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Effects of goat grazing and mowing on seed density and seed mass of *Lespedeza cuneata*

E. Barnewitz, A. Klinkenborg, and J. Scheibel
Biology Department, Grinnell College, Grinnell IA 50112, USA

Abstract

*Sericea Lespedeza (*Lespedeza cuneata*), a non-native perennial legume, is a particularly problematic invasive species for tallgrass prairie restoration, reducing plant and animal diversity while proving difficult to eradicate by traditional management tools. While reduction of aboveground growth is the goal of most eradication programs, the seed bank of* L. cuneata*, which could contribute to the germination of new plants, should also be taken into account when considering the success of any eradication efforts. This study, conducted at the Conard Environmental Research Area in Kellogg, Iowa, examined the effectiveness of seasonal mowing and consecutive summer goat grazing rotations in reducing the density and mass of* L. cuneata *seeds. We found a significant reduction in the density and mass of* L. cuneata *seeds between the mow treatment and all other treatments, while the goat rotations plots were not significantly different from each other or from the control plots in either seed density or seed mass. This data suggests that the mow treatment has been the most effective in reducing the density and mass of* L. cuneata *seeds in the soil. It also appears that even if goat grazing has been effective in reducing aboveground biomass of* L. cuneata*, it might take several more years before the seed bank of* L. cuneata *is significantly reduced.*

Introduction

One of the numerous challenges of restoring tallgrass prairie is the displacement of native species by aggressive non-native species. Sericea Lespedeza (*Lespedeza cuneata*), a perennial legume, is one of many invasive species in the tallgrass prairie region. Studies have shown that *Lespedeza cuneata* can reduce grass production in the prairie by 92% (Eddy and Moore, 1998, as cited by Silliman and Maccarone, 2005). Additionally, in a preliminary study by Eddy and Moore (1998), *L. cuneata* was found to be detrimental to insect diversity and abundance, which also impacts other native species such as insectivorous birds (Blankenship, 2000 as cited by Silliman and Maccarone, 2005). *L. cuneata* is particularly troublesome once established because, as of a 2004 report by the United States Fish and Wildlife Service, there are no economical and environmentally safe ways for eradicating *L. cuneata*.

Lespedeza cuneata was first introduced to the Southeast Prairie of Conard Environmental Research Area (CERA), near Kellogg, Iowa, in 1987 through a contaminated seed mix. In September 2004, a large section of the Southeast Prairie was burned. Since then that section has been mowed or hayed in late August or early September to remove *L. cuneata* before seed maturity. A small section of the prairie was left untreated until 2008 when six experimental 12 meter by 30 meter paddocks were set up for goat grazing. *L. cuneata* blooms in mid to late August so the goats were grazed during two consecutive weeks in the middle of August. The goats were grazed in three plots for one week as the first rotation and in the three other plots the following week for the second rotation. Three plots were established as controls. A similar rotation was conducted the following August in 2009 (Figure 1).

Casual observations show that *L. cuneata* tends to be spindly, chlorotic and with few flowers south of the “hay line” which divides the mowed and unmowed portions of the Southeast prairie. In contrast, *L. cuneata* is the dominant cover in the control plots. In the goat graze plots, the density of *L. cuneata* appears much lower than in the control plots. *L. cuneata* still appears denser in the goat rotation plots than in the mowed treatment. While reducing the density of *L. cuneata* is the goal of both the mowing and grazing treatments, the number of seeds in the soil is also an important indicator of the effectiveness of the treatments. Johnson and Anderson (1986) note that the soil contains a seed bank, or a population of viable seeds, that can produce new plants after a disturbance. This is especially pertinent to the management of the South-East Prairie because *L. cuneata* responds positively to burning, a common prairie management tool (Mottll, pers. comm.).

The purpose of our research was to compare the effect of the different goat grazing rotations and mowing on the seed density and average mass of *L. cuneata* seeds. We hypothesized that the mowed plots, since they appear to have the lowest density of *L. cuneata*, would have both lower seed density and lower average seed mass than both the goat rotation plot and the control plots. The goat plots, where the density of *L. cuneata* appears to have been diminished, would have a lower seed density and lower seed mass than the control plots.

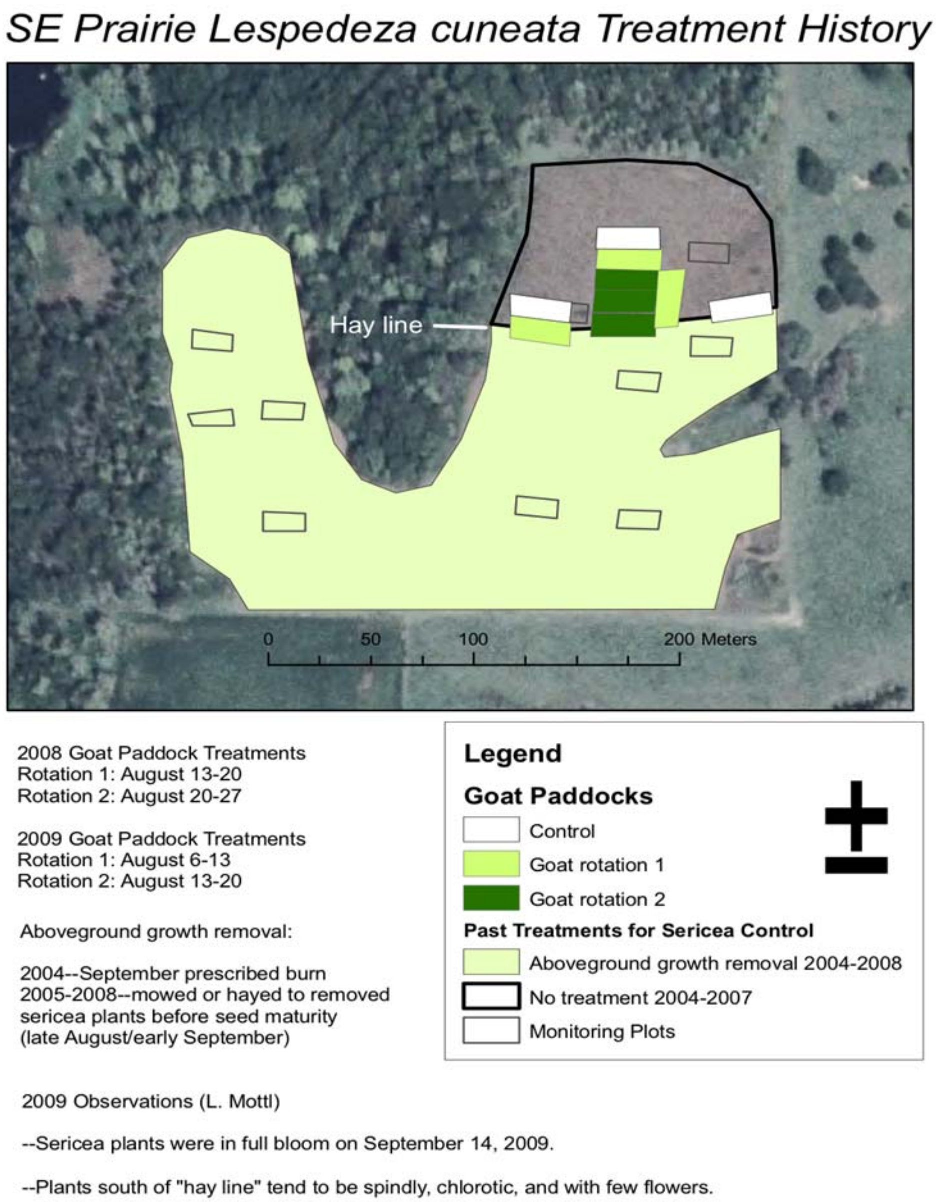

Figure 1. Map of Southeast Prairie at CERA with treatment history and experimental set-up (plots/transects labeled by number).

Methods

In October 2009, we took 108 soil samples (5 cm diameter, 5 cm depth) from the four different treatments in the Southeast Prairie at CERA. We first stratified the 3 goat rotation one plots, 3 goat rotation two plots and 3 control plots into 10m x 12m sections. Using randomly selected coordinates, we took three soil samples from each section for a total of 9 samples per plot and 27 samples per treatment. For the mowed area of the Southeast Prairie, starting from the southwest corner of the goat rotation two, plot 1, we set up three 60m long parallel transects (west to east) every 30m to the south (Figure 1). We took 9 samples from randomly selected coordinates along each transect for a total of 27 samples for the mow treatment.

After collection, we thoroughly pulverized the samples from each plot using mortar and pestle and then aggregated them. Each aggregated plot sample was sieved once through a 2mm sieve to remove organic matter and large soil particles but allow *L. cuneata* seeds to pass through, and a second time through a .42mm sieve to remove fine soil particles but retain *L cuneata* seeds. We then searched the sample by hand and collected the *L. cuneata* seeds, which were large enough (roughly 1 mm) to be readily identifiable. We found this method to be quicker and more effective for finding *L. cuneata* seeds than the soil dispersion in solution method described by Malone (1967) as an alternative to greenhouse germination for finding viable seeds in soil. We obtained a seed count for each plot and then divided the total mass (mg) of the seeds found in each plot by the number of seeds to obtain a mean seed mass per plot. We found a mean seed density per square meter (0-5 cm depth) for each plot based on the total surface area of each soil sample (19.635 cm^2) and the total seed count for each plot. In addition, we obtained the biomass (mg) and density (per m^2) of *L. cuneata* for the six goat rotation plots and three control plots from Klodd et al. (unpublished).

We used Minitab to analyze our data. Because of the nature of the seed density data, we used the non-parametric Kruskal-Wallace test to compare mean seed density between treatments and a standard 2 sample t-test was used to compare mean seed mass between treatments. We used correlation analysis to compare seed density and seed mass with the biomass and density of *L. cuneata* for the two goat rotation and control treatments.

Results

Overall, the mow treatment was consistently significantly different from both the goat rotations and control treatments for mean seed density and mean seed mass, while the goat rotations were consistently statistically similar to each other and to the control treatment for both mean seed density (Table 1; Figure 2) and mean seed mass (Table 2; Figure 3). We did not find any significant correlations between biomass and density of *L. cuneata* and mean seed density or mean seed mass per plot for the goat rotation and control treatments. It is likely that sample sizes were too small for any significant results.

Table 1. Significance of treatment comparisons in Kruskal-Wallace test for mean seed density.

Comparison	Degrees of Freedom	H value	P value
Goat Rotation 1 vs. Goat Rotation 2	1	.05	.827
Goat Rotations vs. Control	1	.07	.796
Mow vs. No Mow (Goat Rotations & Control)	1	6.25	.012

Table 2. Significance of treatment comparisons in 2 sample t-test for mean seed mass.

Comparison	Degrees of Freedom	T value	P value
Goat Rotation 1, Goat Rotation 2	2	-.39	.732
Goat Rotations, Control	2	.82	.499
Mow, No Mow (Goat Rotations & Control)	2	-16.53	.000

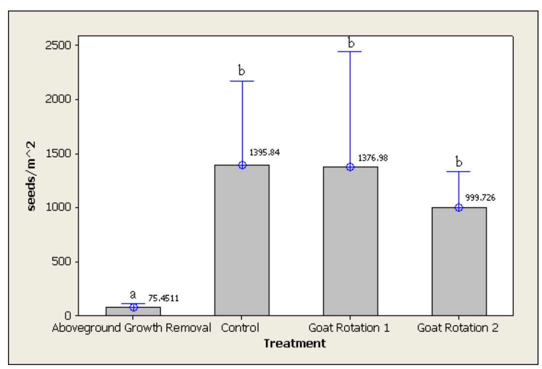

Figure 2. Mean seed density (+ S.E.) for each treatment (n=3). In Kruskal-Wallace tests between treatments, significant differences are indicated by *different letters* (p<.05).

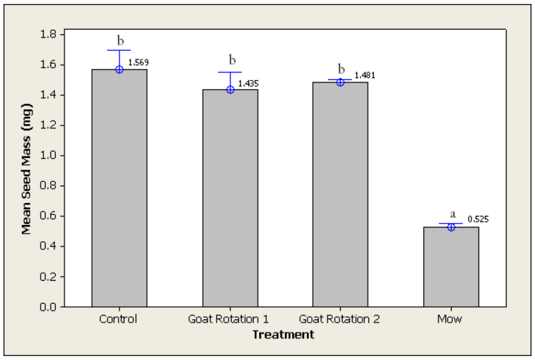

Figure 3. Mean seed mass (+ S.E.) for each treatment (n=3, except mow n=2). In two sample t-tests between treatments, significant differences are indicated by *different letters* ($p<.05$).

Discussion

Our data suggests that mowing has reduced the mean seed density by over 90% (75.5 seeds/m2 vs. 1258 seeds/m2) when compared to the goat rotations and control treatments. The mean seed density of both goat rotations and the control treatments, however, were statistically indistinguishable from each other. There are several reasons why seed density could have been reduced to this degree in the mowed area when compared to the goat rotation and control treatments. First, the mowing treatment was implemented three years earlier than the goat rotations and has been in effect five seasons, while the goat rotations have only been in effect for two seasons. Even if *L. cuneata* seeds have not been infiltrating the seed bank of the goat rotations for the past two seasons, the seed bank may still represent the past seed production before the treatment was implemented (Rabinowitz 1981). Thus significant impacts from the goat rotations on the overall seed bank of *L. cuneata* may not be observed for several more seasons. Because we did not stratify the soil cores, we also do not know which layers contributed the most seeds so our estimation of the seed bank includes both short-term persistent seeds in the top layer of soil and long-term persistent seeds deeper in the soil. Future research on the seed bank of *L. cuneata* should include stratifying soil cores to determine the contribution of layers at different depths and measuring the contribution of seasonal seed rain to the soil through the use of seed traps (Jakobsson et. al, 2006).

The difference between the mowing treatment and the goat rotations could also be due to the fact that mowing effectively eliminates all aboveground biomass, preventing any seed production, while goats selectively graze on *L. cuneata* and do not necessarily prevent all seed production. If this were the case, one would expect that goat grazing would produce some effect on the seed density when compared to the control. Recent studies have shown that the grazing of forbs diminishes reproduction overall by reducing the number of flowering stems and decreasing reproductive allocation (Damhoureyeh and Hartnett, 2002; Hickman and Hartnett, 2002). We would assume similar results for grazing of *L. cuneata* and thus a reduction in seed production. We found, however, that there was no discernable difference in seed density between the goat rotations and the control plots. Thus it appears that if there has been a reduction in seed production of *L. cuneata* due to grazing, it has not resulted in a significant reduction in the seed bank. Therefore the most likely explanation for this inconsistency is that there is a “lag” time between the effect of grazing on seed production and the eventual effect on the seed density in the soil. Future research on *L. cuneata* at CERA could measure the effect of grazing specifically on reproduction in order to determine whether seed production has been reduced.

Mean seed mass in the mow treatment was reduced by over 60% (.525 mg vs. 1.495 mg) when compared to the goat rotations and control treatments. The mean seed mass of both goat rotations and control treatments, on the other hand, did not significantly vary from each other. Herbivory affects all aspects of a plant’s life, from growth and abundance to reproductive output. Certain types of herbivory, however, have a greater effect on reproduction. Spotswood et. al. (2002) found that meristem loss had a greater effect on seed mass than just leaf removal. Mowing mimics meristem loss to a greater degree than the goat grazing because the goats only eat the foliage while mowing cuts the plant nears its base. Therefore, it is likely that seed mass of any seeds produced during treatment would be reduced by a greater degree in the mowing treatment than by the goat rotation treatments. Alternatively, the “lag” time explanation may be more compelling. Future research on *L. cuneata* seeds in the soil bank might include testing the seeds for viability by greenhouse germination or by a tetrazolium test (Malone 1967). Lower seed mass may suggest reduced viability, so our results illustrate that not only are there fewer seeds in the mow treatment than in the other treatments, but that the seeds present are less viable. While these results endorse mowing as an effective treatment for reducing the seed density and seed mass of *L. cuneata*, goat grazing may produce similar results in the coming years. In addition, grazing may be more desirable than mowing for ecological reasons as long-term invasive species control and thus ultimately more functional.

Acknowledgements

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