2004

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Abstract

In 1981, 20% of a 3.3-acre (1.3-ha) portion of an eroded Hochheim loam on the Retzer "Vista" hilltop, in southeastern Wisconsin, was planted in 12-ft (3.7-m) wide "source strips" so that intervening 48-ft (15-m) wide "invasion strips" resulted. A dry-mesic prairie seed mix was used in the two highest elevation source strips and a mesic prairie seed mix was used in three source strips on the lower, side-sloped portion of the hilltop. While the farming-era loss of essentially all of the original topsoil made the site "drier," the associated bringing up of more and more of the subsoil, with time, also made the topsoil seedbed much more clayey. No seed or transplants were ever planted in the invasion strips. An alternating pattern of simulated burning/real burning/simulated burning, etc. was the only treatment done in the six invasion strips. In ten years, early stage forbs had invaded so well that they were found in every square meter of both types of invasion strip treatment. However, most late-stage forbs and all warm-season grasses invaded less than half of the invasion strips after 18 years. After 23 years, the results of belt transect surveys indicate that warm-season prairie grasses would now be found in 70% of the total invasion strip space.

Keywords: invasion strips, prairie restoration, Retzer Nature Center

Although there have been many reports, for many years, of abandoned fields showing a strong natural invasion of prairie species, when there was adjacent prairie (e.g., Thomson 1940, Thomson 1943), there seems to have been very little reporting of trials where such invasion was demonstrated as an establishment technique. Additionally, at the time this project was being planned (about 1980), serious widespread interest was well underway among many non-professionals to do their own prairie plantings. There was also a strong interest among the Waukesha County Park's Naturalist staff—headquartered at Retzer Nature Center—in the use of scarce, local prairie seed so as to be on the "safe side" genetically, and within the Leopoldian Land Ethic perspective.

Site Description

A 3.3-acre (1.3 ha.) portion of an 8.5-acre (3.6-ha) dense Kentucky bluegrass (*Poa pratensis*) oldfield, on a drumlin hilltop, was chosen for this trial of planned prairie invasion. This field was already well underway as a long-term project for self-guided prairie establishment trials. Four plantings had already been established in other portions—one in 1976, another 1978, and two in 1979.

The portion chosen had one possible minor drawback for such a project—its 6–20% slopes were northwest facing—not the classic south or west aspects that are supposed to favor prairie in our region. The other attributes seemed quite favorable. These included being in the hilltop portion of a large drumlin, being very open (surrounding fence rows had negligible forest edge effects), and the loss of essentially all of the site's original Hochheim-loam dark topsoil—documented in hinged-cover, soil profile pits (Steingraeber 1979). The loss of the topsoil was deemed an advantage since the competing European perennial oldfield grasses were known to be more dependant on topsoil fertility than the prairie species. Additionally, a local farmer whose family had rented the site from the federal government, documented that it had been planted in corn as early as 1929. It must have already been very eroded then because one of the first things they reportedly did was to put 70 manure loads on the 8.5-acre field (Retzer Nature Center 1996).

Methods

Site Preparation

A regimen of moldboard plowing and disk tillage was completed by early summer 1981 to prepare 20% of the site that was to be planted as "source strips" or areas with parent prairie plants. These were installed as 12-ft (3.75-m) wide contour strips with the two highest elevation strips for seeding dry-mesic ("PDM") species. The intervening "invasion strips" were 48-ft (15-m) wide and were left for natural invasion by prairie plants.

Two weed control tactics were also applied in 1981. We divided each of the 12-ft wide source strips such that one-half of each strip was treated with a single pass of disking in mid–June and again, in mid–July (the "extra-cultivation" portions), while the other half of each source strip was treated with one to two passes of glyphosate herbicide spray, in early August (the "glyphosate" portions).

Seedbed preparation was done on all source strip areas by spike tooth type tillage operations on August 20, and planting by hand broadcasting on August 21. The intervening "invasion strips," to be left for natural invasion, for the remaining 80% of the area, were 48 ft wide. The plan was to only use stand-wide conventional weed control tactics to foster a natural colonization-type invasion, by weakening the oldfield sod with mowing and removal of appreciable clippings, ("simulated burning") in half of the 48-ft wide invasion strips and use of real fire in the other half of the invasion strips.

Major Treatments

The major treatments started after the early stage (first two years) and were simply the burning of all source strips, and the alternating burning and simulated burning of the intervening invasion strips (simulated burning was mowing to about 3 inches high and raking off heavier clippings, at the same times as real burning). The plan was to use stand-wide conventional weed control tactics to foster a natural colonization-type invasion. These started out as annual treatments in 1983 and 1984 so as to quickly weaken the cool-season, perennial European sod grasses. However, with time, they were changed to biennial (1985–1991) and triennial (1992–1995) management schedules.

Then, after conducting the above managements for a 14-year-period (1995), an equivalent, or even slightly better, invasion was seen so consistently in the simulated-burn strips so as to allow cessation of the time-consuming divided managements. Therefore, starting with the 1995 cycle, the entire 3.3-acre site started to be burned as a single unit (i.e., the whole site was burned as a unit in 1995, 1998, 2001, and spring 2004).

Seed Mixes and Early Stage Conditions

One could also call some portions of this section, early results, but I consider them here because a developing prairie exhibits a multi-stage process wherein the earlier stages are felt to normally have important lasting effects on the late stages that are used for project assessment. Accordingly, a number of start-up and early-stage conditions that are basic to understanding several factors within which some expectations for final results should be perceptible are presented in Table 1.

It should be noted that the two seed mixes comprised of 30 and 36 test species, had 19 species in common (53% and 63% respectively of the "PDM" species and "PM" species). It should also be noted that the average seeding rate of 44.5 lb/acre is much higher than what is often used nowadays because it was hand-cleaned seed, put in at about a maximum planned density rate for sake of experimental purposes. And, while the grass component was about 33% of the total mix weight, which may now seem high, the average of about 11% of first season-established seedlings was not. In fact, this relatively low take, turns out to be one of the most salient aspects in the results section of this paper.

Although somewhat of a minor tangent, some intriguing results were shown for two species with early-state indicator value in this project. That is, a key serious weed, sweet clover (*Melilotus* spp.), recorded as second-year stems, and an evening primrose (*Oenothera biennis*), seeded as a native "nurse crop", both showed good consistency with the results that are summarized in Table 2.

The point in showing this data is not to suggest that the extra cultivation treatment gave such better effects, but rather that several such differences due to the two weed control tactics, were strongly expressed in the early (1982–1983) to early-mid (1985–1986) stages. Although the evening primrose counts were deemed about "just right" for the glyphosate strips, they were so dense as to suppress the other vegetation in the extra cultivation. And while the sweet clover counts seemed too high, even in the extra cultivation strips, the planned very high initial density of prairie, earlier referred to, seemed to make sweet clover a scarcity in the source strips generally by about 1990.

Some other such indicators (for which density measurements were not taken), but that in 1985–1986, seemed to indicate a reverse pattern were: 1) Kentucky bluegrass was definitely stronger in the extra cultivation source strips and 2)

Table 1. Some basic project statistics.

Prairie Species*	Sum Area	Test Species	Seed lb/ acre	% Forbs by wt.	% Grass by wt.	% Grass Seedlings by Oct. '81
2 PDM Source Strips	0.27 acre (0.11 ha)	36	52.4	67.2	32.8	15.3
3 PM Source Strips	0.27 acre (0.11 ha)	30	36.6	65.8	34.2	6.5
6 Invasion Strips	2.77 acre (1.12 ha)	NA	NA	NA	NA	NA
Total	3.3 acre (1.32 ha)	NA	89.0	133.0	67.0	21.8
Averages		NA	44.5	66.5	33.5	10.9

Note: Two prairie species, Canada wild-rye (*Elymus canadensis*) and evening primrose (*Oenothera biennis*), which were used as short-lived native companion crops in this project, have been deleted from this analysis, including from the test prairie species figures.

Table 2. Early-stage expression of two key indications of prairie planting success in the source strips in late spring 1983 (All numbers indicate stems/m²).

	Extra Cultivation		Glyphosate-treated	
	Sweet Clover	Evening Primrose*	Sweet Clover	Evening Primrose*
Two PDM Strips	43.0	9.1	95.5	2.3
Three PM Strips	60.0	7.6	114.8	1.7
Totals	103.0	16.7	210.3	4.0
Averages	51.5	8.4	105.2	2.0

Note: Late spring 1983 evening primrose stem counts were tallies of remaining 1982 floral stems.

the planted gray-headed coneflower (*Ratibida pinnata*) was 30–35% denser in the glyphosate-treated source strips.

The important conclusion that came into focus by about 1990 was that the Table 2 type differences, noted in this project—even if strong—conveyed no detectable effects on test prairie species or competing weeds after about year 10 or 1990.

Results

The important focus for evaluation of results in a long-term project like this one is in the late stage, which started at about year 10 (1990). An amazingly quick natural invasion of early-stage forbs occurred so strongly after ten years that they were found in every square meter-sized spot that was examined everywhere in the invasion strip areas. Species, such as bergamot (*Monarda fistulosa*), black-eyed Susan (*Rudbeckia hirta*), false boneset (*Kuhnia eupatorioides*), stiff goldenrod (*Solidago rigida*) and others, densely populated both the PDM and PM invasion strips and in both types of treatments.

A transect survey done after 18 years (1999) showed that late-state forbs—both *Baptisia* species, prairie dock (*Silphium terebinthinaceum*), rattlesnake master (*Eryngium yuccifolium*), silky aster (*Aster sericeus*), among others, and the warm-season prairie grasses—had become dominant/co-dominant in considerably less than half of the total invasion strip space. However, the results of a July 2004, belt-transect survey, after two more area-wide spring burns, showed a recent gain for the warm-season prairie grasses—such that warm-season grass was found in every square meter examined in 70.4% of the total invasion strip space.

There was an earlier tendency for the mowed/simulated-burn strips to often show a bit better invasion. This was thought to be an artifact of the fact that only those invasion strips were driven across during the early spring burn season when the topsoil is moist. The mowing and removal of clippings only on those strips caused compaction that may have sped the break-up of the bluegrass sod. However, after the April 2004 burn, it was noticed that the pattern was reversed—so that the invasion strips that have only had real burning for the main treatment had a distinct tendency for better prairie invasion—at least for the warm-season prairie grasses.

A serious complication developed in the invasion strips, at the mid-stage, after about five years (1986). There was a notable, distinct preference by sweet clover for the burned invasion strips once the biennial management intervals were begun, while Queen Anne's lace (*Daucus carota*) showed a similar, distinct preference for the mowed/simulated-burned strips. In actual practice, fairly intense unplanned prescribed mowing was applied wherever these serious biennial weeds achieved a "very common" status. This was done mostly from 1986 through 1997. By about 1999, these two invasive biennials were greatly diminished in both the source strips and invasion strips throughout the whole area.

Discussion

The very strong, quick natural invasion of early-stage prairie forbs due to both mowing and burning was a splendid surprise. However, a strong "invasional" type of colonization during roughly the same time frame by two biennial weeds—sweet clover and Queen Anne's lace—that were "hiding" in the seedbank, cast a negative shadow on the project. (I'm very indebted to our maintenance staff for their prompt and considerable weed-control mowing during the 1986–1997 period.) In spite of all this difficulty, an interesting detail emerged in that there was a distinct tendency for sweet clover to be the dominant serious weed in the burned invasion strips, while Queen Anne's lace occupied the mowed/simulated-burned strips. Of course, after stand-wide burning was applied for a while and as the prairie vegetation matured, those two weeds became quite scarce.

Another humbling aspect of the project was the effect of soil erosion. Fortunately, the lead author of the soil survey for Milwaukee and Waukesha counties, Joe Steingraeber, had offered to interpret the soils of the whole self-guided prairie trial area, by emphasizing the two previously mentioned soil profile pits, if we would agree to afterward protect them with hinged covers. He documented that the whole area of this project—at least as far as non-edge portions— was convex-sloped, and all such areas here were Hochheim loams that had lost all of their original, dark topsoil.

Joe's information was superb, but I misapplied it in the sense of expecting that the resultant effect would be both a further "drying" (a drumlin hilltop in our area is already fairly "dry") and a decrease in fertility—both of which should have fostered an even better prairie colonization, including grasses. While all that still seems to hold pretty well in theory, what I overlooked was a third soil factor, which had also changed because of the farming-era erosion. It turns out that the repeated plowing for row crops, on a Hochheim loam, would have to bring up more and more of the clayed subsoil ("B"

Figure 1. 1990 aerial photograph of contour "invasion" strips of prairie at Retzer Nature Center. The mesic strips (PM) are the three dark, narrow strips, while the dry-mesic strips (PDM) are the two dark, narrows strips up the slope. Scale is 1 inch = ca. 100 feet. *Photo courtesy of author*

horizon). That such a resultant clayey soil would be much more resistant to natural invasion than more porous soils is well stated by John Curtis (Curtis 1959, pp. 294–295) in an excellent discussion about much slower prairie establishment on such soils compared to sandy soils.

Besides all this, the seeding date of August 21, 1981 in all five source strips was felt to have been a main factor in the great disparity shown in Table 1 between a roughly 33% average prairie grass component in source strip seed compared to a corresponding early-stage grass density of only about 11%. In a recent article (Schwarzmeier 2004), I convey the results for ordinary soil moisture sites ("imperfectly" though "well-drained") that show much better seedling success for the warm mid–May through mid–July season, than what has been seen for any fall-season plantings.

As far as time frames for someone who might consider using invasion strip, as just reported on, I think that our results, considered with Curtis's discussion (Curtis 1959, pp. 294–295) about prairie colonization in relation to soil type, suggests the following guidelines. For source strips that are at least 8 ft (2.5m) wide and separated by invasion strips of about 45–50 ft (14–16 m) wide, it seems that a strong, good invasion can be expected in 12–15 years with sandy soils and by about 25 years in heavy soils. This assumes that invasion-fostering management is applied on an annual or triennial basis, starting in the third year, and that prairie seed with at least a 30–50% grass component by weight is seeded in from mid–May to mid–July season on ordinary loamy soils in southeastern Wisconsin.

Most land managers would likely try an alternate version of this approach, which we have tried several times since the contour strip project started in 1981. For instance, if the whole site can be seeded at the outset, a much-quicker natural look can be realized by just mixing the native prairie seed with domestic forage varieties that provide an oldfield type of "nurse crop" effect. One benefit of such plantings is that they can multiply the effect of scarce, ecologically safe, prairie seed of local origin. Our two biggest mixed seedings of this type are a 14-acre planting at the Eble Ice Rink (Brookfield, Wisconsin), which was done in 1989, and a 1995 planting of 6.5 acres at Ryan Park (Pewaukee, Wisconsin). From involvement with several such plantings, we recommend planting alsike and red clovers, Chewings-type red fescue, Kentucky bluegrass, Timothy grass, and annual flax along with the prairie seeds. Each of these forage species have all proven to be "prairie compatible" when planted at the outset, with ordinary "restoration" type prairie seed, at a fairly low seeding rate of about 22–35 lb/acre for the total mix (or about the same rate we recommend for hand-cleaned prairie seed planted by itself).

Furthermore, we have found in such mixed-component seeded plantings that the prairie portion has to be at least 15–20% of the total, by weight, so that the compatible forage portion would not be over 80–85%. If a natural prairie appearance is desired, the proportion of grass to forb seed in the prairie component should again be at least 30–50%, probably closer to 50% if the site has heavy soil.

Conclusions

1. Planned invasions have been proven quite workable when seeded source strips have been as far apart as 48 ft (15 m).
2. Planned natural invasional plantings have been demonstrated to be a workable strategy when only 20% of the original area was seeded to prairie.
3. Heavier, clay soil areas should have a seed mix ratio of at least 30–50% prairie grass with 50–70% forb seed (by weight) for such source strip invasions. Although seed mixes with 25–35% prairie grass and 65–70% forb seed will work when the mixes are diluted with prairie-compatible forages, such as alsike clover and Chewings red rescue, in whole-stand plantings.

4. While it seems that simulated burning effects can be very roughly equivalent to real burning effects in oldfield-type prairie invasions, the effort needed to remove the heavy clippings (within 48 hours), may make the effort impractical for handwork projects that exceed about 0.3 acre in size.
5. It was proven very unwise to use biennial burning/mowing type managements of grassland natural areas in our region of the Upper Midwest because such regimens can greatly encourage serious biennial-type weeds, such as sweet clovers, Queen Anne's lace, knapweed and others, even if such species appear to be originally absent from the site.

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