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Value of Goats as a Mechanism for Eliminating *Lespedeza cuneata* from a Restored Tallgrass Prairie

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Abstract

Recent efforts to restore America's tallgrass prairie are challenged by the introduction of invasive species that can monopolize resources and suppress the growth of native plants. Our experiment studied the effects of a new method, goat grazing, on the invasive plant Lespedeza cuneata *and soil conditions in order to determine the value of goats as an invasive plant control mechanism. The study was conducted at the Conard Environmental Research Area of Grinnell College, near Kellogg, Iowa. We collected and tested plant and soil data in October, 2009 from test plots that had never been grazed and plots that were grazed by goats at two different times during the summers,* L. cuneata*'s primary growing period, of 2008 and 2009. We found* L. cuneata *in grazed plots to have significantly lower mean density, biomass, and height; however, soil conditions did not vary among treatments. These results show that goat grazing is an effective eliminator of the invasive species and has minimal impact on the soil. Thus, this treatment may be useful for future restoration efforts that involve species elimination.*

Introduction

Since the 19th century, farmers have exploited the fertile midwestern United States tallgrass prairie ecosystem with sprawling crop fields, displacing native prairie plants (Schweider, 2009). Currently, conservationists are working to restore small segments of former prairie to their original condition. In order to create true prairie habitats, non-native species that threaten native populations must be eliminated. This is commonly done through burning treatments; however, *L. cuneata* is adapted to fire (Ohlenbusch, et al., 2001) and requires an alternative extermination method. Researchers at the Conard Environmental Research Area (CERA) of Grinnell College, near Kellogg, Iowa, are using goat grazing as a mechanism for reducing the population of *L. cuneata*, a thriving invasive species that severely threatens native plants by monopolizing resources (Mottl, personal communication). L. cuneata is a perennial legume brought into a segment of CERA in a contaminated seed mix. It may be detrimental to the prairie ecosystem because it shades out other native plants (Guether et al., 2004), reducing grass production by up to 92% (Eddy and Moore, 1998, as cited by Silliman and Maccarone, 2005) and decreases abundance and diversity of insects that are important in some bird diets (Blankenship, 2000 as cited by Silliman and Maccarone, 2005). *L. cuneata* has a deep woody taproot which produces numerous lateral and downward branches that keep producing more fibrous roots (Ohlenbusch et al., 2001); therefore, the plant spreads very quickly and can withstand drought. While goat grazing may reduce this noxious plant's population, it may also impact several soil conditions, which in turn influence both native and invasive plant growth.

Grazing goats could be a highly beneficial factor in controlling invasive species. While some animals target native prairie plants and leave invasive species to prosper (Knapp et al., 1999), goats are less particular in the plants they consume, often aiming for the plants most available to them (Nastis, 1996). Therefore, goats are more likely to consume abundant invasive species than sparse native plants, potentially making them a valuable invasive plant control mechanism. Additional research shows that grazing animals may cause variation in prairie soil. Goats may cause a small decrease in soil pH and moisture, and their nutrient-rich urine may increase soil nitrogen availability in grazed grasslands (Ritchey et al., 2008), which assists in plant growth and photosynthesis (Knapp et al., 1999). Carbon levels in the soil rise with nitrogen availability, which may increase rates of photosynthesis for some species, thus boosting plant biomass (Walters et al., 2006).

Based on this information, we hypothesize that the goats will increase soil available nitrogen and carbon while slightly decreasing soil moisture and pH. We also hypothesize that goat grazing will reduce density, height, and biomass of *L. cuneata*, because goats graze on the upper part of the plants; removing the tops of plants would eliminate growth buds and reproductive parts (Remaley, 2009). Our tests of goat grazing

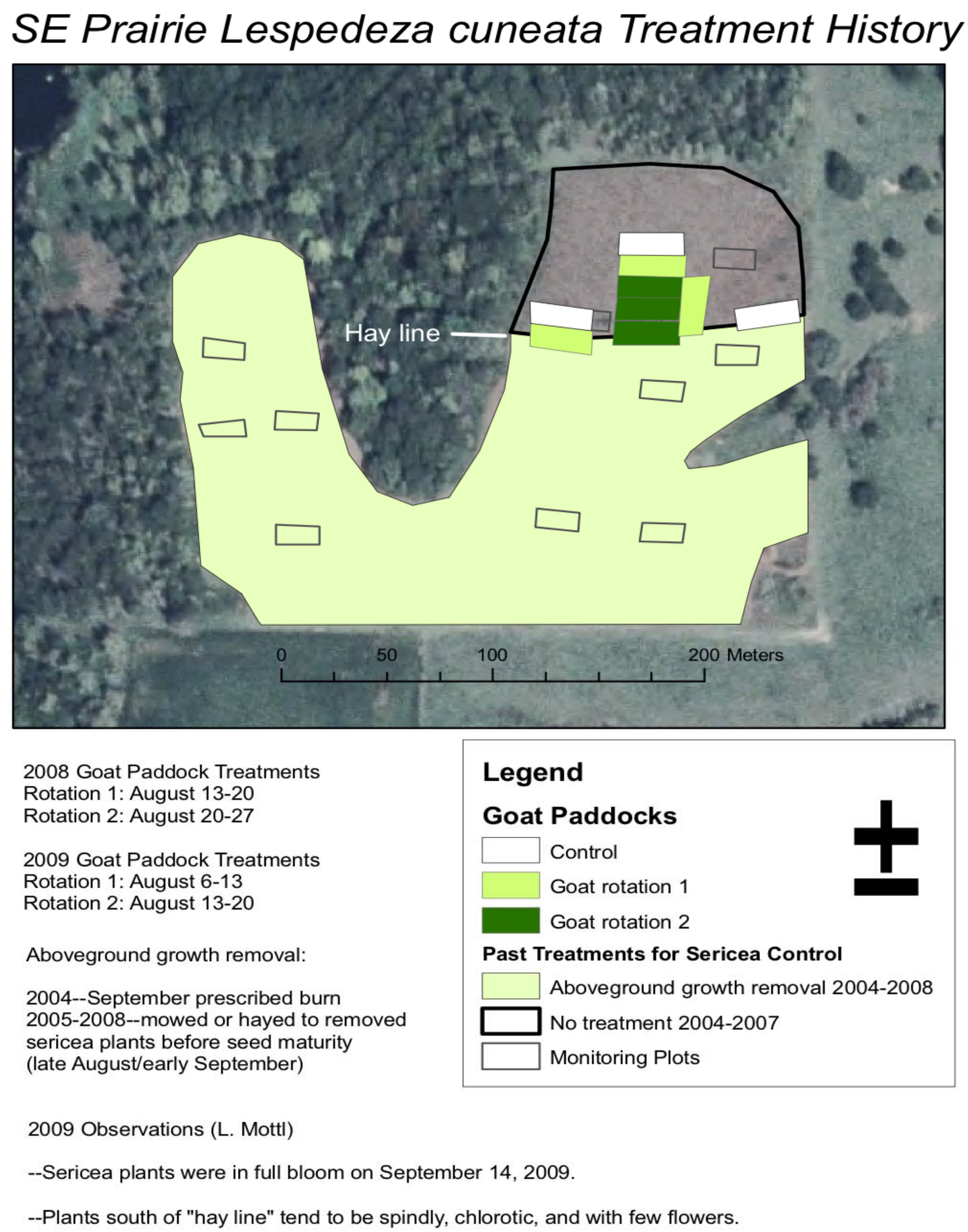

Figure 1. Test area of CERA that was contaminated by *L. cuneata*. All of our observations took place on test plots north of the “hay line.”

effects on *L. cuneata* and soil conditions will be conducted on restored prairie plots exposed to *L. cuneata* seeds that have been periodically grazed by goats for two summers and adjacent ungrazed plots at CERA (Figure 1).

Methods

Our studies took place on nine 30 meter by 12 meter unburned, reconstructed prairie plots. Three of these plots were labeled “Rotation One” plots, grazed by goats for one week in mid-summer of 2008 and 2009. Another three plots, labeled “Rotation Two,” were grazed by the same goats for one week in late summer of the same years. The remaining three plots have never been grazed for the duration of the prairie's reconstruction (Figure 1).

We used stratified random sampling to gather data from our plots. On each plot, we created six 5-meter by 12-meter segments. Within each segment, three 5-cm deep by 2-cm wide soil core samples were collected at a random point. One of the samples from each point was tested for moisture and pH, another was tested for carbon content, and the third sample was sent to Iowa State University in Ames, IA to be tested for available nitrogen.

To measure carbon and moisture content, the soil samples were massed on a gram scale before being ground in a 2 mm sieve and dried in a 40ºC oven for 48 hours. They were then massed again, and the difference between wet and dry masses determined the soil moisture. Then, the samples were ashed in an incinerator for one hour and massed again; the difference in mass between dried and ashed samples determined carbon content. To gather pH data, the second group of samples was ground and dried for 48 hours and mixed with deionized water to form soil solution samples, which were read by Midland Scientific Inc Model 8010 pH meter probe.

We also compared *Lespedeza cuneata* biomass, height, and density among treatments. We measured height and collected the above-ground portion of the plant closest to a random point in every 5 meter by 12 meter segment of each experimental plot and measured plant biomass after drying samples for 48 hours. We measured plant density in one randomly chosen 1-meter wide belt transect within each 5-meter wide segment in the nine experimental plots.

We calculated average values among samples in each plot and then used Minitab to compare treatment means using analysis of variance (ANOVA) and Tukey's multiple range tests.

Results

Clear differences appeared between conditions of *Lespedeza cuneata* in the grazed and ungrazed plots; however, very little difference existed between the species' population in the Rotation One and Rotation Two treatments. We found a variation in the average biomass of individual *Lespedeza cuneata* plants from the Control plots to goat-grazed plots (f=6.98, p=0.027). The average biomass of the species in ungrazed plots was ten times greater than that in the grazed plots, but no significant difference in plant biomass was found between Rotation One plots and Rotation Two plots (t=.35) (Figure 2).

Like biomass, the Control plots possessed significantly higher densities of *Lespedeza cuneata* than the grazed plots. The species' density in the Control plots was more than two times that of Rotation One and more than three times that of Rotation Two (f=18.66, p=0.003). The difference in density of *Lespedeza cuneata* between the Rotation One and Two plots was minimal, 1.3 plants per m^2 (t=1.01) (Figure 3).

Average plant height in the Control plots was approximately two times that of the Rotation One and Two plots (f=31.53 p=.001), and the average difference between Rotation One and Rotation Two plots was 0.1m (t=1.02) (Figure 4). We found a significant positive correlation (r=.972, p=>0.001) between the height and density of *Lespedeza cuneata* in our test plots (Figure 5).

Average soil available nitrogen in the form of NH_{4+} was significantly higher in the ungrazed plots than in the grazed plots (f=5.12, p=0.05), but the difference in NH_{4+} concentration between Rotation One and Rotation Two plots was non-significant (Figure 6, t= -0.38, p= 0.726).

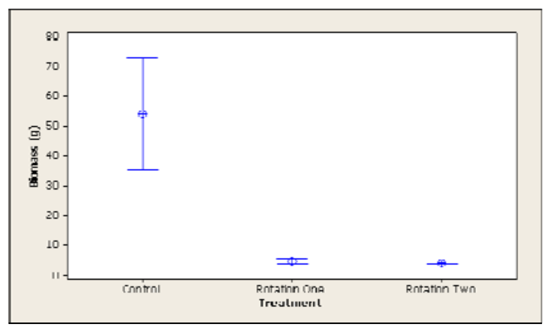

Figure 2. Biomass per plant of *Lepedeza cuneata* in control plots, rotation one plots and rotation two plots. Bars indicate one standard error of the mean. N=3

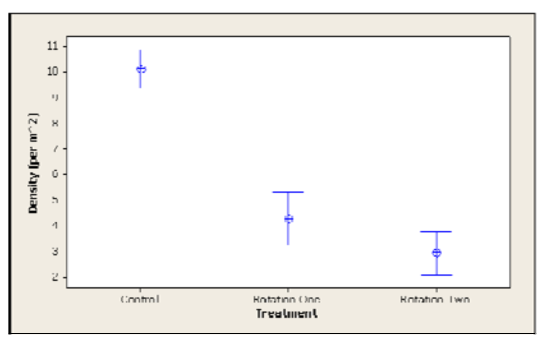

Figure 3. Density of *Lespedeza cuneata* in control plots, rotation one plots and rotation two plots. Bars indicate one standard error of the mean. N=9

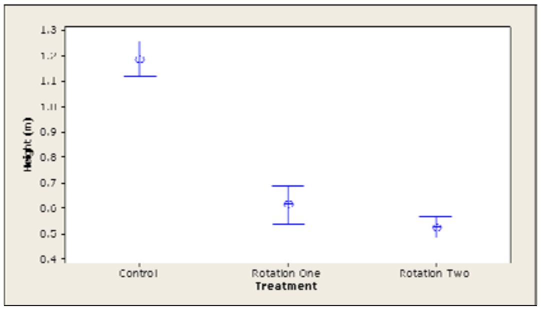

Figure 4. Height of *Lespedeza cuneata* in control plots, rotation one plots and rotation two plots. Bars indicate one standard error of the mean. N=9

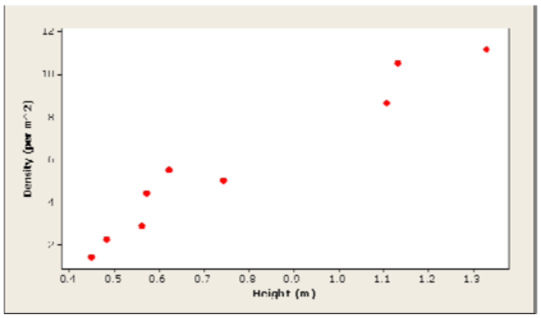

Figure 5. Correlation between height and density of Lespedeza cuneata. Density (per m^2) = - 2.492 + 10.65 Height (m).

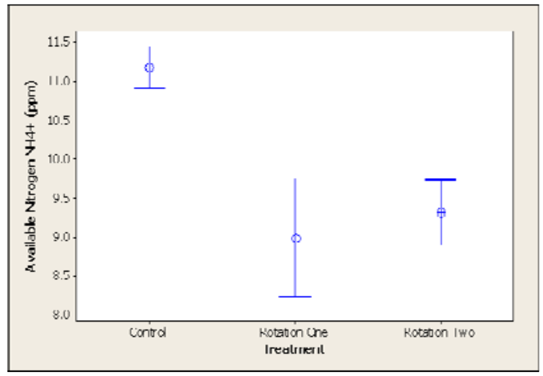

Figure 6. Average available nitrogen in the form of NH_{4+} in the soil in Control plots, Rotation 1 plots, and Rotation 2 plots. Bars indicate one standard error of the mean. N=9

Other differences in soil composition among the plots were not significant. Soil carbon levels varied non-significantly, by about 0.6%, among the Control, Rotation One, and Rotation Two plots (f=0.45, p=.655). Likewise, differences in soil moisture among the three treatments varied only slightly (f=0.81, p=.489), and soil pH showed no significant variation among the plots (f=.800, p=.492) (Table 1).

Table 1. Soil composition.

Treatment	Soil pH		Soil Carbon (%)		Soil Moisture (%)	
	Mean	Standard Error	Mean	Standard Error	Mean	Standard Error
Control	6.43	0.15	5.43	0.32	31.18	0.96
Rotation One	6.54	0.1	5.79	0.42	30.73	0.27
Rotation Two	6.62	0.03	5.17	0.6	30.04	0.47

Discussion

Because the goats consumed large amounts of *Lespedeza cuneata*, they proved to be an effective mechanism for reducing the height, biomass, and density of the invasive species. Our results showed significantly higher *Lespedeza cuneata* stem height and biomass in the ungrazed plots than in the grazed plots. The height and biomass were directly reduced in grazed plots because goats eat the tops off of the plants, therefore eliminating some of the plants' early to mid-summer growth (Hickman and Hartnett, 1999).

The goats' reduction of *Lespedeza cuneata* height and biomass caused the invasive plant to be significantly less abundant in the Rotation One and Two plots than in the Control. Goats tend to graze on vegetation at their neck level (Nastis, 1996), and *L. cuneata* was the only plant that reached that height in most tested areas. Therefore, the goats targeted the plant. In the process, the goats consumed the seed-producing part of the stems, hindering reproduction. Because the population decreased substantially in the grazed plots over the course of CERA's two-year treatment, native plants may be able to take advantage of resources previously monopolized by *L. cuneata* in these areas (Hickman et al., 2002). Research should be done on the plots in following years to see if native plant abundance and diversity has increased after the reduction of *L. cuneata*.

Another trend in our findings is the lack of significant variation between the Rotation plots, showing that the time during August that *L. cuneata* is grazed does not impact the species' population or growth. Rotation Two plots were grazed immediately after the Rotation One plots, which may not have left enough time for significant differences in plant growth to occur, therefore, further studies examining time of grazing should be conducted to determine if the time of grazing in *L. cuneata's* growing season impacts the invasive species' growth. These may include grazing the plant early on in its growing season as well as in its peak growing period, late summer

Our study found that mean NH_{4+} (available nitrogen) in the ungrazed plots was significantly higher than in the grazed plots, which contradicted our hypothesis that available nitrogen levels would be higher in grazed plots due to the deposition of nitrogen-rich goat urine. One possible explanation for the discrepancy could be that *L. cuneata* is a legume which fixes NH_{4+} (Guenther et al., 2004); thus, it is likely that the nitrogen fixed by the abundant *L. cuneata* in Control plots exceeded that of the Rotation One and Two plots, which had significantly lower densities of *L. cuneata*. Also, in Rotation plots, NH_{4+} was deposited by goat urine in sporadic spots, while NH_{4+} in Control plots was distributed thoroughly throughout the soil by extensive root systems of the abundant *L. cuneata* (Ohlenbusch et al., 2001). Therefore, it would be more likely for a soil sample high in available nitrogen to be taken from a Control plot than a Rotation One or Two plot.

Other than manipulating available nitrogen levels, we found that goat grazing did not significantly impact the prairie soil. Soil pH varied little between Control plots and Rotation plots, possibly because each Rotation plot was only subjected to goat grazing for one week every summer since 2008; longer-term animal grazing may cause more drastic differences, as it did in the study performed by Knapp et al. (1999), which grazed animals on tallgrass prairies constantly for twelve years prior to the study. Carbon levels displayed no significant difference among the testing plots. This finding contradicts Walter et al.'s (2003) research, which found grazing animals' urine to increase soil carbon concentration. One reason for the difference in results between our studies might be that the grazing period in Walter's study was 90 days in the summer, while ours was only seven summer days per Rotation; the grazing in our study may not have been intense enough to affect soil carbon concentration at CERA. Finally, there was no significant difference in soil moisture among grazed and ungrazed plots. Frequent rain occurred prior to our soil sampling, so those samples may not have been accurate representations, since the effect of grazing may have been cancelled out by the sudden influx of moisture on the soil. The small difference we saw in moisture among the plots seemed to be influenced by the plots' elevations rather than the treatments; CERA's plots were located on a slight slope, and those at lower elevations showed higher soil moisture levels.

In the context of prairie restoration, goats proved to be a good technique for reducing *Lespedeza cuneata* height and biomass, in turn eliminating the invasive species' density. This decrease in density may allow native plants to grow more aggressively, since they will have more access to resources such as sunlight and water, which were previously monopolized by *L. cuneata*. Additional research should be done to compare biodiversity and plant abundance between grazed and ungrazed plots, in order to test whether or not native plants began to prosper after the reduction of *Lespedeza cuneata*. Also, because our study did not display significant differences in soil conditions among treatments, as previous studies have, future research should be done on plots that have been grazed for longer periods of time, to see if time is a large factor in goats' impact on soil.

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