Do fire and seed additions alter strong seed timing and priority effects on prairie establishment?

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Proposal submitted to the Iowa Department of Transportation LRTF, May, 2009

Proposed starting date: July 15, 2009, Ending date: August 15, 2010

Introduction

Many prairie restoration projects in the United States and Iowa have been planted, and many more are being established (Mlot 1990, Smith 1998). Similarly, a substantial network of Iowa roadsides has been planted with funding from the Living Roadway Trust Fund, and many more plantings are planned. These plantings can reduce erosion, provide wildlife habitat, increase aesthetic value of roadsides, and increase native plant biodiversity. New evidence also suggests that native plants may improve arthropod-mediated ecosystem services such as pollination and pest control for crops in agricultural landscapes (Isaacs et al. 2009). This could be important for promoting public acceptance of and increasing numbers of high-diversity native plantings in Iowa's highly productive and fragmented agricultural landscape. High plant diversity, especially high evenness, may also reduce detrimental insect invasions on plants (Wilsey and Polley 2002). Thus, increasing the diversity of restorations, including roadside plantings, could have far-reaching positive impacts for the state of Iowa.

Despite the importance of diversity in restorations, many projects are somewhat hampered by a lack of knowledge on how to restore the high diversity found in prairies, while at the same time preventing the establishment of a large weedy component. Most information published on prairie restoration emphasizes the number of species, the proportion of grass and forb seed in the seed mixes, and how seed mixes should be planted (e.g. Packard and Mutel 1997, Shirley 1994). This information has been very useful in getting these reconstructions going, but the diversity of plantings is often much lower than the diversity of native prairie remnants (Martin et al. 2005). Many reconstructions are strongly dominated by a few grass species, contain very low diversity of forbs, take a long time to establish, and contain an abundance of weeds (Mlot 1990, Packard and Mutel 1997). In many cases, weedy species such as crown vetch and smooth brome cause projects to fail (*personal observation*). This is probably because there has been less research emphasis on the ecology and management of reconstructed prairies than on the composition of seed mixes.

One method that has been proposed to simultaneously establish native seedlings and prevent weed invasion in new restorations is to plant a cover crop prior to seeding the native prairie species (Shirley 1994). This idea is based on the assumption that the cover plant will act as a nurse plant to the prairie seedlings, and will have a positive effect on seedling recruitment by increasing weed suppression and by lowering the harmful effects of high evaporation and light availabilities. Plowed or bare ground can be a stressful site for seedlings due to very high light availabilities. High light in these conditions causes high surface soil evaporation and drought stress on seedlings, which favors warm season grass seedlings over cool season forbs. Furthermore, plowed ground is ideal habitat for a host of weedy species like crown vetch, smooth brome, foxtail, lamb's quarters, velvet leaf and pigweed, which have higher germination and early growth rates (especially above ground) than do prairie species. Cover crops could also potentially reduce the amount of soil erosion that occurs during planting. However, the majority of evidence supporting the benefits of cover crops was not supported by our previous research.

We established an experiment in Story and Monona counties in 2005 to determine the effects of different native cover crop species and timing of seeding on the establishment of new prairie restorations. We found that seeds added during early spring (Spring Mix) showed much higher abundances of native species and lower abundances of exotics compared to late summer plantings (Fall Mix) (Figure 1). Establishment was much lower when seeds were added in the growing season after the cover crops than when they were added at the same time (Figure 1).

This suggests the prairie species themselves suppressed exotic invasion. The only native cover crop that reduced weed abundance compared to no cover crop was Canada wildrye, but this species did not significantly increase the abundance of native species that came in (Figure 2). Using no cover crop allowed more native prairie species establishment than the side-oats gramma treatment (Figure 2). Other treatments did not differ from the controls. Overall, results from this experiment suggest that seeding new prairie restorations in the early spring with no cover crop will produce the highest prairie species establishment.

Many existing restorations have low diversity due to high dominance of one or a few warm-season grass species, and they can have high levels of exotic weed invasion (Losure et al. 2007). Therefore, methods are needed to improve existing plantings by increasing diversity and reducing exotics. Williams et al. (2007) found that overseeding grass dominated plantings with forb seed mixes can increase forb abundance when plots are burned before seeding, and mowing after seeding enhanced forb abundance. We propose to test if adding seed after burning will increase prairie establishment in currently divergent prairie communities.

Currently, fire is one of the most commonly used tools for managing prairie restoration (Copeland et al. 2002). The majority of prescribed burns take place in the spring to reduce the abundance of cool-season exotics such as smooth brome (Copeland et al. 2002). Similarly, most prairie restorations are seeded in the spring (Packard and Mutel 1997). Results from the original experiment suggest that adding seeds in the spring to bare ground (disked brome fields) with no cover crop species produces the highest prairie establishment. Therefore, in established restorations, we hypothesize that adding seed to ash after a prescribed burn will produce the same effect. If so, then this could be one strategy for re-establishing prairie in existing brome fields. Alternatively, the differences caused by the original treatments may be too strong to overcome. We propose to test these alternative outcomes.

More evidence is needed on methods to increase native species establishment in existing prairie restorations, specifically on whether adding seeds after burning can increase establishment. Therefore, we propose to burn all existing cover crop and seed timing experimental plots from the original experiment in spring, 2010, and add a seed addition treatment to half of the plots immediately after burning to determine if adding seed after fire could significantly increase prairie establishment in low-diversity prairie restorations. Dividing the existing treatments into seeded and non-seeded plots will allow us to continue monitoring the effects of the original cover crop and seed timing plots, which are valuable for informing new restorations, as well as testing a new method to improve existing restorations.

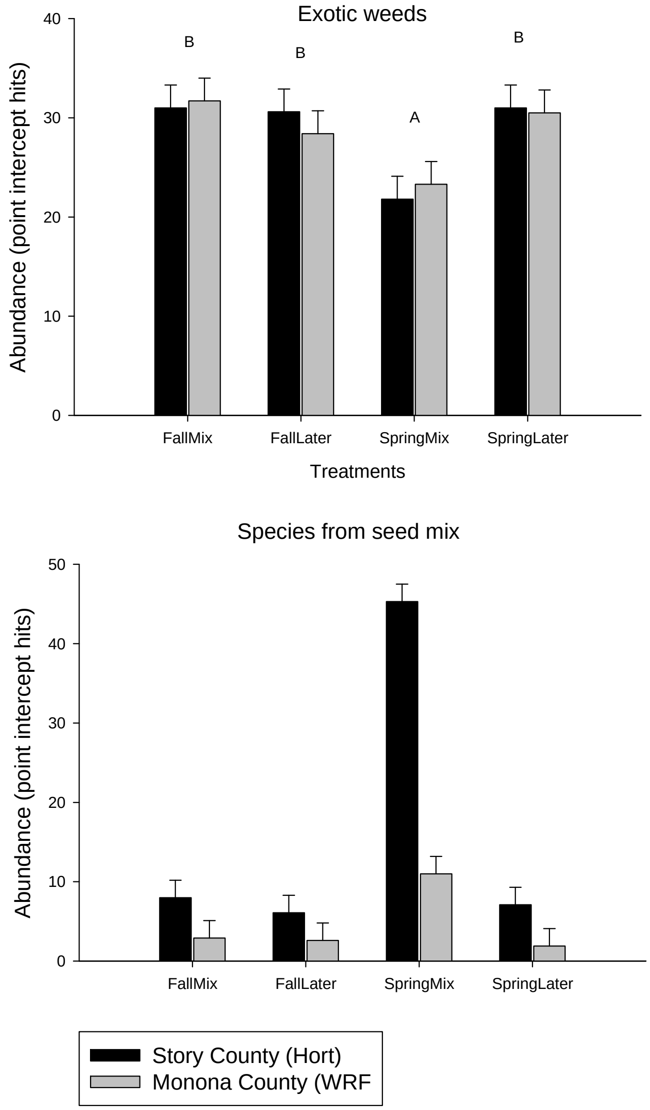

Figure 1. Exotic weed abundance (top) and prairie species abundance from the seed mix (bottom) across treatments. Treatments were fall seeded with the mix added the first fall, fall seeded with the mix added the following spring, spring seeded with the mix added the first spring, or spring seeded with the mix added the following spring.

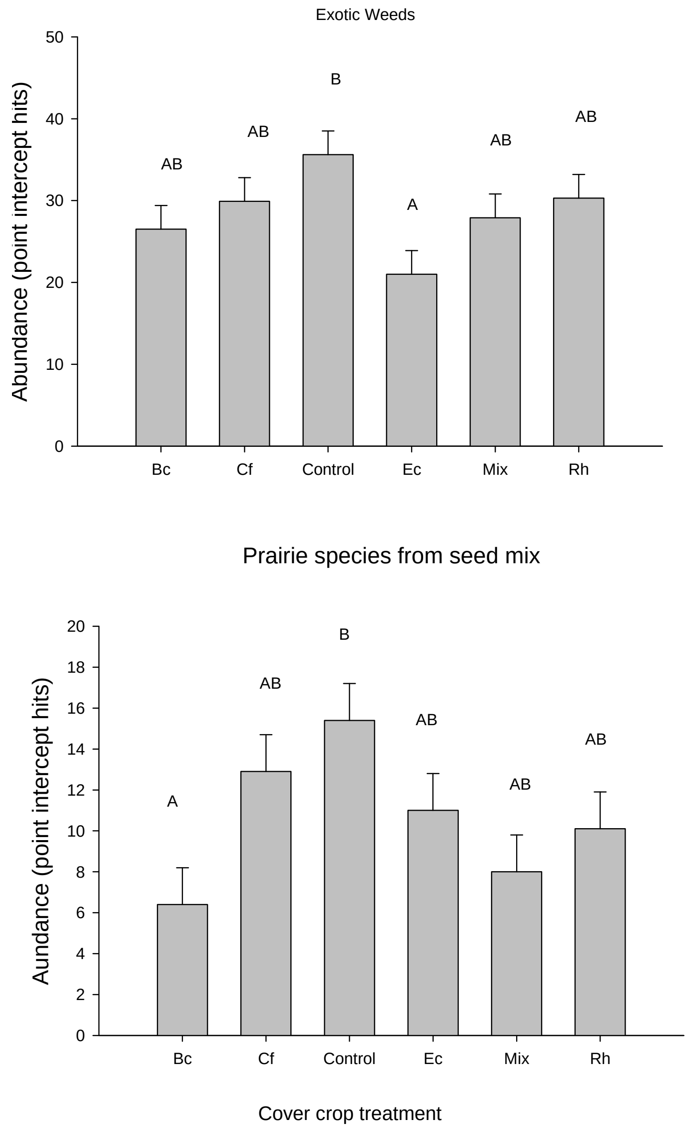

Figure 2. Abundance of exotic weeds (top) and prairie species from the seed mix (bottom) in plots seeded with side-oats grama (Bc), partridge pea (Cf), no cover crop (Control), Canada wildrye (Ec), all four cover crop species combined (Mix) and black-eyed susan (Rh).

Objectives:

1. Determine if the timing of seeding continues to affect prairie species diversity and native species abundance.

2. Determine if native cover crops have any long term effects on prairie species diversity and native species abundance.

3. Determine if seed additions shortly after spring fires can increase prairie establishment and species diversity in divergent prairie communities after plots have established.

The first two objectives will be addressed by sampling the plots in 2009, the fifth year of the study. The third will be addressed with seed additions to a subset of plots in 2010.

Methods

Study sites

Experimental plots were set up on slopes near roadsides at the Iowa State University farms near Ames (Horticulture Farm, a mesic site) and at the Western Research and Demonstration Farms (a dry site) near Castana in Monona County in 2005.

Cover crops

Seed mixes were added to plots that contain one of 6 cover crop treatments: 1. No cover crop (control), 2. Canada wildrye (*Elymus canadensis*), 3. Partridge pea (*Chamaecrista fasciculata*), 4. Black-eyed susan (*Rudbeckia hirta*), 5. Side-oats gramma (*Bouteloua curtipendula*), 6. All four species combined

These 6 treatments have been applied to experimental plots at each of the two sites (Story and Monona Counties). These two sites were selected because 1) they represent a mesic and a dry site and broader generalizations can be made as a result, and 2) they represent sites that are conveniently located for the PI, with the Ames site close to ISU and the Monona County site close to other projects. All plots were placed on slopes so that they are more relevant to roadside plantings.

Original Experimental Design

During 2005, we established a cover crop experiment on the effects of seeding dates at each of the two sites. We propose to sample these plots again during 2009, one year after the first burn in spring 2008. In the original experiment, a split-plot experimental design was used. Plots of 5 x 5 m were marked out at each of the two study areas. Each plot was then split up into four 2 x 2 m subplots with 1 m corridors between them. Each subplot received one of four treatments: 1) spring 2005 planting of cover crop with prairie seed mix, 2) spring 2005 planting of cover crop with prairie seed mix added one year later (spring 2006), 3) fall 2005 planting of cover crop with prairie seed mix, or 4) fall 2005 planting of cover crop with prairie seed mix added the following spring (spring 2006). Spring seeding was conducted in April 2005 by broadcasting the seed mix from Table 1 at the same rate of 10 lbs. per acre in tilled fields formerly dominated by brome. The cover crops included Canada wildrye, Side-oats gramma, Black-eyed susan, partridge pea, and all four cover crop species combined (mixed cover crops). The cover crops were compared to control plots that received the prairie mix only. The mixed treatment uses a mixture of all four cover crops, but has the same overall seed mass. For example, the mixed treatment contains 2.5 lbs per acre of each of the four species, or 10 lbs. per acre total, which is the same as the monoculture plots. This tested the idea that having all of the early emerging species included as a cover crop was better than having only one, perhaps as a result of weed suppression and because of the different microhabitats created by multiple species. There are five replicate plots of each of the main plot treatments (6 treatments) at each of the two sites (Horticulture farm in Story County and Western Research Farm in Monona County), for 30 x 2 = 60 main plots total, and 60 x 4 = 240 subplots total. Biomass of prairie and weed species was estimated with point intercept sampling, which involved counting all plant contacts with a metal pin dropped through the canopy in the middle of each plot during July 2006 (year 2), 2007 (year 3) and 2008 (year 4, after plots burned in spring), and we propose to sample again in July 2009 (year 5, two years after burning) (Jonasson 1998).

Fire and Seed Additions: New Treatment Experimental Design

In spring 2010, we propose to add a new treatment to the existing experiment to determine if the strong differences exhibited by seed timing, cover crops and priority effects (adding prairie mixtures with the cover crop after they established) can be altered to increase prairie establishment, thereby converging the original treatments and increasing diversity. To do this, we plan to burn all plots in late April/early May 2010, and over-seed the original prairie seed mixture (excluding the cover crops seeds, and with the same number of seeds per species) to half of the main plots at each site immediately after the burn (Table 1). Since there are five replicates of six main treatments (cover crops) at each site, three main plots of each treatment will be randomly selected at the Horticulture Farm near Ames and at the Western Research Demonstration Farm in Monona County. This will result in 18 main plots (five of each cover crop) with the fire/seed addition treatment and 12 main plots with the fire treatment only at each site (36 and 24 total). Seeds will be obtained from Allendan Seed Company (Madison County) for the Story County site and from Custom Seed Services (Pottawattamie County) for the Monona County Site. Biomass and abundance of prairie and weed species will be sampled in July 2010 using our point-intercept method. We have found that our point intercept method is highly correlated with biomass.

The original experiment informs us about starting new restorations, and results from this new fire/seed addition treatment will be informative for improving commonly existing low diversity prairie restorations. Results from the first part of the experiment suggest seed timing and priority effects are extremely important. Spring plantings showed higher prairie establishment, and cover crops did not improve prairie establishment as was previously thought. This suggests that increasing diversity in low-diversity restorations may be as easy as adding seed again in the spring when competition from existing prairie vegetation may be low, i.e., right after a burn. Knowing when to add seed could significantly advance our ability to improve existing restorations, and this will test one possible method. Other research also suggests prairie restorations are seed limited, but established grasslands may not be seed limited, which suggests adding seed may not help improve restorations (Martin and Wilsey 2006, Wilsey and Polley 2003). Increasing diversity in this manner may therefore not be possible if the cover crop and seed timing treatment effects are too strong. This may occur if, even after a common management practice such as burning, added seeds are unable to compete with existing vegetation.

The new treatment will also be important for determining if differences in initial species composition can affect fire and seed additions in established restoration, much like how the species composition of the original plots were affected by the initial weed species. For example, initial weeds in the original spring-seeded plots included annuals such as witchgrass (*Panicum capillare*) and ragweed (*Ambrosia artemisiifolia*), but fall-seeded plots contained mainly biennials such as mullien (*Verbascum thapsus*), and these differences may have led to changes in soil moisture and temperature that produced the strongly diverging prairie communities. Along the same lines, fire temperatures during the first burn in 2008 were hotter in spring plantings than fall plantings. It may be, therefore, that common management practices such as burning perpetuate differences in species composition among plantings by altering fire temperatures, and therefore altering plant responses to burning. If the initial species composition affects the outcome of the new treatments, this will be an important result that implies the ways and timing in which we initially restore prairie may have long-lasting impacts on species composition, and these differences may be difficult to alter significantly by seemingly influential management practices such as fire and seed additions.

Education Activities and Broader Impacts

Students in ISU Restoration ecology and Community ecology classes have visited our plots for lab projects. The project has been written up in local newspapers and newsletters. Leanne Martin, the graduate student Co-PI, will also be involved in WISE, Women in Science and Engineering, and will provide outreach efforts to younger school-aged females. These research and educational activities brings exposure to the IDOT-LRTF program. Additional grants from the US Army Corps of Engineers CERL UMMV Cooperative Ecosystem Studies Unit, Leopold Center for Sustainable Agriculture, the Nebraska Nature Conservancy, and Prairie Biotic in Wisconsin have been secured to fund native cover crop research in the past. This broad support from a variety of sources proves that there is broad interest in this research.

Table 1. Seed mix of prairie species that will be added after the cover crop is established.

Species	Family
Warm season grasses	
1. Little bluestem, *Schizachyrium scoparium*	Poaceae
2. Big bluestem, *Andropogon gerardii*	Poaceae
3. Indian grass, *Sorghastrum nutans*	Poaceae
4. Switch grass, *Panicum virgatum*	Poaceae
5. Tall dropseed, *Sporobolus asper*	Poaceae
Cool season grasses	
6. June Grass, *Koeleria macrantha*	Poaceae
7. Porcupine Grass, *Stipa spartea*	Poaceae
Forbs	
8. Wild Bergamot, *Monarda fistulosa*	Lamiaceae
9. Bottle Gentian, *Gentiana andrewsii*	Gentianaceae
10. Butterfly Milkweed, *Asclepias tuberosa*	Asclepiadaceae
11. Dotted[1] or Rough[2] Blazing Star, *Liatris aspera and punctata*	Asteraceae
12. Ground Plum, *Astragalus crassicarpus*	Fabaceae
13. Hoary Vervain, *Verbena stricta*	Verbenaceae
14. Lead Plant, *Amorpha canescens*	Fabaceae
15. Pale purple[1] and Narrow Leaved[2] Coneflower, *Echinacea angustifolia* and *pallida*	Asteraceae
16. New Jersey Tea, *Ceanothus americanus*	Rhamnaceae
17. Ox-eye, *Heliopsis helianthoides*	Asteraceae
18. Prairie Phlox, *Phlox pilosa*	Polemoniaceae
19. Prairie Larkspur, *Delphinium virescens*	Ranunculaceae
20. Prairie Rose, *Rosa arkansana*	Rosaceae
21. Purple Prairie Clover, *Dalea purpurea*	Fabaceae
22. Red Root, *Ceanothus herbaceus*	Rhamnaceae
23. Round_headed Bush Clover, *Lespedeza capitata*	Fabaceae
24. Smooth Aster, *Aster laevis*	Asteraceae
25. Stiff Goldenrod, *Solidago rigida*	Asteraceae
26. White Prairie Clover, *Dalea candidum*	Fabaceae
27. Yellow Coneflower, *Ratibida pinnata*	Asteraceae
28. Primrose, *Oenothera biennis*	Onagraceae
28. Compass plant, *Silphium laciniatum*	Asteraceae
29. Pasque flower, *Anemone patens*	Ranunculaceae

[1] dry site (Monona County) [2] mesic site (Story County)

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Budget

The main expenses for this project will consist of PhD summer research assistantship support for Leanne Martin to re-sample existing plots in 2009 and 2010, and to add additional fire and seed treatments in 2010. Time will also be spent preparing reports and manuscripts from the project. Seed mixes, travel expenses to Monona County, and land rental fees will comprise the remainder of the expenses.

<u>Direct costs</u>	
Student Research Assistantship (4 months of salary at $1,675)	$ 6,700
July 15 – August 15 2009	
May 15 – June 15 2010	
June 15 – July 15 2010	
July 15 – August 15 2010	
Benefits (13.2%)	$ 884
Seed Mixture	$ 800
Travel Expenses	$ 1,300
Rental of ISU Farm Land ($100/acre/year at two farms)	$ 200

	$ 9,884
<u>Indirect costs (8%)</u>	$ 791

Total	$10,675