Precision Prairie Reconstruction (PPR): A Technique for Increasing Native Forb Species Richness in an Established Grass Matrix

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ABSTRACT

Precision Prairie Reconstruction (PPR) is a site-specific application for enhancing native species richness (specifically, native forbs) in old fields dominated by a few non-native grass species. The method consists of establishing microcommunities of native grasses and forbs in an existing grass matrix. The microcommunities are created by broadcast seeding simulated small-scale disturbances (8.06 m^2) installed over a percentage of the site. The PPR results were compared with two standard restoration techniques: herbicide/drill-seeding and rototill/broadcast seeding. A PPR design that disturbed only 25% of the area resulted in total species richness, native grass frequency, and native forb richness, stability, and density over the entire plot that were similar to what was found in the conventional rototill/broadcast method and produced better results than the herbicide/drill-seeding method. The PPR technique involved less cost and less overall disturbance than traditional herbicide application/drill-seeding or rototill/broadcast seeding methods. PPR offers an alternative approach for increasing native grass and forb diversity in old fields dominated by a few non-native grass species.

Keywords: brome (*Bromus*), forb diversity, grass matrix, precision prairie reconstruction (PPR), small-scale disturbances

Introduced grass species such as smooth brome (*Bromus inermis*) and Kentucky bluegrass (*Poa pratensis*) cover millions of hectares of pastures and old fields that were formerly species-rich prairie landscapes, and attempts at restoration have not always been satisfactory (Wilson and Gerry 1995, Blankespoor and May 1996, Lesica and DeLuca 1996, Duckwitz 2005, Murphy and Grant 2005). A notable problem in prairie restorations is a decline in seeded forb species richness over time, and one of the main causes is the presence of large stands of introduced perennial grasses (Wilson 2002). Smooth brome is especially problematic in the Upper Midwest and Northern Great Plains, where it can make up more than 80 percent of the biomass and form monocultures that appear to resist recolonization by native species (Larson et al. 2001). The long-term effect of introduced perennials does more than simply determine species composition; it also affects ecosystem processes (Wilson 2002). Pastures dominated by smooth brome and Kentucky bluegrass have ecosystem properties such as nutrient cycling and water-use patterns that are different from those of native grasslands (Trlica and Biondini 1990, Hunt et al. 1991). For example, Vinton and Goergen (2006) have shown that smooth brome alters the nitrogen cycle in a feedback loop that provides it with a competitive advantage over native species.

Despite various techniques such as mowing, interseeding, cultivating, and prescribed burning (Packard and Mutel 1997, Whisenant 2005), restored pastures and old fields that were dominated by introduced species often go back to species-poor sites dominated by a few grasses (Kindscher and Tieszen 1998, Allison 2002, Sluis 2002). Prescribed burning, mowing, and herbicide application can reduce the abundance of smooth brome, but without sustained control efforts, the species is remarkably persistent (Willson and Stubbendieck 2000). We know from extensive experimentation that, in the Northern Great Plains, fire and other control methods such as herbicide applications depend heavily for their success on the presence of a minimum of 20% of native species in the matrix (Dill et al. 1986, Willson and Stubbendieck 2000). A grass matrix dominated by a few introduced species inhibits the germination, establishment, and persistence of most native species, especially native forbs, which account for most of the diversity in native prairie sites (Wilson and Pärtel 2003, McLachlan and Knispel 2005, Gendron and Wilson 2007). At sites dominated by smooth brome and with less than 20% native species, Willson and Stubbendieck (2000) suggest that alternative methods for prairie restoration should be tried.

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We propose an alternative, ecological method based on field observation and data gathered on the work of a prairie ecosystem engineer, the plains pocket gopher (*Geomys bursarius*) (C. Grygiel, pers. obs.). Ecosystem engineers have been defined as organisms that modify or create habitats (Jones et al. 1994, Wright et al. 2004, Byers et al. 2006). One pocket gopher can overturn prairie soil at the rate of one to three mounds per day, bringing 2.3 T/ha of subsoil to the surface annually, with most of the activity occurring in the spring and autumn (Andelt and Case 2007). The disturbances caused by pocket gophers and their impacts on vegetation diversity have been extensively studied (Teipner et al. 1983, Inouye et al. 1987, Gibson 1989, Huntly and Reichman 1994, Klaas et al. 1998, Rogers and Harnett 2001). Gopher disturbance can have positive, negative, or neutral impacts on vegetation diversity (Huntly and Reichman 1994, Steuter et al. 1995, Olff and Ritchie 1998, Rogers and Harnett 2001).

The goal of this study was to test whether seeded simulated small-scale-disturbances can be used as a technique for increasing native species richness on sites dominated by a few introduced perennial grasses. The working hypothesis is that by installing specific quantities of small-scale disturbances and seeding with native species, a self-sustaining community will be established that will generate a constant source of propagules, which in time will colonize the surrounding vegetation matrix (taking advantage of favorable conditions that can occur over the years) and thus increase native species diversity. We had two specific objectives: to systematically install and seed simulated small-scale disturbance treatments covering 5%, 25%, and 50% of the study area and compare these results with conventional rototill/broadcast-seeding and herbicide/drill-seeding methods in terms of total species richness, native forb richness, and native forb density across the entire field; and to compare the stability of the richness of the native forb communities generated by the above-mentioned treatments over multiple years. Data from the first five growing seasons are presented.

Study Site

The study was conducted in an old field on The Nature Conservancy's (TNC) Bluestem Prairie Scientific and Natural Area near Glyndon, Minnesota, USA (2,356 ha, 46°49'49.096" N, 96°27'21.017" W). The 30-year annual mean precipitation is 538 mm, with the highest precipitation levels occurring as rain in May (66 mm), June (89 mm), July (73 mm), and August (64 mm). The 30-year mean temperature is 5°C, and mean monthly temperatures range from -14°C in January to 21°C in July and August. Soils at the study site are classified as Aquic Haploborolls, Sandy Mixed (Flaming fine sand) and Udorthentic Haploborolls, Sandy Mixed (Lohnes coarse sandy loam).

The site had been farmed (small grains) until approximately 1968. It was then seeded to smooth brome, an accepted management practice at the time, and grazed by domestic livestock. The site was purchased by The Nature Conservancy in 1972, 28 years before our study, and was managed with a four-year prescribed burn cycle with no grazing. The site had not been burned for three years prior to the installation of our study, and burning was suspended for six years after. The schedule of burning in the experimental study plots has been changed to a six-year cycle (see Discussion for further details). The data we present covers the period before the first burn event on the experimental site using the new schedule (in year 6). We continue to monitor the vegetation on the experimental site, and in five more years we will analyze data that will include an entire burn cycle. The results, thus, represent a preburn condition (in the Discussion section we elaborate on the implications).

Native vegetation on the study site and the surrounding area is northern tallgrass prairie (Barker and Whitman 1988). At the time of the study the dominant vegetation on the site was smooth brome and Kentucky bluegrass with very few native forbs and grasses, as verified by a baseline study conducted prior to installing the experimental study plots.

Treatments

The study was organized as a randomized block design with five experimental treatments, a control, and five replications. Each block consisted of six 44 m × 44 m plots with a 6 m buffer zone surrounding each plot and a 6 m buffer zone between blocks (Figure 1). Treatments and controls were randomly assigned to plots within each block. Treatments consisted of three levels of small-scale disturbances that were individually rototilled/broadcast seeded, comprising 5%, 25%, and 50% of the plots; a restoration treatment consisting of rototilling/broadcast seeding (R&B) of the entire plot (equivalent to 100% disturbance); a restoration treatment consisting of herbicide application/drill seeding (H&D) of the entire plot; and the untreated control (Figure 1).

Individual small-scale disturbances (SSDs) were 2.84 m × 2.84 m in size, determined from previous research on pocket gopher disturbance sizes and patterns (C. Grygiel, pers. obs.). The 5%SSD treatment consisted of three equidistant transects (11 m apart) and four equidistant SSDs per transect (8.8 m from center to center) for a total of 12 SSDs. The 25%SSD treatment consisted of ten equidistant transects (4 m apart) and six equidistant SSDs per transect (6.3 m from center to center) for a total of 60 SSDs. The 50%SSD treatment consisted of 15 equidistant transects (2.84 m apart) with eight SSDs per transect (4.9 m apart) for a total of 120 SSDs. In the 50%SSD treatment, the SSDs were arranged in a checkerboard pattern so as not to have side-by-side SSDs from

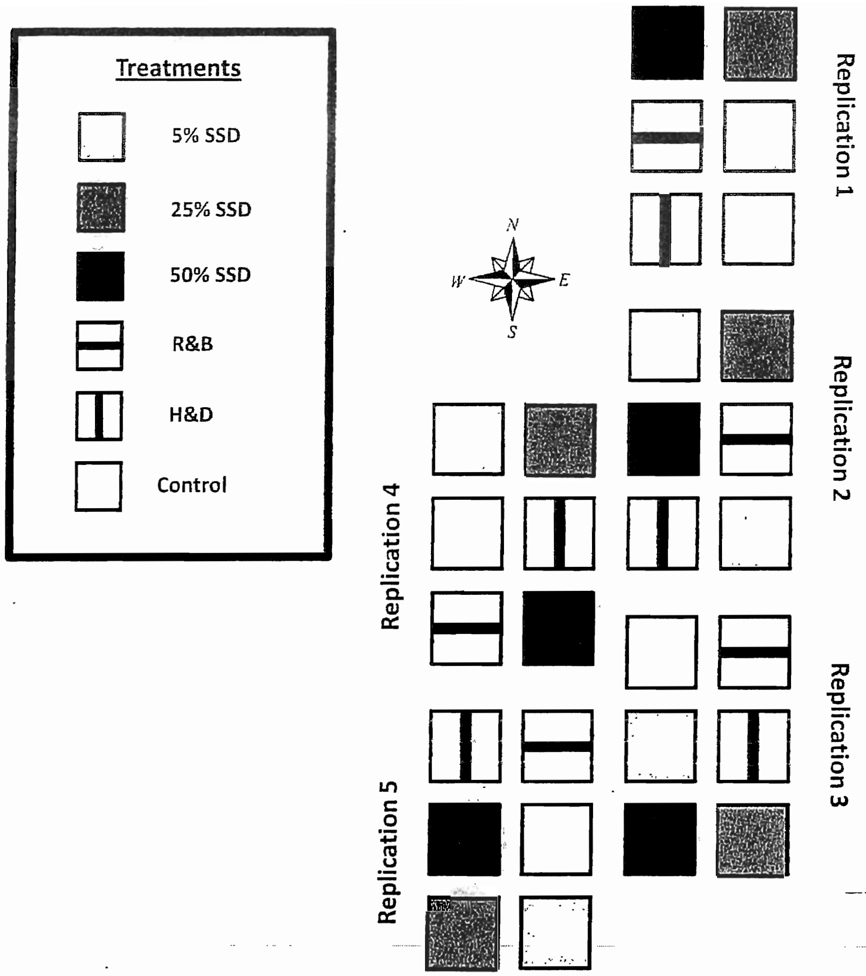

Figure 1. Precision Prairie Reconstruction (PPR) experimental site on The Nature Conservancy's Bluestem Prairie Scientific and Natural Area (Glyndon MN). Treatments consisted of simulated small-scale disturbances at the rate of 5%, 25%, and 50% (5%SSD, 25%SSD, and 50% SSD), herbicide and drill seeding (H&D), rototilling and broadcast seeding (R&B), and control. Each plot was 44 m × 44 m surrounded by a 6 m buffer zone.

adjacent transects. For that reason, SSDs in even-numbered transects were displaced 4.9 m from the starting point of SSDs in odd-numbered transects. The SSDs were located in a regular pattern along transects to facilitate their installation by a tractor-mounted rototiller and to make the method applicable to larger installations where patterns can be created using GPS coordinates.

The SSDs were constructed using a Farm King rototiller, 1.8 m in length and powered by an 80 kW tractor. The SSDs were then broadcast seeded with a Vicon pendulum spreader (Iowa Farm Equipment, Moscow IA) attached to the same tractor. The pendulum movement of the spout ensures that the seeding rate is equal in both sides of the spreader. An important priority for this study was the use of standard equipment that was already on hand and being used for conventional restoration practices in the area.

The R&B treatment consisted of a complete rototilling and broadcast seeding of the experimental plots with the same equipment used for the installation of the SSDs. The H&D treatment consisted of treating the experimental plots with Roundup (Monsanto, St. Louis MO; 18% glyphosate, 0.73% diquat, 0.3% imazapic) applied at the rate of 5.9 L/ha (first week of October), and then drill-seeded (third week of October) using a Truax drill (Truax, New Hope MN) attached to a 80 kW tractor and modified to plant prairie seeds. In large fields, the management standards sometimes require additional applications of Roundup to eliminate green spots; in our case, the plots were small enough that we could thoroughly cover them with Roundup. We conducted a visual survey before planting to detect any significant control failures (there were none). The control plots received no treatments.

The seed mixture of grasses and forbs common to the native vegetation of the area comprised seed purchased from Prairie Restoration (Princeton MN) or hand collected by the researchers. All seeds used in this experiment were collected from within 80 km of the study site in accordance with TNC requirements (Table 1). Species were seeded at the rate of 27 kg/ha in the 5%SSD, 25%SSD, 50%SSD, and R&B treatments and 13.5 kg/ha in the H&D treatment, which are the standard practices for broadcast seeding and drill seeding rates in the area. The ratios are not arbitrary, since there is an extensive practical literature regarding drill vs. broadcast seeding rates. The overwhelming recommendation is that broadcast seeding rates should be at least one-third to two times higher than the rates used when drill seeding (see, for example, Dorner 2002, Pacific Northwest Natives 2003), owing to survival problems associated with reduced moisture, predation, inadequate soil contact, etc.

The R&B treatment plots and the SSDs were rototilled to a depth of 20 cm with two passes of the tiller and seeded during the third week of October. Planting was done in fall because our prior experience in a large-scale restoration and biodiversity experiment in the Sheyenne National Grasslands had shown that in this area fall planting is, in general, more effective than the common spring and summer planting (Biondini 2007). In part, this is because it solves the stratification or scarification requirement of many of the seeded native forbs through the freezing and thawing of the ground (Levang-Brilz and Biondini 2002). It also provides a good moisture environment for germination from snow melt and April rains (Biondini 2007). There is a drawback involving some of the C_4 grasses, particularly blue grama (*Bouteloua gracilis*), which clearly does better in spring and summer planting, and it may be a reason why both blue grama and sideoats grama (*Bouteloua curtipendula*) had such low survival rates (Table 1). Following seeding, a harrow was lightly dragged over the SSD treatment plots and the R&B treatment plots. No herbicide, with the exception of the H&D treatment, was used in this phase of the study.

Table 1. Native grasses and forbs used in the seeding treatments on the Precision Prairie Reconstruction (PPR) experimental site on The Nature Conservancy's Bluestem Prairie Scientific and Natural Area (Glyndon MN). Survivability is the average percent survival over the length of the experiment across all treatments. Species nomenclature follows USDA-NRCS (2008).

Species	Survivability (%)
Grasses	
Agropyron caninum var. *mitchellii* (= *Elymus trachycaulus* ssp. *trachycaulus*)	10
Andropogon gerardii	73
Bouteloua curtipendula	20
B. gracilis	1
Koeleria pyramidata (= *K. macrantha*)	1
Schizachyrium scoparium	76
Sorghastrum nutans	21
Stipa spartea (= *Hesperostipa spartea*)	10
Forbs	
Achillea millefolium	72
Allium stellatum	0
Amorpha canescens	7
Anemone canadensis	0
A. cylindrica	1
Artemisia dracunculoides (= *A. dracunculus*)	11
Cerastium arvense	1
Echinacea angustifolia	12
Helianthus maximiliani	0
H. rigidus ssp. *laetiflorus* (= *H. pauciflorus* ssp. *subrhomboideus*)	16
Liatris aspera	3
Oenothera biennis	12
Penstemon gracilis	1
P. grandiflorus	22
Petalostemon candidus (= *Dalea candida* var. *candida*)	10
Petalostemon purpureum (= *Dalea purpurea*)	13
Potentilla arguta	15
Ratibida columnifera	0
Rudbeckia hirta	3
Solidago nemoralis	3
Solidago rigida (= *Oligoneuron rigidum* var. *rigidum*)	42
S. speciosa	24
Verbena stricta	65
Zizea aurea	10

Vegetation Sampling and Data Analysis

All treatments were sampled from 2001 to 2005. The sampling was conducted in mid-July each year using 20 nested quadrats (0.1 m^2 nested inside 0.25 m^2) randomly distributed within the study plots. The entire 0.25 m^2 quadrat was sampled for forb density by species, while the 0.1 m^2 quadrat was sampled for grasses, also by species.

Species richness was estimated as the average number of species per treatment. Differences in species richness (total and seeded forbs), seeded forb density, and average seeded grass frequency among treatments were analyzed using a randomized block analysis of variance (RAOV) with a repeated observation model (years being the repeated observation factor) (Winer 1962). In accordance with Tilman (1996), the coefficient of variation (CV) in seeded forb richness was used over the five year period of the study (CV = SD/mean) as a measurement of seeded forb community stability: the higher the CV the lower the stability.

Results

The fifth growing season marked the final year for this phase of the study. Total species richness (forbs and grasses) in the fifth year was similar in the R&B, 25%SSD, and 50%SSD treatments, but significantly higher ($p < 0.01$) than in the 5%SSD and the control (an average of 29 species vs. 16 species) (Figure 2). The H&D treatment showed an intermediate response (22 species).

The R&B and 25%SSD treatments had similar average numbers of seeded forbs (9), significantly more ($p < 0.01$) than in the 5%SSD and control treatments (1.5) (Figure 3). The 50%SSD and H&D treatments showed an intermediate response with an average of 5 seeded forbs (Figure 3). Similar results were found with respect to forb density. In the fifth growing season, the mean total seeded forb density was the highest in the R&B and 25%SSD treatments ($p < 0.05$) and the lowest in the 5%SSD and control treatments: average of 12 vs. 0.6 plants/m^2 (Table 2). Similarly, the frequency of seeded grasses averaged 0.37 in the R&B and 25%SSD treatments vs. 0.08 in the 5%SSD (Table 2).

The variability in the seeded forb richness over the five-year period was

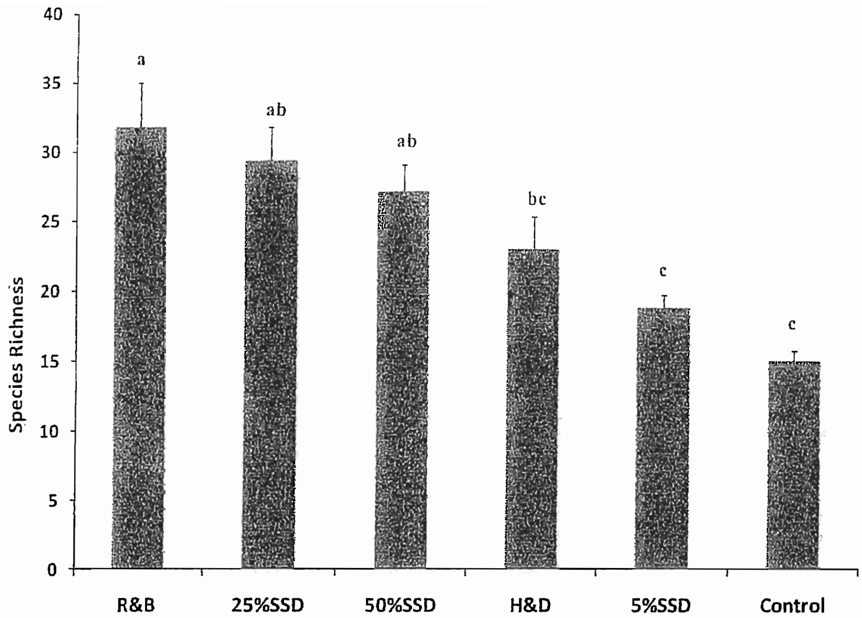

Figure 2. Year 5 mean species richness (± 95% CI) of grasses and forbs. Treatments consisted of simulated small-scale disturbances at the rate of 5%, 25%, and 50% (5%SSD, 25%SSD, and 50% SSD), herbicide and drill seeding, rototilling and broadcast seeding, and control. Treatments without a common letter are statistically different ($p < 0.01$).

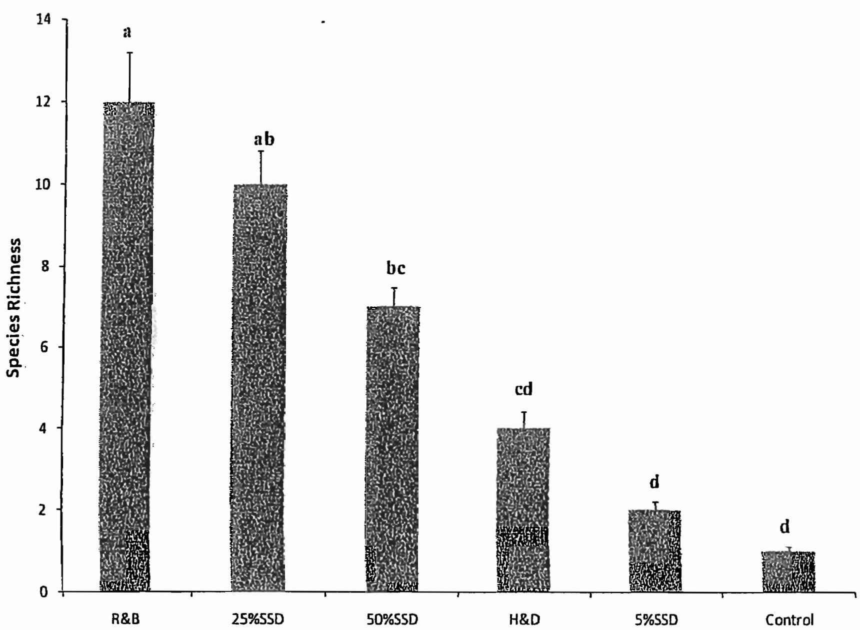

Figure 3. Year 5 mean species richness (± 95% CI) of seeded native forbs. Treatments consisted of simulated small-scale disturbances at the rate of 5%, 25%, and 50% (5%SSD, 25%SSD, and 50%SSD), herbicide and drill seeding, rototilling and broadcast seeding, and control. Treatments without a common letter are statistically different ($p < 0.01$).

similar in the R&B, 25%SSD, and 50%SSD treatments but 50% lower ($p < 0.01$) than in the H&D, 5%SSD, and control treatments: an average CV of 0.45 vs. 0.9 (Figure 4). In comparison, the CV for growing season precipitation for the same time period was 0.25.

Discussion

Our study tested a novel methodology for increasing forb species richness in a non-native grass matrix. A method that involved rototilling and seeding, in a systematic pattern, only 25% of a designated grassland site (the 25%SSD treatment) resulted in total species richness, seeded forb richness, stability of the seeded forb richness, seeded forb density, and seeded grass frequency in the matrix vegetation that after five years were statistically similar to values achieved using a conventional method of rototilling and seeding 100% of the site. Furthermore, the 25%SSD treatment was more effective than both the conventional treatment of herbicide and drill seeding and the 5%SSD treatment. The 5%SSD appears to be insufficient to significantly increase species richness above the levels in the control treatment (Figures 2–4). While the 5%SSD treatment results in persistent forb communities within the disturbance patches, these communities are simply too few to have a statistically significant effect on the landscape. The 50%SSD and the H&D treatments were less effective for the establishment and persistence of seeded forbs over the entire landscape for the five-year study period (Figures 2–4). In the case of the H&D treatment, a proximate cause for the low levels of seeded forbs may be related to the seeding method, that is, drilling. Literature for the Northern Great Plains (Bakker et al. 2003, Wilson et al. 2004) shows that drilling is less effective than broadcasting for the long-term establishment or survival of native forbs. Finally, the higher stability (low CV) of the forb community that we find in the 5%SSD and R&B treatments (Figure 4) is most likely related to their higher forb richness (Table 2, Figure 3), since there is an extensive literature showing an inverse relationship between community-level CV and species richness (see, for example, Tilman 1996, Biondini 2007).

The practical implication of these findings is that the 25%SSD treatment could prove to be a cost-effective method for increasing species richness in a standing grass matrix without the need for repeated interseeding or a complete reinstallation of the site. Table 3 shows a cost estimate for the various methods in dollars per

Table 2. Average forb density (plants/m^2) and grass frequency for the seeded species plus *Bromus inermis* and *Poa pratensis* in 2005 for each treatment: small-scale disturbances (SSD), control (C), herbicide and seed drilling (H&D), and rototilling and broadcast seeding (R&B). Statistics were calculated for total seeded forb density and average grass frequency. Treatments with different letters are different at $p < 0.05$. Note: we list only densities or frequencies greater than 0.05.

	Treatment					
Species	25%SSD	50%SSD	5%SSD	C	H&D	R&B
			Forbs (plants/m^2)			
Achillea millefolium	4.0	1.1	0.6	—	1.1	5.3
Amorpha canescens	0.2	—	—	—	0.2	0.2
Artemisia dracunculoides (= *A. dracunculus*)	2.2	0.4	—	—	—	2.7
Echinacea angustifolia	—		—	—	—	0.3
Helianthus rigidus	2.0	2.2	—	—	—	0.5
Oenothera biennis	0.2	—	—	—	—	—
Penstemon grandiflorus	—	—	—	—	—	0.3
Petalostemum candidus (= *Dalea candida* var. *candida*)	0.4	—	—	—	—	0.2
Petalostemum purpureum (= *Dalea purpurea*)	0.2	0.2	—	—	—	0.3
Potentilla arguta	—	—	—	—	0.2	—
Rudbeckia hirta	—	—	—	—	—	0.4
Solidago rigida (= *Oligoneuron rigidum* var. *rigidum*)	0.8	0.4	—	—	—	1.0
Solidago speciosa	0.4	0.5	—	—	—	0.4
Verbena stricta	0.9	0.3	0.2	0.4	0.4	1.1
Total density	11.3[a]	5.1[b]	0.8[d]	0.4[d]	1.9[c]	12.7[a]
			Seeded Grasses (frequency)			
Andropogon gerardii	0.7	0.4	0.1	—	0.6	0.8
Bouteloua curtipendula	0.1	—	0.1	—	—	0.1
Schizachyrium scoparium	0.4	0.3	0.1	—	0.1	0.6
Sorghastrum nutans	0.1	0.1	—	—	0.1	0.1
Average frequency	**0.33[a]**	**0.20[b]**	**0.08[c]**	**0.00[d]**	**0.20[b]**	**0.40[a]**
			Original Grasses in the Old Field (frequency)			
Bromus inermis	1	1	0.98	1	0.94	0.97
Poa pratensis	0.98	0.99	0.99	0.96	0.94	0.99

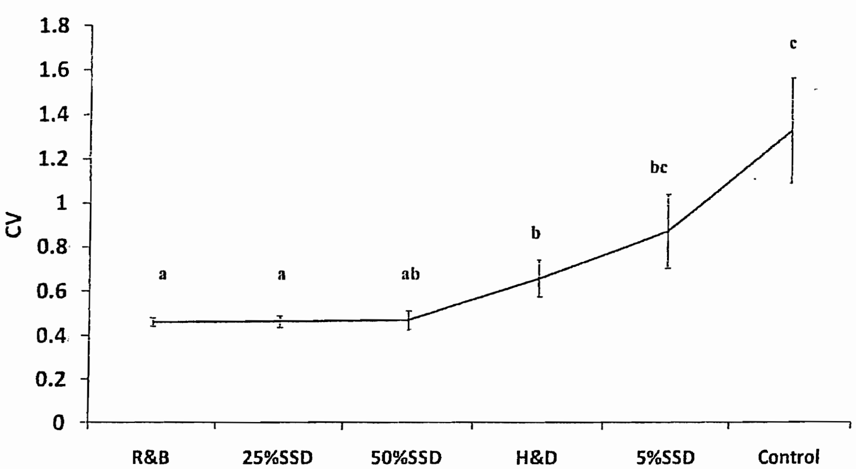

Figure 4. Coefficient of variation (± 95% CI) for seeded forb richness over the five years of the study. Treatments consisted of simulated small-scale disturbances at the rate of 5%, 25%, and 50% (5%SSD, 25%SSD, and 50%SSD), herbicide and drill seeding, rototilling and broadcast seeding, and control. Treatments without a common letter are statistically different ($p < 0.01$).

hectare. The values were derived from the actual cost that Prairie Restoration charged for seeding and installation (in year 2000 dollars). The cost of the 25%SSD treatment was approximately one-third the cost of the traditional R&B treatment, with most of the savings from lower seed cost. The values in Table 3 are not an estimate of how much it would cost to actually implement these treatments under normal restoration conditions involving hundreds of hectares, since some of the activities, such as setting up the transects for the disturbances and field marking the location of individual disturbance sites, were conducted by the researchers and graduate students. We thus recommend using a GPS system to create a stratified, even distribution of disturbances to minimize cost. The values in Table 3 simply represent the seed, cultivation, and seeding costs on the relatively small scale of the experimental plots. An additional factor to consider is that some of the forb species we used are in short supply, and thus the cost may substantially increase when the restoration involves large areas. The survival data we included in Table

Table 3. Cost of experiment installation as billed by Prairie Restoration (Hawley MN) in 2001. These values represent the seed, cultivation, and seeding costs on the relatively small scale of the experimental plots: small-scale disturbances (SSD), control (C), herbicide and seed drilling (H&D), and rototilling and broadcast seeding (R&B). The total cost for the experiment was $27,860 ($5,510 for seed and $22,350 for installation). The installation costs include operator wages, rototilling, herbicide application, and drill seeding as pertinent to each treatment. Fieldwork time and labor costs could be substantially reduced by using GPS to locate individual sites. All costs listed below are adjusted to reflect $/ha.

Treatment	Seed cost	Installation Cost	Total
5%SSD	$124	$454	$578
25%SSD	$619	$2,577	$3,196
50%SSD	$1,237	$5,566	$6,803
H&D	$1,237	$7,319	$8,556
R&B	$2,475	$7,174	$9,649

1 could be used as a guide to which species may not be worthwhile to use in this area.

As we explained earlier, these first five years of data (plus the three years before setting up the experiment) did not involve prescribed burning (the plots were burned in year 6 as part of the normal management of the site) or grazing. Our own experience in the northern tallgrass prairie ecoregion has shown that for the forb community (the main focus of our research), fire alone is not a sufficient disturbance to change community composition (Biondini et al. 1989). Specific fire seasons tend to enhance or mask the forb community structure arising from other disturbances, in particular droughts (Biondini et al. 1989). That is, fire is not an exceptional event but falls within the year-to-year climatic variation. An extensive review of the literature for the Northern Great Plains by Higgins and colleagues (1989) has shown that while fire can indeed increase the density and biomass of grasses, it has limited to negative effects on most forbs. Furthermore, there is a body of evidence showing that fire has only minimal and short-term effects in controlling the two major introduced species that dominated our site, smooth brome and Kentucky bluegrass (Wilson 2002). Similar results were found by Biondini and Manske (1996) and Biondini and others (1998) for grazing. It is also worth mentioning that at moderate stocking rates, large grazers do not appear to significantly alter plant species assemblages or alter the trajectory of plant succession (Jefferies et al. 1994, Biondini et al. 1998, Briske et al. 2008).

While we do recognize the importance of fire for the maintenance of grasslands (native or restored), data from the Sheyenne National Grasslands (near our site and in the same ecoregion) indicate an average fire return interval (for natural fires with no suppression) of 6–8 years with an average burned area of 6–8 ha (Higgins 1984). Wright and Bailey (1982) calculate an average fire return interval of 8–9 years for the entire northern tallgrass prairie ecoregion, significantly longer than the 3–5 years they estimated for the southern tallgrass prairie from which the bulk of the data and research on fire and fire response has come (Hartnett et al. 1996). The current fire regime used by TNC (including our experimental plots) has been changed to a six-year cycle to reflect this information.

Our results involve only five years without a burning cycle and therefore should be considered as tentative. We continue to monitor the vegetation on the experimental site. Preliminary observations, two years after the prescribed burn, suggest a continued increase of seeded native forb density and seeded native grass frequency in the SSDs as well as the matrix. We plan to sample the study again in three years to evaluate progress.

Implications for Application

- Precision Prairie Reconstruction (PPR) using strategically placed, broadcast-seeded, simulated small-scale-disturbances (8.06 m^2) covering 25% of the area (25%SSD) was as effective as the standard method of rototilling and broadcast seeding the entire area (R&B) for increasing total species richness, native seeded forb richness, native seeded forb density, and native seeded grass frequency in an old field dominated by two introduced grasses, smooth brome and Kentucky bluegrass.
- The 25%SSD treatment was superior to the 5% and 50% small-scale disturbance treatments as well as the herbicide/drill (H&D) treatment of the entire old field.
- The cost of implementing (seed, cultivation, and seeding) the 25%SSD treatment was approximately one-third that of the R&B treatment.
- These results are from the first five years of treatment implementation; longer-term results that include a prescribed burn cycle will be evaluated in future research.

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