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Effect of mid-summer haying on growth and reproduction in prairie forbs

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Mid-summer haying is a common management practice for prairies; plant species could differ in the effect of haying on subsequent growth and reproduction. We examined the effect of haying on prairie species by performing a clipping experiment. For each of seven species, sixteen plants were chosen and half were randomly assigned to a clipping treatment and half to a control treatment. Experimental plants (and surrounding vegetation) in the clipped treatment were cut to a ten cm height in summer for two years. Measurements of plant height and the number of inflorescences were taken on all plants prior to clipping in June and in the fall each year. For many species, clipped plants were smaller than control plants in the fall after clipping. However, after overwintering, there were few significant differences in plant size or reproductive output between plants that were previously clipped and control plants. Some species, however, did show persistent effects of clipping. For example, both plant size and number of inflorescences were reduced by clipping in *Lespedeza capitata*. Similarly, clipped plants of *Amorpha canescens* had fewer inflorescences the year after clipping compared to control plants. Future studies should examine long-term effects of haying on plant growth and reproduction, and explore whether such effects depend on plant life forms or flowering phenologies.

Key words: Amorpha, Lespedeza, *management practice, mowing, prairie*

Introduction

The prairies of the Central United States have been dramatically reduced because of agriculture and human usage (Samson and Knopf 1994). The remaining prairies are managed by burning, mowing, haying, and grazing. Experimental studies involving cut vegetation include mowing or clipping treatments; typically in these studies there is no mention of removal of cut vegetation from the site. For example, prairie "clipping" studies evaluated the effect of grazing on grass biomass or forage quality (e.g., Aldous 1930) and Williams, Jackson, and Smith (2007) noted that frequent mowing created gaps that allowed for forb establishment from seed. To directly simulate haying, mown vegetation should be removed. Effects on growth of grass species can be differential: for example, the timing of mowing treatments and whether mown vegetation was removed affected the control of an invasive grass in Oregon and the maintenance of native species (Wilson and Clark 2001). Haying in Kansas prairies often maintains the abundance of C3 grasses and forbs in the community, which can be excluded by C4 grasses under other management practices (Collins et al. 1998). In general, the net result of haying management is often high plant diversity, with most diversity due to forb species (Jog et al. 2006).

Despite the overall positive effect of haying and mowing on forb species diversity, species may be affected in different ways. For example,

dominant forbs in a Nebraska prairie were not significantly altered by haying (Hover and Bragg 1981) while *Aster ericoides* was reduced in Kansas mown prairies (Gibson, Seasted, and Smith 1993). In these studies, researchers examined changes in percent cover of forb species in the context of larger community ecology studies. Percent cover changes, however, can be difficult to interpret from an individual plant perspective, and provide no information on haying effects on plant reproduction. To directly examine how haying affects the demography of forb species, we examined plant size and reproduction of individual plants of seven species of prairie forbs exposed to experimental haying treatments.

Methods

Study Species

We chose common forbs that are often used in restoration projects. These species are from five families: Asclepiadaceae (*Asclepias tuberosa* L., butterfly milkweed), Asteraceae (*Ratibida pinnata* (Vent.) Barnh., grayhead prairie coneflower; *Silphium laciniatum* L., compass plant), Fabaceae (*Amorpha canescens* Pursh, lead plant; *Lespedeza capitata* Michx., round-head lespedeza), Mimosaceae (*Desmanthus illinoensis* (Michx.) MacM., Illinois bundleflower), and Lamiaceae (*Salvia azurea* Lam., blue sage) (names based on the Great Plains Flora Association 1986). All species are iterocarpic perennials. All are herbaceous with the exception of the woody shrub, *A. canescens*. Flowering time is variable, with *A. tuberosa, A. canescens,* and *D. illinoiensis* flowering earlier (May/June – August), while the other four species flower from June/July to September/October (Great Plains Flora Association 1986; Freeman and Schofield 1991).

Study Site

The experiment was conducted on the 1 hectare Dogleg Prairie, 10 km NE of Lawrence, KS (latitude 39.052957, longitude -95.195331). The prairie has never been plowed and was historically managed by haying, burning, and grazing. Between 1997 and 2006, the prairie was burned in the spring in eight of the 10 years; no burning was done during this study. Soils at the site include Oska silty clay loam and Pawnee clay loam (Dickey, Zimmerman and Rowland 1977). Mean temperature (degrees C) for 2007 and 2008 were 13.00 and 11.64, respectively, with lowest monthly mean temperatures of -1.71 (February 2007) or -2.00 (January 2008) and highest monthly mean temperatures of 27.36 (August 2007) and 24.98 (July 2008). Yearly precipitation totals (mm) were 978.9 (2007) and 1073.8 (2008) (www.ksr.ku.edu).

Field Methods

On June 20, 2007, sixteen plants of each species were chosen (these "target plants" had to be 1.5 m from other conspecifics and have at least one stem $\geq$ 30 cm tall). Half of the plants of each species were randomly assigned to a clipping treatment and half to a control treatment. The clipping treatment simulated haying since it removed above-ground parts of both the target plant and its neighbors. The protocol involved first placing a plastic hoop (110 cm diameter) on the ground so that it was centered over the target plant; all plants within the hoop were cut to a 10 cm height and removed from the site. The specific size of the hoop was arbitrarily chosen; it was, however, large enough to include neighboring plants that were likely directly competing with the target plants. Clipping was done on July 5th to correspond with the typical time of haying in eastern Kansas (June to mid-July; personal communication, Craig Freeman). Prior to clipping, we placed a colored wire around each plant base to relocate it over the next 1 ½ year period.

In 2007, measurements of cumulative height and the number of inflorescences were taken on all plants prior to clipping (June 20-29) and afterwards in the fall (August 27-September 8). Height was defined as the cumulative height in cm of all stems present on a plant; plant

reproduction was quantified by counting the number of inflorescences per plant. Height and number of inflorescences were also assessed on June 21 – June 24, 2008; experimental plants were then clipped June 27, 2008 and height and reproductive data were taken on September 6 – 7, 2008. At all survey dates, we also noted if a plant had no above-ground stems present.

Statistical Analysis

We first determined if there were differences between control and clipped groups in the presence or absence of above-ground stems using Fisher exact tests at each survey date. For analyses of effect of plant size and reproduction, variation in initial plant size would make it difficult to see clipping effects. We thus used a response variable of "change in size or reproduction" over a defined time period. Specifically, for plants for which above-ground stems were present, we subtracted the cumulative June height, 2007 from the cumulative fall height (August or September 2007) to quantify the change in plant size. Positive values signify the plant was increasing in size while negative values indicate the plant was decreasing in size. A similar approach was used to analyze the change in the number of inflorescences for each species between June and August/September surveys. This "change" variable was then analyzed using a Wilcoxon-Mann Whitney test to determine if there were significant differences in the change in cumulative height and reproduction between the control and clipped plants over the summer. We used this nonparametric test because several data sets were skewed. Similar analyses were done for height and reproduction between June 2007 and June 2008, and between June 2007 and the end of the study in September 2008.

Results

There were no significant differences in the proportion of plants with above-ground vegetation between the control and clipped treatments of a species at any date.

Plants that were clipped in July 2007 often had a smaller cumulative height in fall 2007 than prior to clipping; comparisons of control and clipped plants for change in height were statistically significant for several species (Table 1). There were no significant treatment effects for the change in cumulative height over the June 2007 – June 2008 time period (Table 1). However, for all but one species, the median value for the change in cumulative heights for clipped plants was a smaller number than the median value for change in height for unclipped plants (Table 1). Analyses on 2008 data were less likely to show a clipping effect than analyses on 2007 data; however, it is important to realize that 2008 results are likely not independent of events in 2007. Only *L. capitata* had a significant difference between control and clipping treatments for cumulative height change from summer 2007 to fall 2008 (Table 1).

Six of the seven species reproduced consistently across the study period (Table 2). As with cumulative height, the strongest effect of clipping was within a year, with often a net reduction in the number of inflorescences from June to August/September for clipped plants. For most species, the change in number of inflorescences between June 2007 and June 2008 for clipped versus control plants was not significant (Table 2). For both *L. capitata* and *A. canescens*, clipped plants had reduced numbers of inflorescences compared to control plants, even after over-wintering (Table 2). For *A. canescens,* for example, the median change in number of inflorescences between summer 2007 and summer 2008 was slightly positive for control plants but negative for clipped plants, leading to a statistically significant comparison (Fig. 1).

Discussion

Haying is a successful form of prairie management: it can be used in locations where burning is impractical, it promotes high biodiversity, and it provides income for landowners (Collins et al. 1998; Jog et

Table 1. Median difference in cumulative height (cm) for control and clipped plants for three time periods (summer 2007- fall 2007, summer 2007-summer 2008, summer 2007 – fall 2008). Differences were calculated as, for example, fall 2007 height – summer 2007 height, so that a positive value indicates an increase in plant size and a negative value indicates a decrease in plant size. P values were calculated using a Mann Whitney test; comparisons that are statistically significant at the 0.05 level are indicated in boldface. No data are presented for *A. tuberosa* for summer-fall 2008 because of high apparent mortality of control plants. Sample sizes are presented in parentheses; note that sample sizes could decrease or increase across time, either due to plant death or because stems may die back in the fall, and then re-sprout at other times.

	Summer 2007-Fall 2007			Summer 2007-Summer 2008			Summer 2007-Fall 2008		
	Control	Clipped	*P*-value	Control	Clipped	*P*-value	Control	Clipped	*P*-value
Asclepiadaceae									
A. tuberosa	**-1.5 (8)**	**-152.0 (5)**	**0.01**	-55.0 (5)	-68.5 (6)	0.78	-	-	
Asteraceae									
R. pinnata	-59.0 (8)	-177.0 (7)	0.07	-8.8 (8)	-149.0 (7)	0.12	-129.0 (8)	-205.5 (7)	0.15
S. laciniatum	-19.0 (8)	-127.0 (6)	0.07	51.5 (8)	14.0 (8)	0.16	-26.5 (8)	-135.5 (7)	0.25
Fabaceae									
A. canescens	**-27.5 (8)**	**-198.5 (8)**	**0.04**	-151.0 (8)	-188.0 (8)	0.64	-187.3 (8)	-132.0 (8)	0.19
L. capitata	**18.0 (7)**	**-108.0 (6)**	**0.00**	19.5 (6)	-56.0 (5)	0.08	**81.0 (6)**	**-97.0 (5)**	**0.01**
Lamiaceae									
S. azurea	**33.0 (7)**	**-56.5 (8)**	**0.03**	25.0 (5)	-53.5 (4)	0.39	-60.3 (4)	-60.0 (5)	0.71

al. 2006). Haying, however, also is a major disturbance: nearly all the above-ground vegetation of the plant is removed during the summer season when growth and reproduction occurs. If maintaining biodiversity is a management goal, one should ask whether all forb species are equally affected by haying or whether there are differential effects. For example, haying prevents reproduction in the rare Mead's milkweed (*Asclepias meadii*) and for this species, haying management is correlated with changes in clonal size (Bowles, McBride, and Betz 1998). It is important to note, however, that prairie haymeadows are also the main location where Mead's milkweed and many other prairie species are currently found, emphasizing the importance of haymeadows at the landscape level in maintaining prairie vegetation.

For the species in this study, there was no significant difference in presence of above-ground stems between the clipped and control treatments. It is thus likely that plant survival did not differ between treatments, although we cannot rule out that the root systems were still alive for plants without above-ground vegetation. Although the clipped treatment had negative effects on plant size and reproduction within the year of clipping, most clipped plants were able to grow back the following spring. The net result is that there were few significant differences for the control versus clipped treatments when change in plant size or reproduction was measured over a year's period of time. These results likely point to the strong compensatory ability of prairie plants, and possibly to the effects of haying in reducing competition from neighboring plants. However, it is important to emphasize that statistical power, and thus our ability to detect significant differences between treatments, was limited by our relatively small sample sizes per treatment.

Some species, however, appear more affected by clipping than others (Tables 1, 2; Fig. 1). It is noteworthy that *A. canescens*, the only woody species in our study, had reduction in reproduction. Mowing and haying are commonly used to reduce woody plant biomass in prairies; these approaches are probably effective due to several factors including

Table 2. Median difference in number of inflorescences for control and clipped plants for three time periods (summer 2007- fall 2007, summer 2007-summer 2008, summer 2007 – fall 2008). Differences were calculated and interpreted as described in Table 1. *P* values were calculated using a Mann Whitney test; comparisons that are statistically significant at the 0.05 level are indicated in boldface. No data are presented for *A. tuberosa* for summer-fall 2008 because of high mortality of control plants; no data are presented for *S. azurea* for two time periods because it did not reproduce in 2008. Sample sizes are presented in parentheses; note that sample sizes could decrease or increase across time, either due to plant death or because stems may die back in the fall, and then re-sprout at other times.

	Summer 2007- Fall 2007			Summer 2007- Summer 2008			Summer 2007- Fall 2008		
	Control	Clipped	*P*-value	Control	Clipped	*P*-value	Control	Clipped	*P*-value
Asclepiadaceae									
A. tuberosa	-13.50 (8)	-10.00 (5)	1.00	1.00 (5)	-3.00 (6)	1.00	-	-	
Asteraceae									
R. pinnata	-2.50 (8)	-4.00 (7)	0.68	-5.00 (8)	-3.00 (7)	0.86	-5.00 (8)	-4.00 (7)	1.00
Fabaceae									
A. canescens	**-10.00 (8)**	**-41.00 (8)**	**0.02**	**8.00 (8)**	**-31.00 (8)**	**0.02**	**-7.50 (8)**	**-41.00 (8)**	**0.02**
L. capitata	**32.00 (7)**	**-6.50 (6)**	**0.00**	-3.00 (6)	-4.00 (5)	0.47	**70.50 (6)**	**-3.00 (5)**	**0.00**
Lamiaceae									
S. azurea	1.00 (7)	0.00 (8)	0.49	-	-		-	-	

mortality of some woody plants following cutting, inability of some woody species to re-sprout, changes in competitive ability within communities following cutting, and/or inability of some woody species to recolonize areas following management treatments. Gibson, Seasted, and Briggs (1993), for example, quantified reductions in cover and richness of several woody prairie species, including *A. canescens*, following mowing and burning treatments. Similarly, Rooney and Leach (2010) found that woody species increased in frequency when management of a Wisconsin prairie switched from mowing to prescribed burns. In addition to *A. canescens,* another legume (*L. capitata*) also responded negatively to our haying treatment. We are not aware, however, of any reason why legumes would be particularly vulnerable to haying; in fact, Ilmarinen and Mikola (2009) found that mowing treatments had positive effects on legumes in a semi-natural grassland in Finland.

The seven species we examined also differed in reproductive phenology, with species flowering from May to October. Howe (1994) found that mid summer burns favored growth of early versus late flowering species. In a similar way, we could hypothesize that reduction in biomass due to clipping in July might reduce number of inflorescences for later flowering species. The later flowering *L. capitata* did have a reduction in reproductive output due to the haying treatment; however such an effect was not seen in *R. pinnata*, which flowers at a similar time (two other late flowering species, *S. laciniatum* and *S. azurea,* did not have sufficient sample sizes of flowering plants for such comparisons). The reduction in reproductive output of *A. canescens* in our study parallels reduction in reproduction due to grazing seen by Hickman and Hartnett (2002).

Ecological studies have suggested several reasons for effects of mowing and haying on species composition (i.e., changes in light levels, reduction in competitive by dominant species, reduction in litter; Parr and Way 1988; Ilmarinen and Mikola 2009). To further explore the differential effects of haying on forb species in prairies, we recommend that studies such as ours be repeated with larger

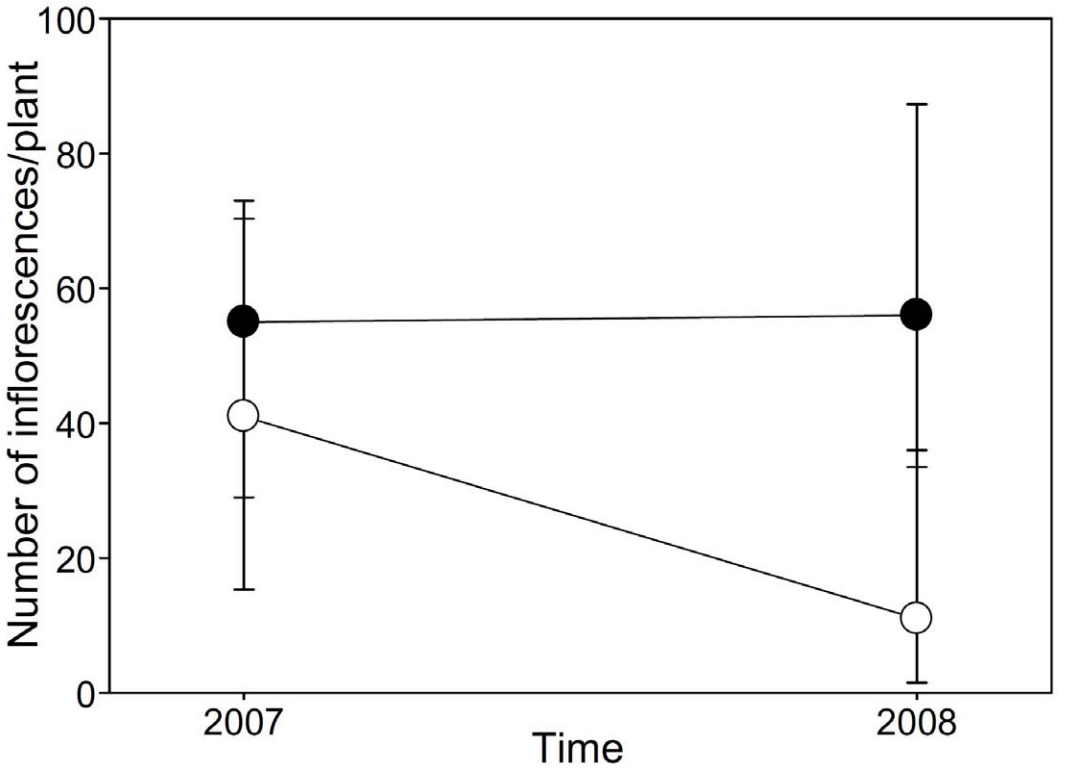

Figure 1. Number of inflorescences of *A. canescens* in June 2007 and June 2008 for control (closed symbols) and clipped (open symbols) treatments. Error bars indicate the 25th and 75th quartile; the symbol is the median.

sample sizes. In addition, following other grassland studies (Liira and Zobel 2000), studies of a larger number of species would allow comparisons between species that differ in plant life form (annual vs. biennial vs. perennial; location of meristems; leaf size) and reproductive phenology. Species-specific differences could also exist in the compensatory ability of plants to send up new shoots after repeated cuttings. If so, the effect of haying on plant growth and reproduction may depend on whether haying is repeated yearly, or whether haying is rotated with other treatments. Further, as discussed by Hickman and Harnett (2002) in the context of grazing, there are not always direct links between individual plant and population dynamic responses to prairie management techniques. In conclusion, more detailed research on haying effects would complement recent work on differential responses of prairie plant species to burning and grazing management (Brudvig et al. 2007).

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