species, germinating early from seeds left in the soil bank from years past (Cummings et al. 2007a).

Although there was a significant increase in total standing biomass post-burn, the majority of this increase came from an increase in standing sericea lespedeza biomass. This increase in standing sericea lespedeza biomass from 2014 to 2015 was seen in fall, spring, and unburned plots. However, in the fire only secondary treatment, standing sericea lespedeza biomass was significantly lower in both spring and fall compared to the unburned plots. This indicates that another factor influenced the substantial increase in standing sericea lespedeza biomass from 2014 to 2015. The amount of precipitation between the two years may explain the significant increase in standing sericea lespedeza biomass. There was a 72% increase in precipitation in April-August between 2014 and 2015 at the Marias des Cygnes National Wildlife Refuge (Western Region Climate Center, 2016). Year to year climate changes, especially after a prescribed burn, have an extremely important role in the regeneration of the prairie vegetation composition (Gibson and Hulbert, 1987; Risser 1987; Gibson, 1988).

Additionally, a trend was observed in the secondary treatments where sericea lespedeza stem density was higher the grass standing biomass was decreased. Although grass biomass overall decreased post-burn, it was significantly higher in areas where sericea lespedeza density was decreased, such as in the herbicide plots of all three fire treatments. Similar findings support this trend that highly dense sericea lespedeza will decreasing grass biomass (Cummings et al. 2007a). Since sericea lespedeza productivity was very high in 2015, forming dense stands, it may explain the decrease in grass standing biomass post-burn. Grass standing biomass within the mow secondary treatments was not significantly decreased compared to that of the fuel load addition (litter) or fire only subplots. This supports the idea that a mid-summer mow application will not negatively affect the grass standing biomass.

Unfortunately, these results are from a single prescribed burn. After a disturbance, such as the fire and secondary treatment regimes described in this experiment, prairie ecosystem can greatly vary in the length of time it takes to show any change in vegetation composition, especially one with such dense sericea lespedeza (Glenn-Lewin, 1980; Collins and Adams, 1983). A continuation of these fire regimes will give more insight as to the exact combination of treatments that will affect sericea lespedeza density and biomass production the most. However, due to the mixture of significantly decreased standing sericea lespedeza biomass in the mown fall burn plots and decrease in grass standing biomass in the spring burn plots, it appears that a shift from current fire regimes will be useful for landowners. Combining mowing and fall fire may be a successful management practice as compared to spring fires alone.

LITERATURE CITED

Allred, B.W., Fuhlendorf, S.D., Monaco, T.A. and Will, R.E. 2010. Morphological and physiological traits in the success of the invasive plant *Lespedeza cuneata*. Biological Invasions 12:739-749.

Anderson, R.C. 2006. Evolution and origin of the central grassland of North America: climate, fire, and mammalian grazers. Journal of the Torrey Botanical Society 133:626-47.

Bell, N.E. 2012. Impact of patch-burn grazing on sericea lespedeza (*Lespedeza cuneata*) seed viability. [master's thesis]. Emporia, KS: Emporia State University.

Bell, N.E. and Koerner, B.A. 2009. Impact of patch-burn management on *Sericea lespedeza*. 94th Annual ESA Meeting, August 4, 2009.

Biondini, M.E., Steuter, A.A. and Grygiel, C.E. 1989. Seasonal fire effects on the diversity patterns, spatial distribution and community structure of forbs in the northern mixed prairie, USA. Vegetation 85:21-31.

Brandon, A.L., Gibson, D.J. and Middleton, B.A. 2004. Mechanisms for dominance in an early successional old field by the invasive non-native *Lespedeza cuneata* (Dum. Cours.) G. Don. Biological Invasions 6:483-493.

Collins, S.L. and Adams, D E. 1983. Succession in grasslands: Thirty-two years of change in a Central Oklahoma tallgrass prairie. Vegetation 51:181-190.

Cope, W.A. and Burns, J.E. 1971. Relationship between tannin levels and nutritive values of sericea lespedeza. Crop Science 11:231-33.

Crawley, M.J. 1997. Plant-herbivore dynamics. Plant Ecology. Blackwell Science, Oxford. p 401–474.

Cummings, D.C., Bidwell, T.G., Medlin, C.R., Fuhlendorf, S.D., Elmore, R.D. and Weir, J.R. 2007a. Ecology and management of Sericea lespedeza. NREM-2874. Oklahoma Cooperative Extension Service, Oklahoma State University, Stillwater, Oklahoma. 8.

Cummings, D.C., Fuhlendorg, S.D. and Engle, D.M. 2007b. Is altering grazing selectivity of invasive forage species with patch burning more effective than herbicide treatment? Rangeland Ecology and Management 60:253-60.

D'Antonio, C.M. 2000. Fire, plant invasions, and global changes. Covelo, California, USA: Island Press. p 65-93.

Eddy, T.A., Davidson, J. and Obermeyer, B. 2003. Invasion dynamics and biological control prospects for sericea lespedeza in Kansas. Great Plains Research: A Journal of Natural and Social Sciences. 13:217-30.

Fuhlendorf, S.D. and Engle, D.M. 2004. Application of the fire–grazing interaction to restore a shifting mosaic on tallgrass prairie. Journal of Applied Ecology 41:604-614.

Gibson, D.J. 1988. Regeneration and fluctuation of tallgrass prairie vegetation in response to burning frequency. Bulletin of the Torrey Botanical Club 115:1-12.

Gibson, D.J. and Hulbert, L.C. 1987. Effects of fire, topography and year-to-year climatic variation on species composition in tallgrass prairie. Vegetation 72: 175-185.

Glenn-Lewin, D. C. 1980. The individualistic nature of plant community development. Vegetation 43:141-146.

Hamilton, R.G. 2003. Effects of late summer burns on sericea lespedeza. Native Warm-Season Grass Newsletter 22:4-5.

Kansas Department of Agriculture, 2011. Kansas Plant Pest Alert: Sericea Lespedeza. Available from: www.ksda.gov.

Kalburtji, K., Mosjidis, J. and Mamolos, A. 2001. Allelopathic plants. *Lespedeza cuneata*. Allelopathy Journal 8:41–50.

Keane, R.M. and Crawley, M.J. 2002. Exotic plant invasions and the enemy release hypothesis. Trends in Ecology Evolution 17:164–170

Keeley, J.E., Lubin, D. and Fotheringham, C.J. 2003. Fire and grazing impacts on plant diversity and alien plant invasions in the southern Sierra Nevada. Ecological Applications 13: 1355-1374.

Koger, C.H., Stritzke, J.F. and Cummings, D.C. 2002. Control of sericea lespedeza (*Lespedeza cuneata*) with triclopyr, fluroxypyr, and metsulfuron. Weed Technology 16:893-900.

Mack, R.N. 1985. Invading plants: their potential contribution to population dynamics. London, England: Academic Press. p 127-142.

Maron, J.L. and Vila, M. 2001. When do herbivores affect plant invasion? Evidence for the natural enemies and biotic resistance hypotheses. Oikos 95:361–373.

Ohlenbusch, P.D., Bidwell, T., Fick, W.H., Scott, W., Clubine, S., Coffin, M., Kilgore, G., Davidson, J. and Mayo, J. 2007. Sericea lespedeza: History, characteristics, and identification. Kansas State University MF-2408.

Price, C.A. and Weltzin, J.F. 2003. Managing non-native plant populations through intensive community restoration in Cades Cove, Great Smoky mountains National Park, USA. Restoration Ecology 11:351-358.

Rejmanek, M. 2000. Invasive plants: Approaches and predictions. Austral Ecology 25:497-506.

Richardson, D.M., Pysek, P., Rejmanek, M., Barbour, M.G., Panetta, F.D. and West, C.J. 2000. Naturalizations and invasion of alien plants: Concepts and definitions. Diversity and Distributions 6:93-107.

Risser, P.G. 1987. Effects of abiotic factors on energetics and nu trient cycles in grasslands and savannas. In: L. R. Pomeroy & J. J. Alberts (eds), Ecosystems, analysis and synthesis. Springer-Verlag. In press.

Robbins, M.B., Peterson, A.T. and Ortega-Huerta, M.A. 2002. Major negative impacts of early intensive cattle stocking on tallgrass prairies: The case of the greater-prairie chicken (*Tympanuchus cupido*). North American Birds 56:239-44.

Samson, F.B. and Knopf, F.L. 1996. Prairie conservation: Preserving North America's most endangered ecosystem. Washington, DC, US: Island Press. p 41.

Stevens, S. 2002. Element stewardship abstract for Lespedeza cuneata (Dumont-Cours.) G. Don sericea lespedeza, Chinese bush clover. Arlington VA, US: The Nature Conservancy. p. 1-12.

Towne, E.G. and Kemp, K.E. 2003. Vegetation dynamics from annually burning tallgrass prairie in different seasons. Journal of Range Management 56:185-192.

USDA, NRCS. 2011. The PLANTS Database. Available from: http://plants.usda.gov.

Vermeire, L.T., Bidwell, T.G. and Stritzke, J. 1998. Ecology and management of sericea lespedeza. Oklahoma State University Cooperative Extension Bulletin F-2874. Available from: http://www.okrangelandswest.okstate.edu/pdfFiles/OSUextPubs/F-2874.pdf.

Wong, B.M., Houseman, G.R., Hinman, S.E. and Foster, B.L. 2012. Targeting vulnerable life-stages of sericea lespedeza (*Lespedeza cuneata*) with prescribed burns. Invasive Plant Science and Management 5:487-493.

Zedler, J.B. and Kercher, S. 2004. Causes and consequences of invasice plants in wetlands: Opportunities, opportunists, and outcomes. Critical Reviews in Plant Sciences 23:431-452.

Table 2. Mean sericea lespedeza stem density (stems/m^2) at the Marias des Cygnes National Wildlife Refuge, Pleasanton, KS. Densities were collected in fall 2014 and 2015 prior to fall prescribed burns. Herbicide and mow treatments were applied in summer 2014 before stem densities were counted. 2014 data represents pre-fire counts, while 2015 is post-fire. Significant differences ($P < 0.05$) in secondary treatment indicated with XYZ. Values are means ± one standard error.

	2014			2015		
	Fall	Spring	Unburned	Fall	Spring	Unburned
Herbicide	0.00	0 .00	7.14 ± 7.14	5.81 ± 1.78 ^{Y}	1.90 ± 1.29 ^{Y}	9.00 ± 7.73^{Y}
Mow	67.38 ± 15.20	62.20 ± 19.56	81.44 ± 21.55	70.13 ± 11.91 ^{YZ}	76.80 ± 18.81^{YZ}	74.89 ± 12.62^{Z}
Fuel Addition	53.00 ± 19.14	78.83 ± 19.89	49.00 ± 16.82	97.82 ± 35.27 ^{Z}	91.58 ± 17.02^{YZ}	59.42 ± 15.86^{YZ}
Fire Only	74.21 ± 21.62	128.67 ± 36.77	102.80 ± 20.58	102.57 ± 27.46 ^{Z}	147.00 ± 38.73^{Z}	93.50 ± 19.89^{Z}

Figure 1. Distribution map of sericea lespedeza, *Lespedeza cuneata*, in the United States (adapted from Ohlenbusch et al., 2007).

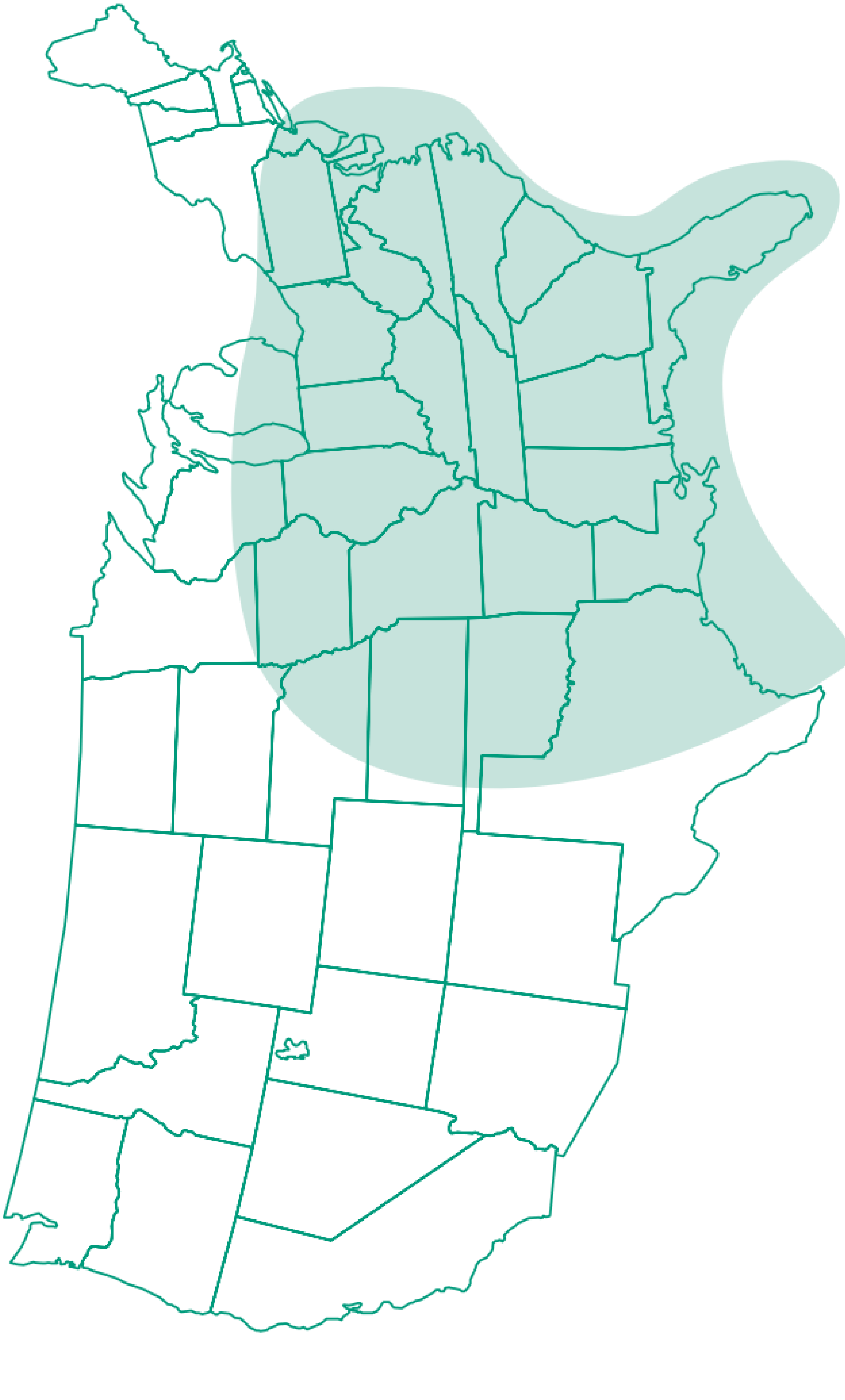


Figure 2. Aerial view of the Marias des Cygnes National Wildlife Refuge, Pleasanton, KS. Field site indicated by the rectangle in the lower southeast corner.

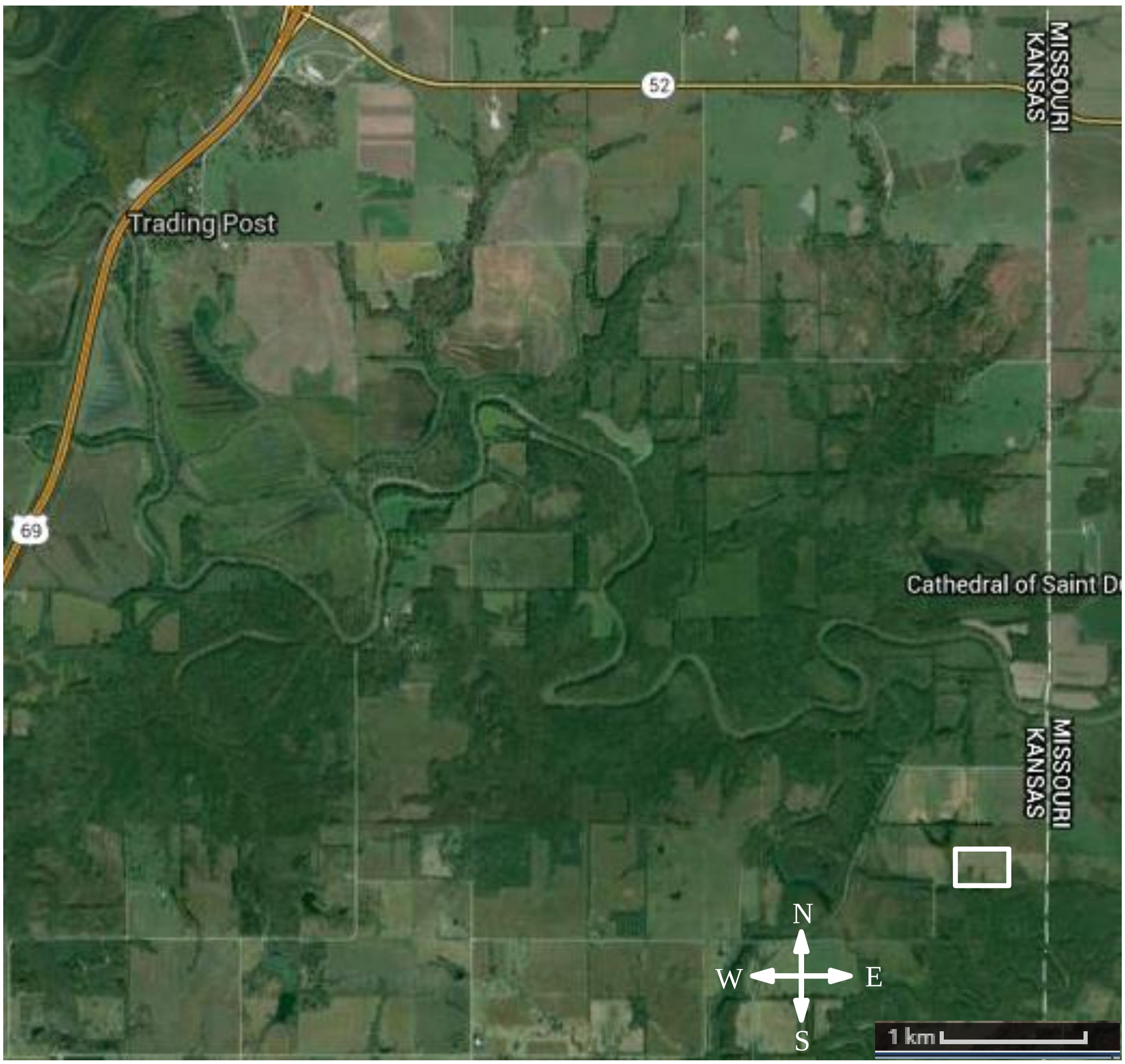

MISSOURI
KANSAS
52
Trading Post
69
Cathedral of Saint D
MISSOURI
KANSAS
N
W
E
S
1 km

Figure 3. Example layout of fire treatment for experimental plots at the Marias des Cygnes National Wildlife Refuge. Solid squares represent sampling location for total productivity, sericea lespedeza productivity, and sericea density with each subplot. Both fire season and secondary treatment were randomly assigned. Fuel load additions (litter) and burn only secondary treatments within the unburned plots were left untreated.

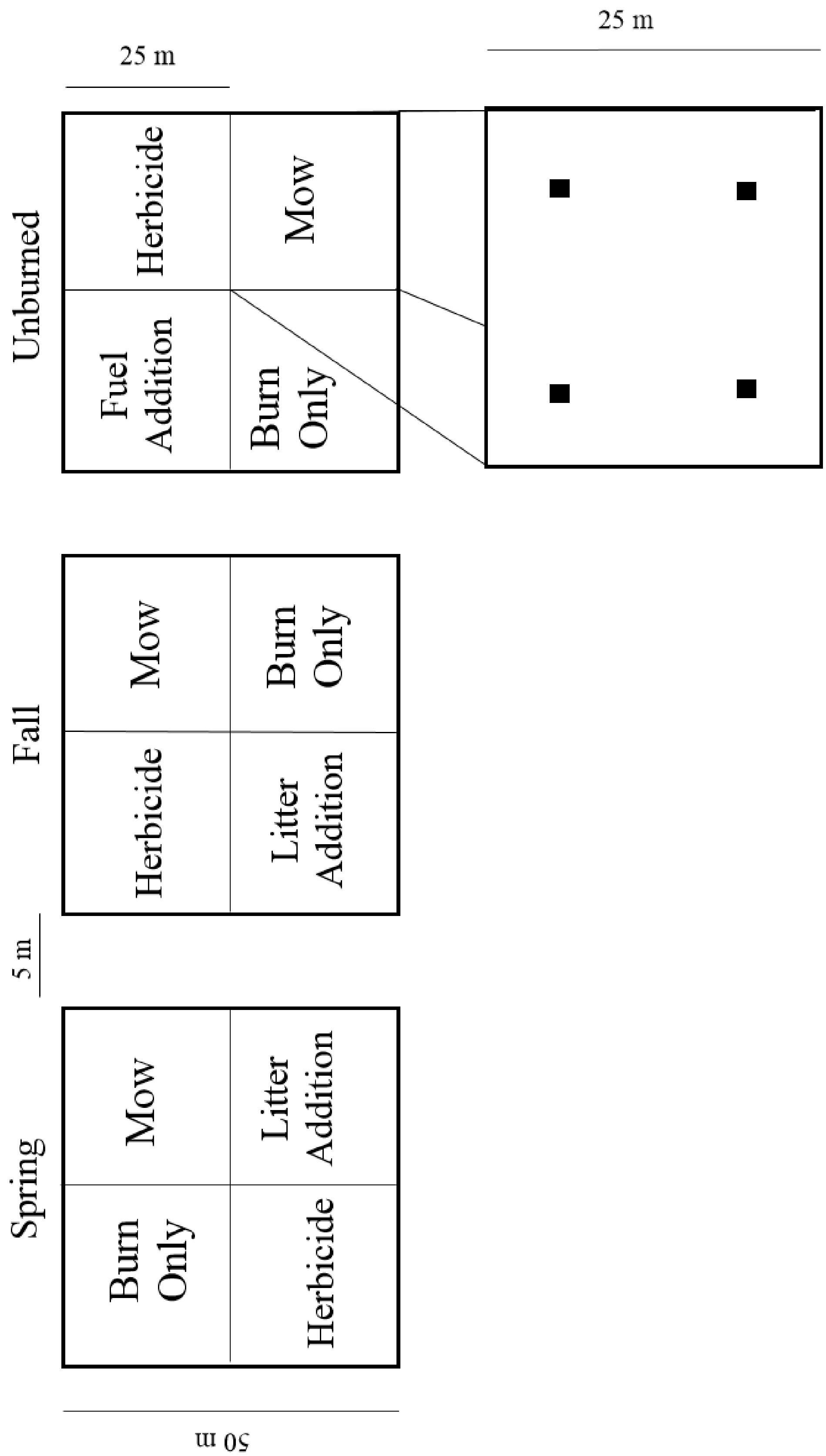
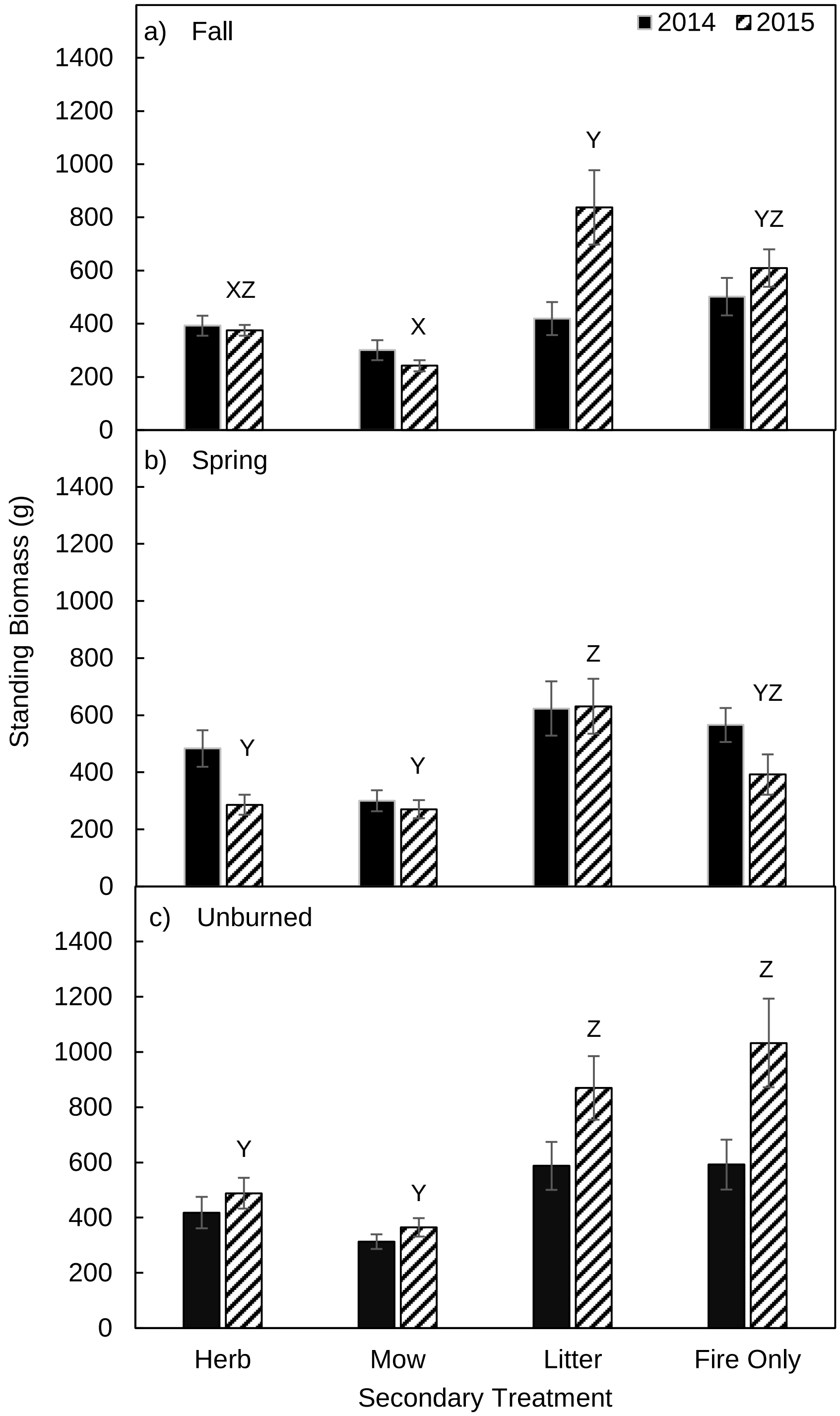

25 m
25 m
Unburned
Herbicide
Mow
Fuel Addition
Burn Only
Fall
Mow
Burn Only
Herbicide
Litter Addition
5 m
Spring
Mow
Litter Addition
Burn Only
Herbicide
50 m

Figure 4. Total standing biomass at Marias des Cygnes National Wildlife Refuge, Pleasanton, KS. Bars are means ± standard error. Solid bars represent 2014 (pre-burn) means from fire seasons, while hatched bars represent 2015 (post-burn) means from fire seasons. Significant differences ($P < 0.05$) between secondary treatments are indicated by bars with different uppercase letters X, Y, Z within the same fire season.



2014
2015
a) Fall
b) Spring
c) Unburned
Standing Biomass (g)
0
200
400
600
800
1000
1200
1400
XZ
X
Y
YZ
Y
Y
Z
YZ
Y
Y
Z
Z
Herb
Mow
Litter
Fire Only
Secondary Treatment

Figure 5. Total standing biomass at Marias des Cygnes National Wildlife Refuge, Pleasanton, KS. Bars are means ± standard error. Solid bars represent 2014 (pre-burn) means from fire seasons, while hatched bars represent 2015 (post-burn) means from fire seasons. Significant differences (P< 0.05) between fire seasons are represented by bars with different uppercase letters A, B, C within secondary treatment groupings.

\

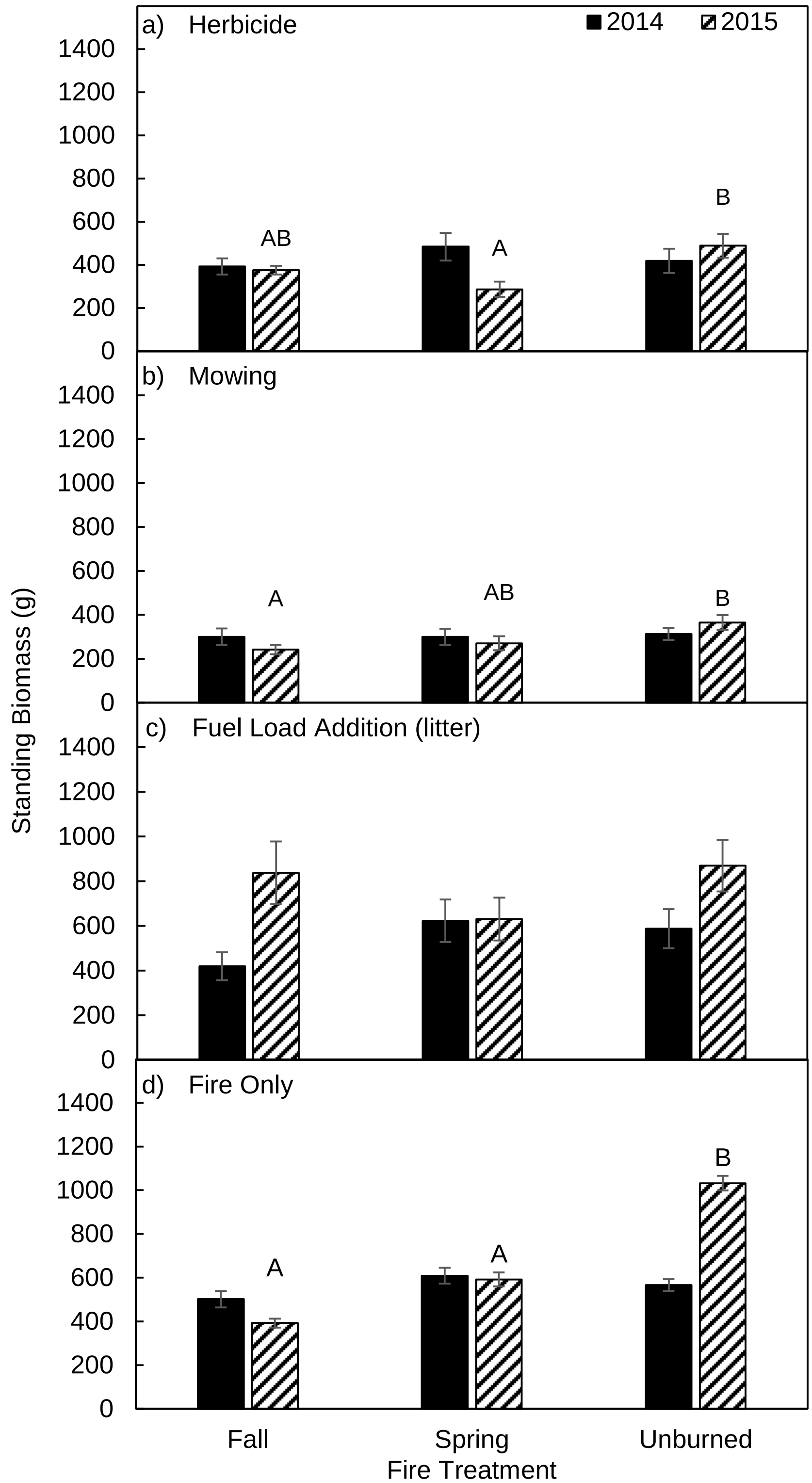

a) Herbicide
2014
2015
AB
A
B
b) Mowing
A
AB
B
c) Fuel Load Addition (litter)
d) Fire Only
A
A
B
1400
1200
1000
800
600
400
200
0
Standing Biomass (g)
Fall
Spring
Unburned
Fire Treatment

Figure 6. Standing grass biomass at Marias des Cygnes National Wildlife Refuge, Pleasanton, KS. Bars are means ± standard error. Solid bars represent 2014 (pre-burn) means from fire seasons, while hatched bars represent 2015 (post-burn) means from fire seasons. Significant differences ($P < 0.05$) between secondary treatments are indicated by bars with different uppercase letters X, Y, Z within the same fire season.

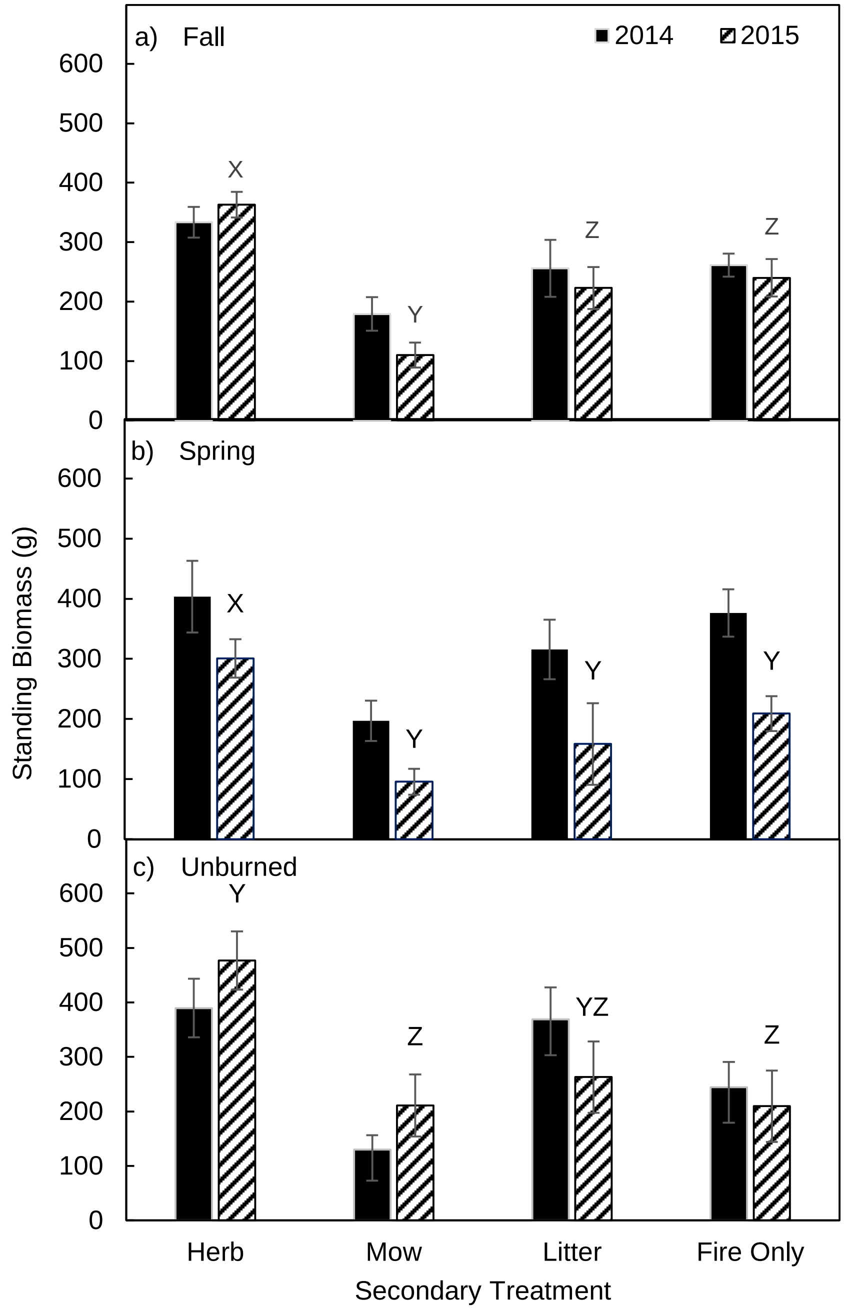

a) Fall
2014
2015
600
500
400
300
200
100
0
X
Y
Z
Z
b) Spring
600
500
400
300
200
100
0
X
Y
Y
Y
c) Unburned
Y
600
500
400
300
200
100
0
Z
YZ
Z
Standing Biomass (g)
Herb
Mow
Litter
Fire Only
Secondary Treatment

Figure 7. Standing grass biomass at Marias des Cygnes National Wildlife Refuge, Pleasanton, KS. Bars are means ± standard error. Solid bars represent 2014 (pre-burn) means from fire seasons, while hatched bars represent 2015 (post-burn) means from fire seasons. Significant differences ($P < 0.05$) between fire seasons are represented by bars with different uppercase letters A, B, C within secondary treatment groupings.

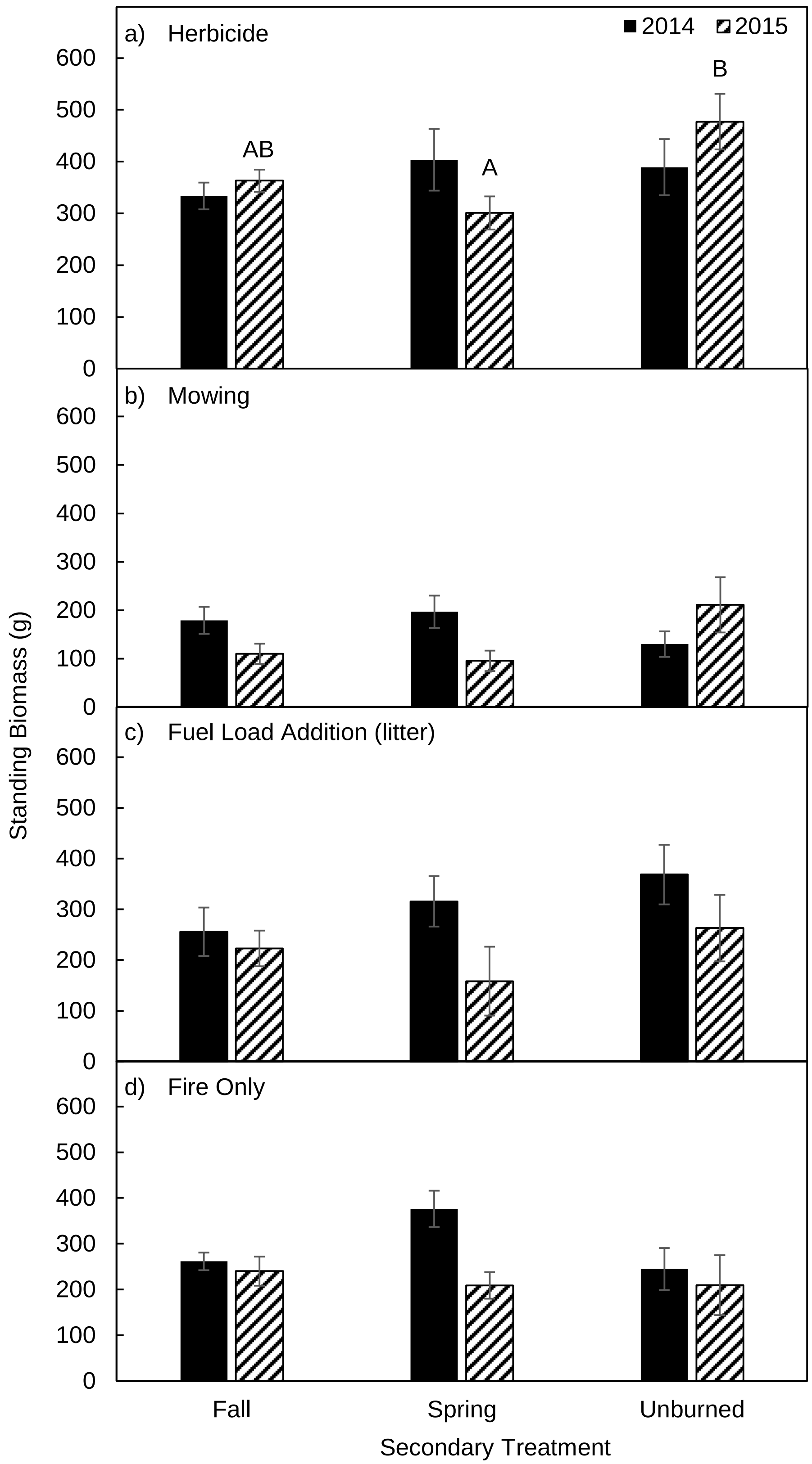

a) Herbicide
2014
2015
AB
A
B
b) Mowing
c) Fuel Load Addition (litter)
d) Fire Only
0
100
200
300
400
500
600
Standing Biomass (g)
Fall
Spring
Unburned
Secondary Treatment

Figure 8. Standing forb biomass at Marias des Cygnes National Wildlife Refuge, Pleasanton, KS. Bars are means ± standard error. Solid bars represent 2014 (pre-burn) means from fire seasons, while hatched bars represent 2015 (post-burn) means from fire seasons.

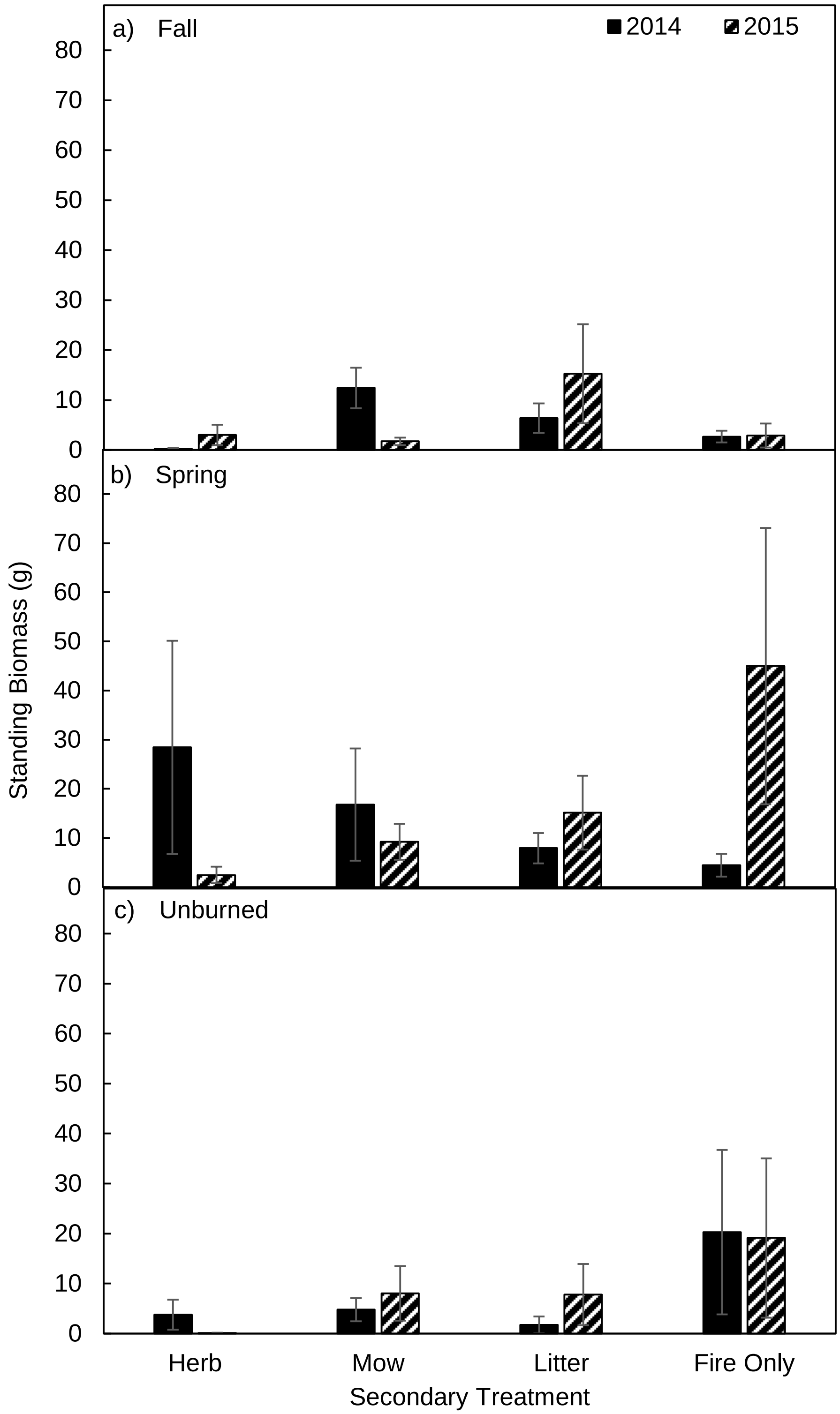

a) Fall
2014
2015
b) Spring
c) Unburned
Standing Biomass (g)
0
10
20
30
40
50
60
70
80
Herb
Mow
Litter
Fire Only
Secondary Treatment

Figure 9. Standing forb biomass at Marias des Cygnes National Wildlife Refuge, Pleasanton, KS. Bars are means ± standard error. Solid bars represent 2014 (pre-burn) means from fire seasons, while hatched bars represent 2015 (post-burn) means from fire seasons.

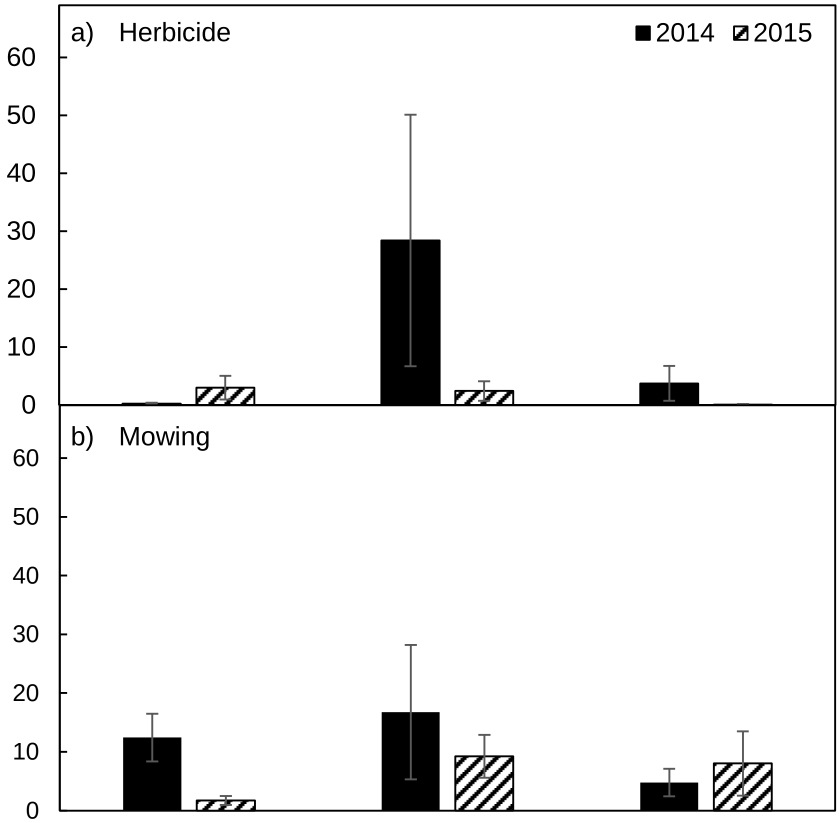

a) Herbicide
2014
2015
60
50
40
30
20
10
0
b) Mowing
60
50
40
30
20
10
0

Figure 10. Standing sericea lespedeza biomass at Marias des Cygnes National Wildlife Refuge, Pleasanton, KS. Bars are means ± standard error. Solid bars represent 2014 (pre-burn) means from fire seasons, while hatched bars represent 2015 (post-burn) means from fire seasons. Significant differences ($P < 0.05$) between secondary treatments are indicated by bars with different uppercase letters X, Y, Z within the same fire season. Graph A is fall burn, B is spring burn, and C is unburned.

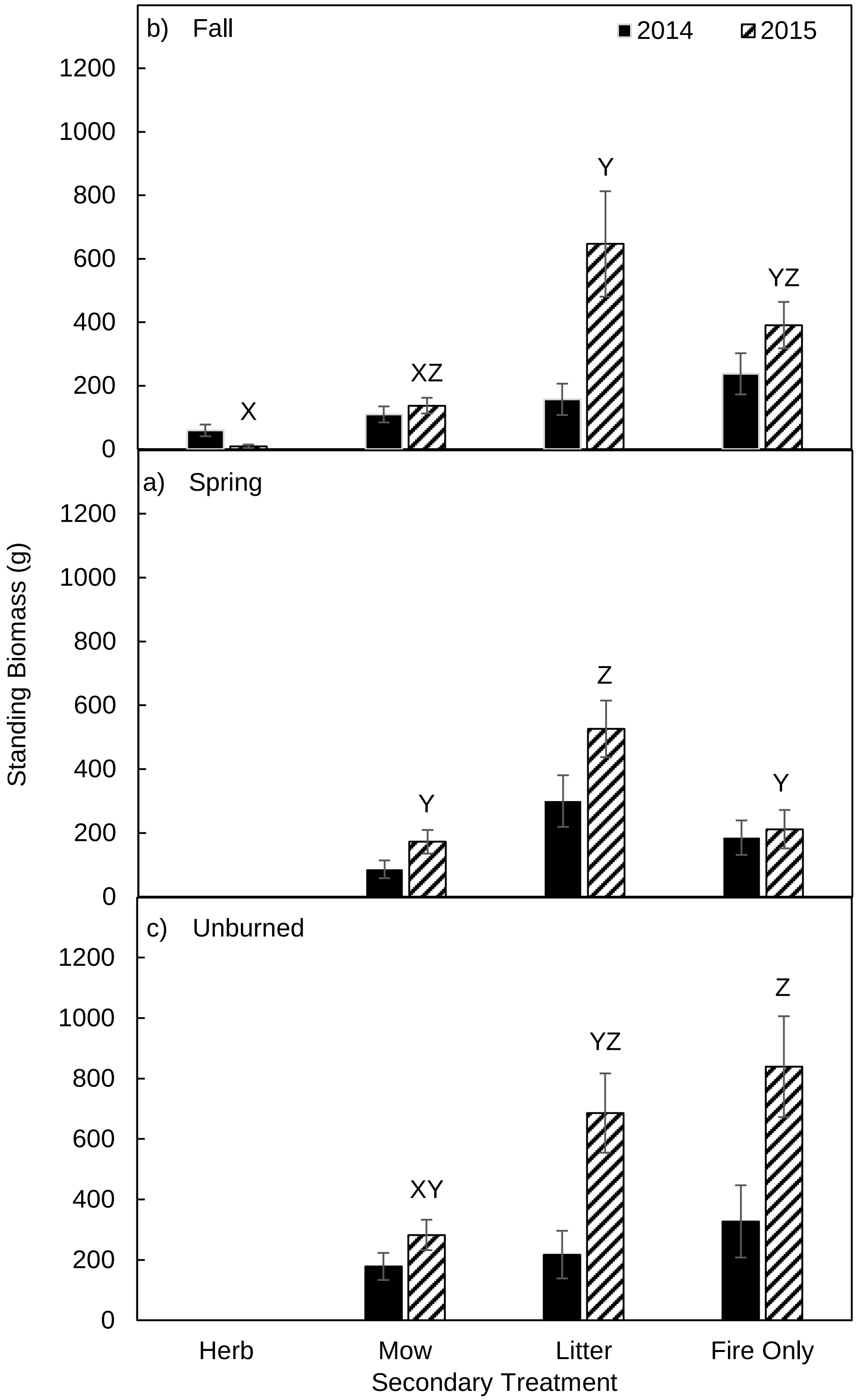

b) Fall
2014
2015
X
XZ
Y
YZ
a) Spring
Y
Z
Y
c) Unburned
XY
YZ
Z
Standing Biomass (g)
0
200
400
600
800
1000
1200
Herb
Mow
Litter
Fire Only
Secondary Treatment

Figure 11. Standing sericea lespedeza biomass at Marias des Cygnes National Wildlife Refuge, Pleasanton, KS. Bars are means ± standard error. Solid bars represent 2014 (pre-burn) means from fire seasons, while hatched bars represent 2015 (post-burn) means from fire seasons. Significant differences ($P < 0.05$) between fire seasons are represented by bars with different uppercase letters A, B, C within secondary treatment groupings. Graph A is herbicide addition, B is mowing treatment, C is fuel load addition (litter), and D is fire only.

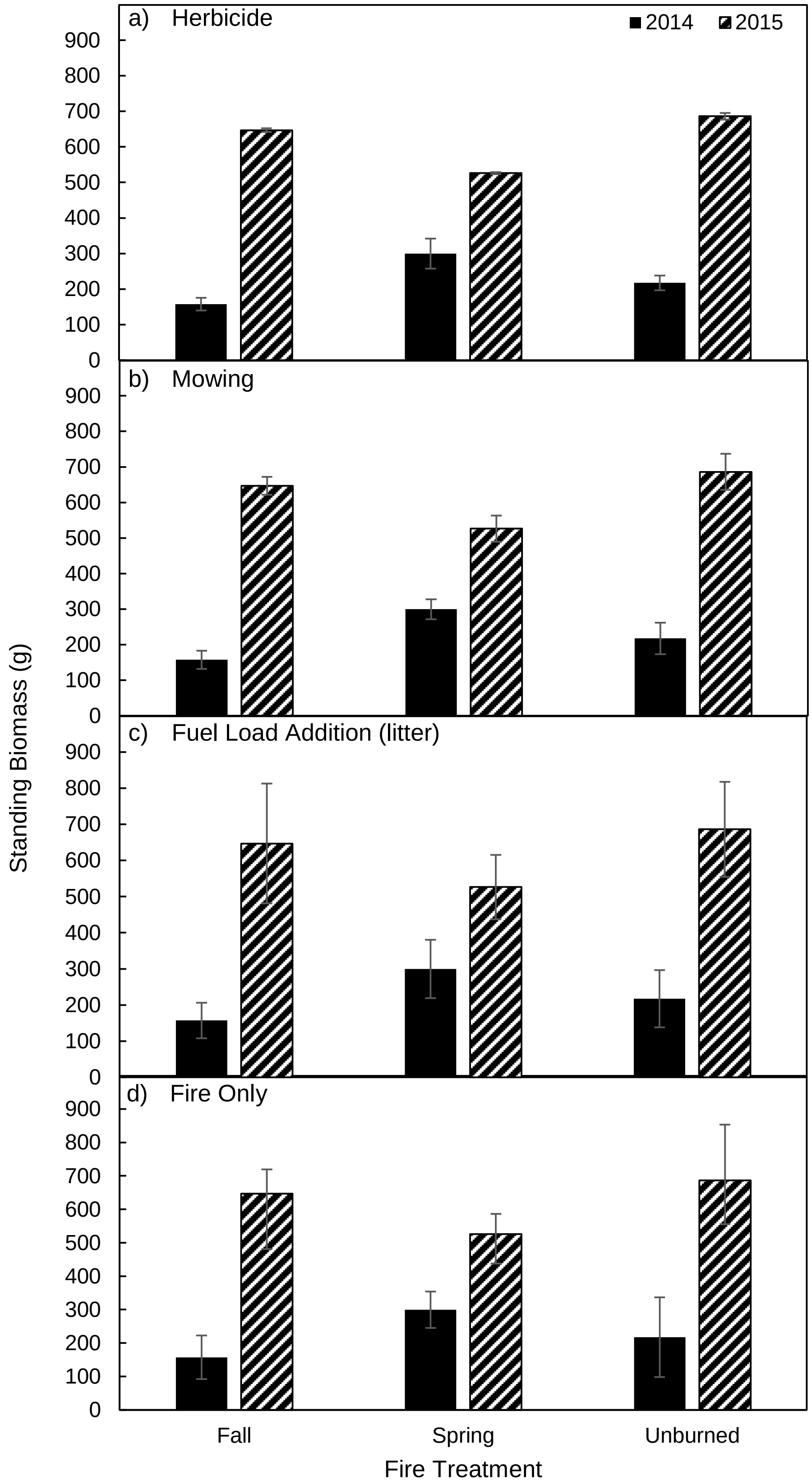
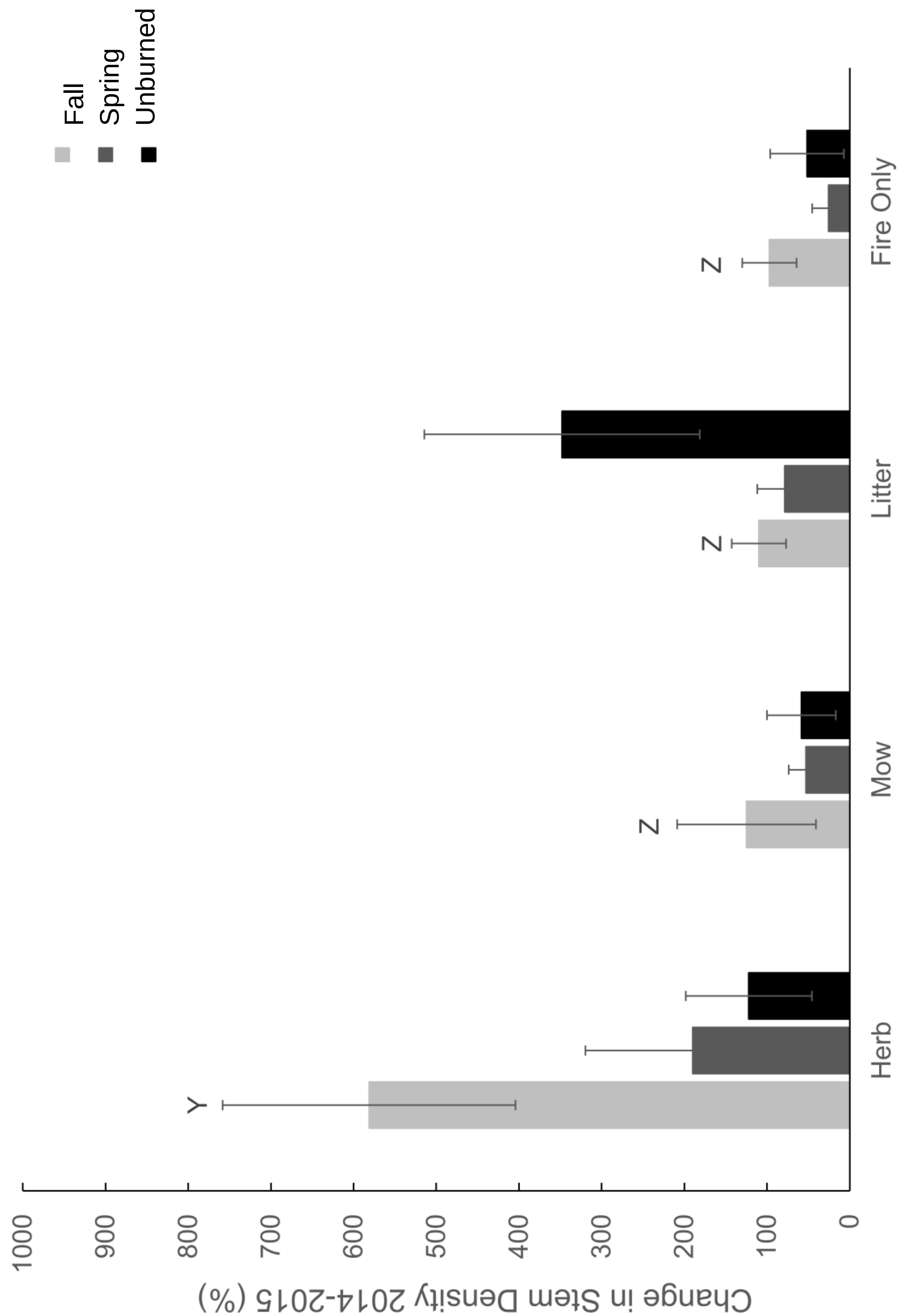

a) Herbicide
2014
2015
b) Mowing
c) Fuel Load Addition (litter)
d) Fire Only
0
100
200
300
400
500
600
700
800
900
Standing Biomass (g)
Fall
Spring
Unburned
Fire Treatment

Figure 12. Percent Change in sericea stem density at the Marias des Cygnes National Wildlife Refuge, Pleasanton, KS. Bars are means ± standard error. Solid bars represent 2015 (post-burn) means for fire seasons. Significant differences ($P <$ 0.05) between secondary treatments are indicated by bars with different uppercase letters X, Y, Z within the same fire season.


Fall
Spring
Unburned
Change in Stem Density 2014-2015 (%)
1000
900
800
700
600
500
400
300
200
100
0
Y
Z
Z
Z
Herb
Mow
Litter
Fire Only

____
Signature of Author

____
Date

The impact of fuel load and fire season on the control of sericea lespedeza, *Lespedeza cuneata*______________________________
Title of Thesis

____
Signature of Graduate School Staff

____
Date Received