Tillers 2000, **2**, 31-38

Annual burning decreases seed density in the upper soil layers of the seed bank

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Abstract

The seed bank records the plant-life history of the prairie and is a source of regeneration following disturbance. Prairie flora have adapted and evolved unique responses to the periodic presence of fire. In order to determine the effects of burning on the seed bank and the prairie in general, we germinated soil samples from burned and unburned plots in a tallgrass prairie at CERA. We recorded the total number of seedlings, number of monocot individuals, number of dicot individuals, and number of morphospecies found in the upper (0-5 cm) and lower (5-10 cm) layers of soil within burn and no burn plots. Our research indicated that the number of viable seeds and the abundance of dicots varied significantly with burning. Although we hypothesized that burning would increase seed bank density because fire bolsters plant reproductive capacity, thus increasing seed bank input, we found that burning actually decreases the number of viable seeds in the seed bank. We attribute this to two important consequences of fire—opening of the canopy and lethal temperatures. Our results suggest that burning promotes diversity of plant species above ground while reducing viable seed density in the upper layers of the seed bank.

Introduction

With the prairie ecosystem covering less than 0.1% of its presettlement expanse, reconstruction attempts are crucial to maintenance of this ecosystem. To accurately reconstruct a prairie, the different factors affecting the vegetation should be isolated and studied. Particularly interesting is the effect of fire on prairie flora, that is primarily made up of grasses (monocots) and forbs (dicots). These plants disperse seeds on the prairie floor and over time new soil layers accumulate over the distributed seeds, or seed rain. This compilation of subterranean seeds forms the seed bank. Because of its rich history, the seed bank can be utilized to study long-term effects of disturbances such as fire.

Fire can positively effect the prairie ecosystem by improving reproductive responses, stimulating grasses to flower and releasing once-inaccessible nutrients bound up in ground cover to mingle freely in the soil (Turner 1997, Murray 1986). Burning opens the canopy allowing access to sunlight, which gives subdominant species, such as forbs, a chance to grow, thus increasing plant diversity (Howe 1999). Fire has also been shown to deplete the upper layers of the seed bank by damaging seeds and by encouraging seed germination (Turner 1997). The seed bank is an important source of this new germination after disturbance and is therefore essential to the prairie ecosystem's response to fire.

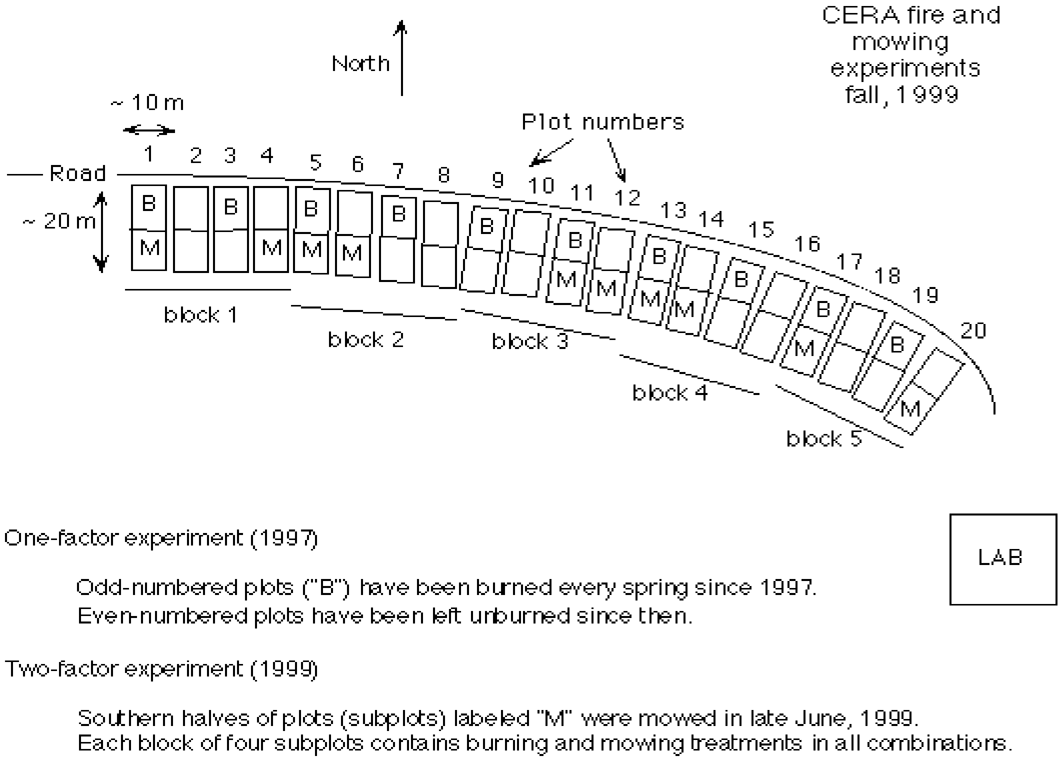
Our experiment utilized burned and unburned plots of prairie to investigate the effects of fire and soil depth on seed bank density and diversity. We compared this information to the current ground cover in order to look at sexual reproduction in monocots and dicots, and to separate this from the effects of monocot reproduction via rhizomes. We hypothesized that there would be a greater diversity and number of germinating seeds in the burn plots, because burning has been shown to increase reproductive responses and therefore increase seed bank input. Because seeds at lower depths have had to survive longer (Westoby 1988), we hypothesized that there would be fewer viable seeds in the lower layer than in the upper layer of the seed bank.

Methods

We conducted our investigation at Conard Environmental Research Area (CERA), a reconstructed prairie in central Iowa. Ten replicate burned and unburned prairie plots (Fig.1), systematically arranged in an alternating pattern, were all seeded with grasses (*Andropogon gerardi, Andropogon scoparius, Sorghastrum nutans, Panicum virgatum)* in 1987 and with forbs (unknown) in 1990. All plots were burned each spring from 1989-1996. The odd numbered plots have been burned every April since 1997 (DeLong 1998).

On 11 October 2000, we chose eight random points in each plot, from which we extracted 10 cm deep soil samples using a 2 cm diameter sampler. We took a large number of small samples from each plot because most species in the seed bank are irregularly distributed in clusters (Baskin 1998). In total, we collected 251.3 cm^3 of soil per plot. We separated the upper portion of the core (0-5 cm) from the lower (5-10 cm) to make one sample for the top and one for the bottom for each plot. In total, we had 2 samples per plot, each consisting of eight individual cores.

The following day, we filled 25x25x6 cm trays with 5 cm of sterile, moistened soil. On top of this, we spread each sample and then covered them with another thin layer of sterile soil. In order to monitor possible contamination, we randomly placed four control trays filled only with sterile soil among the ordered trays. We placed the 44 trays in the



One-factor experiment (1997)

Odd-numbered plots ("B") have been burned every spring since 1997.
Even-numbered plots have been left unburned since then.

Two-factor experiment (1999)

Southern halves of plots (subplots) labeled "M" were mowed in late June, 1999.
Each block of four subplots contains burning and mowing treatments in all combinations.

Fig. 1 CERA experimental plots – we used only the burn and no burn plots 1-20 greenhouse at Grinnell College, under florescent light on a 16 light- 8 dark cycle. We watered the samples daily to maintain sufficient moisture for growth. Each week for five weeks we recorded the numbers of seedlings, the week of seedling emergence, the type of morphospecies germinated, and type of plot from which the seedling emerged. Because of the difficulty in identifying seedlings, we organized them into morphospecies by grouping seedlings with similar morphology. We used a nested ANOVA to analyze number of seedlings, monocots, dicots, and morphospecies in burn vs. no burn plots and upper vs. lower seed bank layers. We also analyzed morphospecies data using a rank-abundance curve.

To compare seedling emergence data to existing floral composition, on 30 October 2000 we measured the percent grass cover by randomly choosing twenty 0.25 m^2 quadrat sections of each experimental plot. We used a t-test to compare mean percent grass cover between burn and no burn plots.

Results

Effect of Burning

The number of seedlings and number of dicots were significantly greater in no burn plots than in burn decreased more dramatically with burning than number of monocot seedlings and morphospecies (Figs. 3, 4, 5, 6). plots (Table 1). There was no significant difference in the number of monocots found between burn and no burn plots (Table 1). We found that a few morphospecies dominated the viable seeds found in both burn and no burn seed banks and that there was no difference in average number of morphospecies between these plot types (Table 1). The slope of the rank abundance curve indicates that the no burn plots have a more evenly distributed abundance of species (Fig. 2).

Effect of seed depth

The number of seedlings, number of monocot individuals, number of dicot individuals, and number of morphospecies were significantly greater in upper plots (Table 1). Although we didn't statistically test our results, there was no clear interaction between burning and seed depth in any of the four categories (Fig. 3, 4, 6), except for a possible interaction for number of dicot seedlings (Fig. 5). In the upper samples, the mean number of seedlings and number of dicot seedlings

Percent Grass Cover

While we found significantly more grasses in no burn plots than in burn plots, we find this data suspect (Fig. 7). Our results accurately found grasses to be more dominant in all plots.

Table 1. Nested ANOVA results for seedling number, monocot, dicot and morphospecies variation

Seedling Number

	DF	Seq SS	F	P
Burn/no burn	1	55.23	4.43	0.042
Upper/ Lower	2	287.05	11.52	0.000
error	36	448.5		

*no seedlings germinated in the control plots

Dicot

	DF	Seq SS	F	P
Burn/no burn	1	40.00	6.04	0.019
Upper/ Lower	2	122.50	9.24	0.001
Error	36	238.60		

Monocot

	DF	Seq SS	F	P
Burn/no burn	1	1.225	0.33	0.572
Upper/ Lower	2	46.25	6.15	0.005
error	36	135.3		

Morphospecies

	DF	Seq SS	F	P
Burn/no burn	1	0.625	0.35	0.559
Upper/ Lower	2	27.45	7.64	0.002
Error	36	64.7		

*there were 14 total morphospecie

Fig.2 Rank Abundance Curve for seedling emergence at +5 weeks

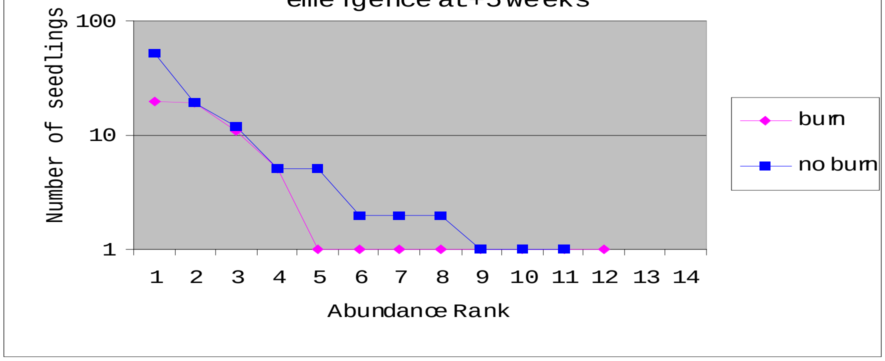


Fig. 3 Mean seedling number in upp
5 cm) and lower (5-10 cm) seed ban
affected by annual burning (+/-

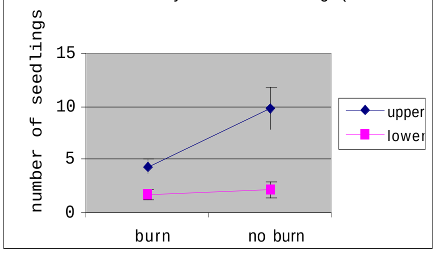
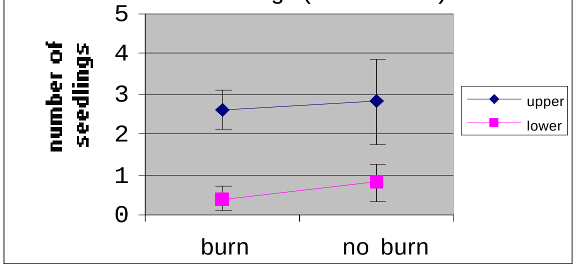


Fig. 4 Mean monocot number
upper(0-5 cm) and lower (5-10
seed bank as affected by ann
burning (+/- S.E.)



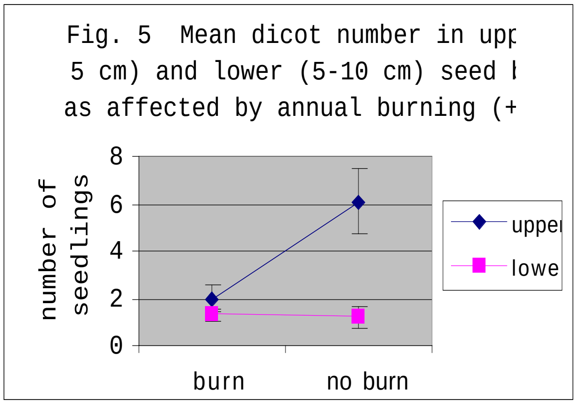


Fig. 5 Mean dicot number in upp
5 cm) and lower (5-10 cm) seed
as affected by annual burning (+

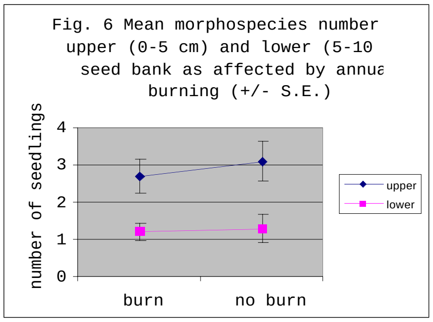


Fig. 6 Mean morphospecies number
upper (0-5 cm) and lower (5-10
seed bank as affected by annua
burning (+/- S.E.)

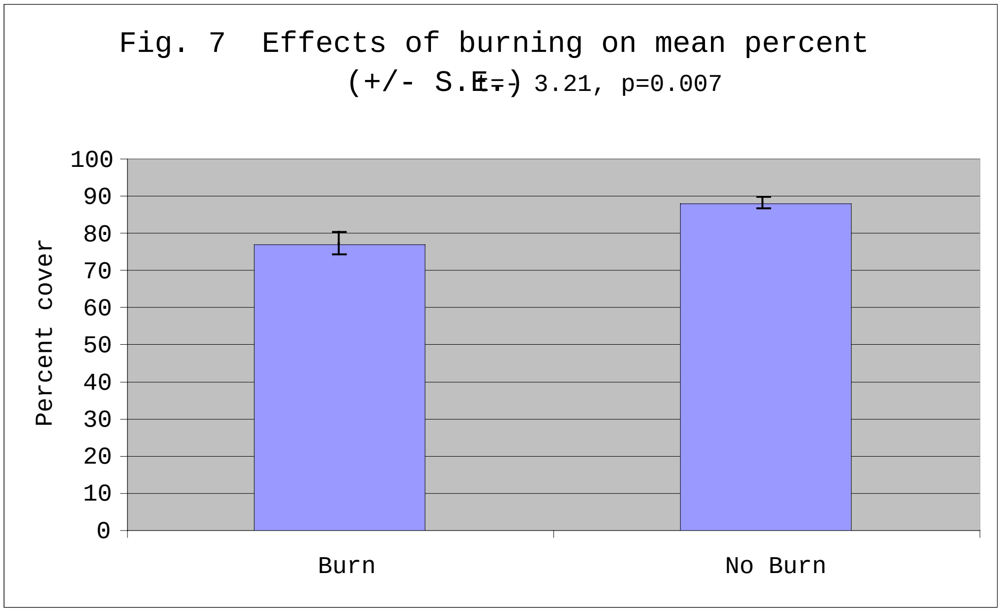


Fig. 7 Effects of burning on mean percent
(+/- S.E.) t= 3.21, p=0.007

Discussion

Burn Treatment

Although we hypothesized that burning would increase seed bank density because fire bolsters plant reproductive responses, thus increasing seed bank input, we actually found burning to decrease density. We credit our results to two important consequences of fire—opening of the canopy and lethal temperatures. Burning is known to decrease seed bank density by consuming and damaging seeds in the upper 2 cm of soil (Ferrandis 1998). Further, because the canopy is opened, more sunlight directly hits the soil surface and warms the soil, creating optimal conditions for seed germination (Howe 1999). Because more seeds germinate, there are fewer seeds present in the seed bank in the subsequent year. Louda (1990) found that seedling competition by established plants in no burn plots reduced the germination success of native thistle in Sandhills prairie by nearly 50%. With lower germination success in no burn plots, more seeds remain in the seed bank.

Timing of the burn also may influence seed bank density in burn plots. Forbs and grasses generally germinate in spring but flower and fruit in the fall (Howe 1999). April is a critical time for young seedlings, and burning at this time will likely kill a good portion of the newly sprouting biomass (Reichman 1987). These exterminated seedlings not only subtract from the seed bank, but also reduce future additions to the seed bank by being unable to contribute to seed rain in the following autumn. Forbs in particular are damaged by spring burning because seeds are their only means of reproduction and new growth (Howe 1999).

Although our results suggested that percent grass cover decreases with burning, we found copious research suggesting that percent grass cover actually increases with burning (Benning 1993, Hulbert 1969, Reichman 1987). We therefore reject our data because our use of random sampling in small plots allowed large forbs to occasionally fill the quadrats, creating an inaccurate representation of grass cover in the plot. It is reasonable to question our results because grasses are well equipped to deal with fire. Their basal meristems often escape damage by fire, and they primarily use rhizomes in reproduction (Reichman 1987). Therefore, lack of significance between burn and no burn plots for number of monocot seedlings can be explained by the fact that monocot seeds remain in the seed bank regardless of burn treatment.

In contrast, forbs have apical meristems that are located at the tips of aboveground growth, which render them more susceptible to fire. As a result, dicots are less abundant aboveground in plots burned in the spring (Howe 1999). The positioning of meristems and the increased dominance of grasses, which effectively outcompete forbs, combine to produce the result that there were significantly fewer dicot seedlings in the burn plots.

Morphospecies diversity was not significantly different between burn and no burn plots. This is a result of two factors. First, the two types of plots have the same planting history (DeLong 1998), and accordingly the same initial diversity. Second, the burn and no burn plots are small in size (10mx10m), and adjacently alternating, which allows for movement of seeds between plots. Our no burn plots had a more even distribution of diversity, but we accredit this result to our small sample size with the majority of the morphospecies having only one representative (Fig. 2).

Seed Depth

Due to successive deposits of biomass and soil particles onto the prairie floor, seed depth has been found to correlate positively with seed age (Witkowski 1991). Over time, fewer viable seeds survive microbial decomposers, fire, water damage, and subterranean predators to be recorded in the lower depths of the seed bank. As shown by Baskin in 1998, total number of seeds in the seed bank for all species declined exponentially with time. We attribute the significantly greater number of monocot individuals, dicot individuals, and morphospecies in the upper soil layer to the higher density of seeds in this portion of the seed bank.

In conclusion, we reject our original hypothesis and accept that burning significantly affects dicot but not monocot density in the seed bank. Our experiment suggests that burning reduces seed bank density by sterilizing more seeds and opening the canopy. Experiments on seed rain by Coriell *et al.* in 2000 at our sample site, found that there was no significant difference in seed rain between the burn and no burn plots. Being the plants that first emerge after fire, we wonder if monocots put their reproductive energies into rhizomes instead of into producing quality seeds. These poor quality seeds would not survive to become a viable part of the seed bank. An experiment to test this hypothesis would involve subjecting monocot and dicot seeds to environmental conditions such as water, heat, wind and cold to determine which seeds have a higher survival rate. Isolating the effects of fire and seed depth on seed bank germination can contribute to a more complete understanding of the basis of the prairie ecosystem. Examining the seed bank provides prairie restorers with important information regarding prairie regeneration after disturbance.

Acknowledgements

The authors would like to publicly appreciate Professor Jonathan Brown and Professor Christina Caruso for their guidance and input in the production of this paper. They would also like to thank the writing lab and our peer editors for their discerning eye which they committed to our paper. Additional thanks to Larissa Mottl for her assistance in research and early stages of planning.

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