

QUANTITATIVE TRENDS IN PROGRESSION TOWARD A PRAIRIE STATE BY SEED BROADCAST AND SEEDLING TRANSPLANT METHODS

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Abstract. A 0.63 ha area at a College of DuPage Prairie Restoration site was planted with 28 prairie species using two restoration methods: seed broadcast and seedling transplant. The Wilhelm Assessment Method was used to compare vegetational changes for these two methods in the absence of weed removal and fire during this four-year study. To record vegetational changes, plant species were identified and tallied along a 0.5 m wide transect for 21 north-south lines. The transects were 10 m apart and varied in length from 3.8 to 55.2 m. A seed broadcast area of 196.7 m² and a seedling transplant area of 42.7 m² were sampled for four years. There was a slow and steady decline in number and percent coverage of weed species (numerical rating < 4) and an increase in the percent coverage of prairie species (numerical rating ≥ 4) for both methods of restoration. The rating indices for both planting methods consistently increased. There were no significant differences ($p > .05$) between the restoration treatments during this four-year study. Progression toward a prairie state can be achieved by either seed broadcast or seedling transplant methods.

INTRODUCTION

The reestablishment of prairie species by seeding or transplanting on areas where the original vegetation was completely removed has been accomplished in several areas of the United States (Dale and Smith 1983). Prairie restorationists and researchers have reported the success of native prairie restoration in the Midwest (Anderson and Cottam 1970, Becic and Bragg 1978, Harper 1983, Schulenberg 1970, Sperry 1983). Most assessment analyses of prairie restoration or reconstruction sites have been qualitative, that is, good or poor, and not in terms of consistent standards (see Harper 1983, Sperry 1983).

Quantitative analyses of prairie restoration projects include Anderson and Cottam's (1970) "prairie continuum", used to describe the frequency of vegetational change in the H.C. Greene Prairie in the University of Wisconsin Arboretum. Woehler and Martin (1983) documented annual vegetation changes from 1975 to 1980 in Wisconsin, using stratified random measurements to calculate the "importance values" of plants. Dale and Smith (1983) compared the percent cover of prairie grasses and weeds for five years to report the successional changes in a reconstructed prairie in Arkansas. Finally, Liegel and Lyon (1986) noted vegetational trends through five years for a prairie restoration site in southern Wisconsin, using percent cover for each species present.

This study compares quantitatively the vegetational changes in a seed broadcast area with those in a seedling transplant area in the absence of weed removal and fire. Quantitative analysis was accomplished using the Wilhelm Assessment Method (Swink and Wilhelm 1979, Wilhelm and Ladd 1988).

SITE LOCATION AND DESCRIPTION OF STUDY AREA

The study site is immediately north of a marsh on the campus of the College of DuPage in Glen Ellyn, Illinois: SW of NE Quarter, Sections 26 and 27, Township 39, Range 10 in DuPage County, Illinois. The study area of 0.63 ha is roughly rectangular in shape (Figure 1). Approximately one-half of the site is bordered by a thick stand of cattails (*Typha latifolia* L. and *T. angustifolia* L.) and sandbar willow (*Salix interior* Rowlee) on the south side and lawn grass on the north side.

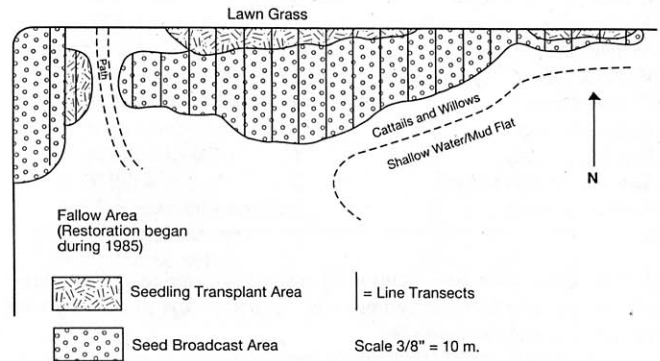


Figure 1. College of DuPage Prairie Restoration Area.

Prior to 1965, the study area was farmed. From 1965 to 1975 the area remained fallow. Twenty to 25 cm of gravel was spread on the area during 1975, and it served as a parking lot until 1984. During Spring 1984, clay and rubble subsoil from a newly constructed complex on the College of DuPage campus was dumped on the study site and contoured from an elevation of 228.1 m to 230.1 m above sea level. The restoration area was then top-dressed with 7-10 cm of black soil from another construction site on campus. Soil, chemical, and structural characteristics of the site are listed in Table 1.

MATERIALS AND METHODS

All seeds were collected during 1983 from sites within a 40 km radius of the College of DuPage to ensure local genotypes. They were kept in cold storage until early February 1984. The seeds were

Table 1. Site soil characteristics.

Soil ph	8.0		PPM
Organic matter	3.57%	Zn	80.21
		B	58.00
Kg/ha		Mn	783.47
		Fe	28,627.33
		Cu	15.41
		Al	23,185.00
		Na	<69.49
<hr/>			
Cation percent			
P	0.06		
K	0.60		
Ca	3.76		
Mg	2.30		
S	0.26		

The soil data is a composite of three random samples. It was analyzed by Department of Soil Science, University of Wisconsin Extension, Madison, Wisconsin 53705-4364.

Table 2. Seedlings of prairie species planted in seedling transplant area during spring, 1984. Nomenclature is from Swink and Wilhelm (1979).

Species	Rating index	Number of seedlings
<i>Amorpha canescens</i>	10	144
<i>Baptisia leucantha</i>	8	72
<i>B. leucophaea</i>	15	144
<i>Coreopsis palmata</i>	8	357
<i>Echinacea pallida</i>	8	251
<i>Eryngium yuccifolium</i>	9	196
<i>Liatris pycnostachya</i>	6	306
<i>Parthenium integrifolium</i>	7	288
<i>Penstemon digitalis</i>	4	23
<i>Petalostemum candidum</i>	15	681
<i>P. purpureum</i>	9	144
<i>Potentilla arguta</i>	9	36
<i>Solidago rigida</i>	4	216
<i>Sporobolus heterolepis</i>	9	5,256
<i>Verbena stricta</i>	4	72

then stratified with fine damp sand and refrigerated at 4°C to duplicate winter conditions. Legumes were scarified and inoculated with their appropriate *Rhizobium*.

During early April 1984, seeds from 15 prairie species (Table 2) were planted into a 50-50 mixture of "Jiffy Mix" (Ball Seed Company) and sterilized black soil in the College of DuPage greenhouse. During early to mid-May 1984, the seedlings were transplanted to individual jiffy pots and, after a week, acclimatized outside in a semi-shaded area. During late May and early June 1984, the acclimatized seedlings were transplanted to the restoration site (Figure 1). The entire restoration site was disced to a depth of 5-8 cm to level off the soil and break up soil clumps prior to transplanting and seed broadcasting.

A mixture of 24 prairie species (Table 3) were broadcast adjacent to the seedling transplant area (Figure 1) from mid-May to early June 1984. Seeds were broadcast, lightly raked into the soil, and then compacted into the soil with a lawn roller that weighed 90 kg.

Oat straw and wheat straw were lightly scattered over both the seed broadcast and seedling transplant areas to conserve soil moisture and protect the seedlings from direct sunlight. Both areas were irrigated until 1 July 1984 whenever rainfall was insufficient.

For both planting methods, mesic-xeric species were introduced on higher elevations and mesic-hydric species on lower elevations. Whenever possible, species associations as described by Swink and Wilhelm (1979) were planted together.

The choice of plantings was based on seed availability, seed germination and competitiveness (Schramm 1978, Schulenberg 1972), time and space available to grow and transplant seedlings, and overall aesthetics. Although some different species were planted in each area, there was no significant difference ($p > .05$) in their average numerical rating ($X^2 = 0.273$; Goodness of Fit, Zar 1984).

To record vegetational changes, 196.7 m² were sampled in the seed broadcast area, and 42.7 m² were sampled in seedling transplant area. Plant species were identified and tallied along a 0.5 m wide transect for 21 north-south lines during October of 1984, 1985, 1986, and 1987 (Figure 1). Nomenclature is from Swink and Wilhelm (1979). Tillers were counted as one individual. The transects, 10 m apart and from 3.8 to 55.2 m in length, were permanently marked.

The analyses were completed from 1984 to 1987 at the College of DuPage Restoration Project in Glen Ellyn, Illinois. Quantitative analysis was accomplished using the Wilhelm Assessment Method (Swink and Wilhelm 1979, Wilhelm and Ladd 1988). Wilhelm's method was used because terms such as high quality are nebulous, at best. One person's significant may be another's exceptional,

Table 3. Seeds of prairie species planted in seed broadcast area during spring, 1984. Nomenclature is from Swink and Wilhelm (1979).

Species	Rating index	Weight in grams
<i>Amorpha canescens</i> (including calyces)	10	863
<i>Andropogon gerardi</i>	4	7,037
<i>A. scoparius</i>	5	272
<i>Coreopsis palmata</i>	8	136
<i>C. tripteris</i>	5	341
<i>Echinacea pallida</i>	8	681
<i>Eryngium yuccifolium</i>	9	636
<i>Lespedeza capitata</i>	4	91
<i>Parthenium integrifolium</i>	7	318
<i>Petalostemum candidum</i> (including calyces)	15	182
<i>P. purpureum</i> (including calyces)	9	1,907
<i>Potentilla arguta</i>	9	36
<i>Pycnanthemum virginianum</i>	5	454
<i>Ratibida pinnata</i>	4	726
<i>Rudbeckia hirta</i>	1	204
<i>Silphium laciniatum</i>	5	1,907
<i>S. perfoliatum</i>	5	82
<i>S. terebinthinaceum</i>	5	341
<i>Solidago rigida</i>	4	772
<i>Sorghastrum nutans</i>	5	200
<i>Spartina pectinata</i>	4	590
<i>Sporobolus heterolepis</i>	9	341
<i>Vernonia fasciculata</i>	5	114
<i>Veronicastrum virginicum</i>	6	145

Note: *Monarda fistulosa* (Rating index 4) *Penstemon digitalis* (Rating index 4), and *Panicum virgatum* (Rating index 5) were not knowingly included in the seed broadcast mixture.

depending on different philosophical alignment or technical experience in the field of natural area assessment (Wilhelm and Ladd 1988). Thus, repeatable application of such an assessment system is problematic. Wilhelm adopted an assessment method for the Chicago region that is based on a complete list of the Chicago region flora. For each species, a numerical rating has been assigned. These ratings identify each taxon's relative autecological value with respect to all other taxa in the flora (Swink and Wilhelm 1979). Then, based on autecological values for the species, a rating index for the community is generated as follows:

$$I = \frac{R}{\sqrt{N}}, \text{ where } I = \text{Rating Index}$$

R = the sum of the numerical ratings for all taxa recorded for the area, and
N = the number of recorded taxa.

RESULTS AND DISCUSSION

Table 4 lists the plant species found growing in the seed broadcast area from 1984 to 1987. There were 22 prairie species present with a numerical rating of 4 or above. Species with a numerical rating of 4 or above were considered as native tallgrass prairie species that belong to the prairie community (Kirt 1989, Voigt and Mohlenbrock 1978). The Rating Index from 1984 to 1987 increased from 13.79 to 18.39 (Table 4). Weed species coverage decreased from 74% during 1984 to 56% in 1987 while the coverage of prairie species increased from 26% to 44% during this four year period (Figure 2). The Rating Index increase and the decrease of weed species suggest that the seed broadcast restoration area is progressing toward a prairie state in the absence of weed removal and fire.

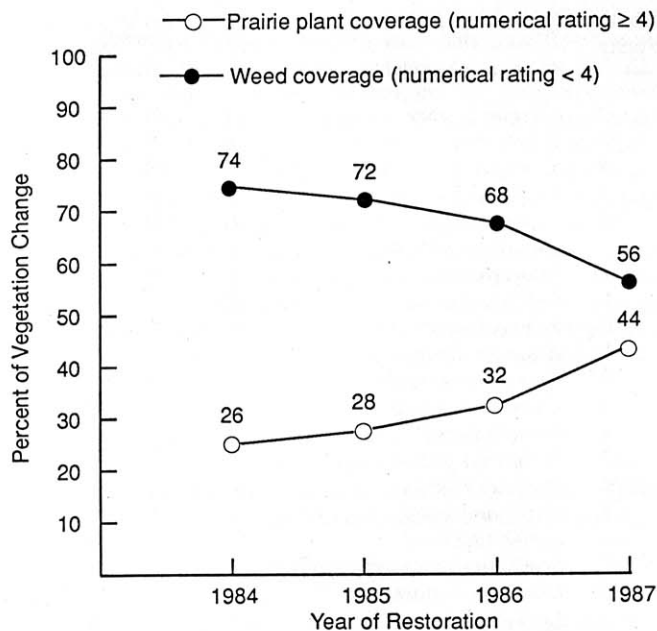


Figure 2. Percent of vegetation changes for plant species growing in seed broadcast area.

Table 4. Assignment of rating values and abundance of plant species in the seed broadcast area from 1984-87. Nomenclature is from Swink and Wilhelm (1979).

Numerical rating	Recorded taxa	Number of plants			
		1984	1985	1986	1987
-1	<i>Abutilon theophrasti</i>	110	109	3	0
0	<i>Acalypha rhomboidea</i>	6	3	2	1
-2	<i>Agropyron repens</i>	123	191	232	169
1	<i>Agrostis alba</i>	13	5	2	0
-1	<i>Amaranthus retroflexus</i>	16	0	5	0
0	<i>Ambrosia artemisiifolia</i>	193	1615	90	31
0	<i>A. trifida</i>	1	4	3	1
10	<i>Amorpha canescens</i>	4	7	29	38
4	<i>Andropogon gerardi</i>	541	791	638	662
0	<i>Anthemis cotula</i>	0	1	0	0
-3	<i>Arctium minus</i>	5	5	2	3
0	<i>Atriplex patula</i>	16	4	0	0
4	<i>Aster novae-angliae</i>	0	0	0	3
1	<i>A. pilosus</i>	9	98	379	329
*	<i>Avena sativa</i>	298	0	0	0
1	<i>Barbarea vulgaris</i>	56	1	0	0
0	<i>Bidens sp.</i>	4	1	0	0
-1	<i>Brassica kaber</i>	37	0	0	0
-1	<i>Bromus inermis</i>	0	29	21	0
1	<i>Cerastium vulgatum</i>	12	0	8	0
1	<i>Chenopodium album</i>	284	107	1	1
1	<i>Cichorium intybus</i>	18	72	5	4
-3	<i>Votdoi, stbrmdr</i>	63	166	191	158
-3	<i>C. vulgare</i>	17	23	23	10
8	<i>Coreoposis palmata</i>	44	42	43	30
5	<i>C. tripteris</i>	281	313	218	172
1	<i>Cyperus strigosus</i>	302	76	0	0
1	<i>Dactylis glomerata</i>	2	0	7	9
1	<i>Daucus carota</i>	32	33	632	222
0	<i>Digitaria sanguinalis</i>	127	16	0	0
8	<i>Echinacea pallida</i>	98	103	86	61

Table 4. continued

Numerical rating	Recorded taxa	Number of plants			
		1984	1985	1986	1987
0	<i>Echinochloa crusgalli</i>	252	6	3	0
0	<i>Erigeron canadensis</i>	0	43	9	1
9	<i>Eryngium yuccifolium</i>	8	7	9	15
-1	<i>Euphorbia supina</i>	33	0	8	0
1	<i>Festuca elatior</i>	20	24	4	5
2	<i>Helianthus grosseserratus</i>	0	3	2	0
0	<i>Hibiscus trionum</i>	76	119	17	0
-1	<i>Hordeum jubatum</i>	4	18	34	13
-1	<i>Lactuca scariola</i>	0	10	0	0
0	<i>Lepidium virginicum</i>	1	95	16	0
4	<i>Lespedeza capitata</i>	0	0	1	1
-2	<i>Lychnis alba</i>	0	17	0	0
-2	<i>Melilotus sp.</i>	7	0	0	2
4	<i>Monarda fistulosa</i>	0	1	3	0
-1	<i>Nepeta cataria</i>	4	2	0	0
0	<i>Oxalis stricta</i>	21	44	0	0
1	<i>Oenothera biennis</i>	0	1	1	0
1	<i>Panicum capillare</i>	40	5	2	0
5	<i>Panicum virgatum</i>	0	4	8	3
7	<i>Parthenium integrifolium</i>	18	4	8	5
-3	<i>Pastinaca sativa</i>	18	0	0	0
4	<i>Penstemon digitalis</i>	0	0	0	1
15	<i>Petalostemum candidum</i>	62	57	45	67
9	<i>P. purpureum</i>	102	78	131	110
1	<i>Phleum pratense</i>	0	4	6	0
0	<i>Plantago major</i>	132	233	55	51
0	<i>P. rugelii</i>	19	5	6	0
1	<i>Poa annua</i>	13	2	0	0
0	<i>P. pratensis</i>	108	267	204	180
0	<i>Polygonum pensylvanicum</i>	203	33	0	0
2	<i>Populus deltoides</i>	24	6	3	4
9	<i>Potentilla arguta</i>	1	8	6	4
0	<i>P. norvegica</i>	13	28	4	0
5	<i>Pycnanthemum virginianum</i>	6	5	2	2
4	<i>Ratibida pinnata</i>	496	573	314	254
5	<i>Rorippa islandica fernaldiana</i>	16	0	0	0
1	<i>Rudbeckia hirta</i>	134	136	30	28
-1	<i>Rumex crispus</i>	31	44	13	6
1	<i>Salix interior</i>	10	8	9	7
-1	<i>Setaria faberii</i>	116	11	1	0
0	<i>S. glauca</i>	299	38	4	2
-1	<i>S. viridis</i>	137	113	4	2
5	<i>Silphium laciniatum</i>	192	196	161	173
5	<i>S. perfoliatum</i>	19	18	28	13
-1	<i>Solanum americanum</i>	15	0	3	0
1	<i>Solidago altissima</i>	7	2	15	56
4	<i>S. rigida</i>	77	96	165	185
-2	<i>Sonchus uliginosus</i>	10	48	1	1
5	<i>Sorghastrum nutans</i>	24	41	51	58
5	<i>Spartina pectinata</i>	7	9	8	7
9	<i>Sporobolus heterolepis</i>	1	2	1	1
0	<i>Taraxacum officinale</i>	309	145	119	19
1	<i>Trifolium hybridum</i>	37	47	9	5
1	<i>T. pratense</i>	44	36	12	2
1	<i>T. repens</i>	52	31	90	1
-1	<i>Xanthium americanum</i>	1	1	0	0
N	(Number of recorded taxa)	72	72	66	50
I	(Rating Index)	13.79	15.32	16.37	18.39
*	No numerical rating				

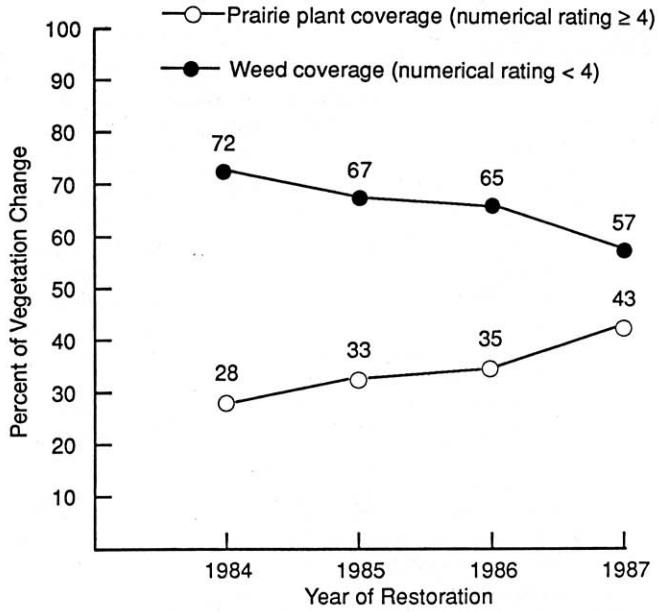


Figure 3. Percent of vegetation changes for plant species growing in seedling transplant area.

Table 5 lists the plant species found growing in the seedling transplant area from 1984 to 1987. During 1987, 19 prairie species with a numerical index of 4 or above were present in the seedling transplant area. Of these 19 species, big bluestem (*Andropogon gerardi* Vitman), New England aster (*Aster novae-angliae* L.), tall coreopsis (*Coreopsis tripteris* L.), and compass plant (*Silphium laciniatum* L.) germinated from seeds from the adjacent seed broadcast and marsh areas. The Rating Index from 1984 to 1987 increased from 14.29 to 20.83 (Table 5). Weed species coverage decreased from 72% to 57% while the coverage of prairie species increased from 28% to 43% during this four year period (Figure 3). This increase in Rating Index and decrease of weed species suggests that the seedling transplant area is also progressing toward a prairie state.

Table 5. Assignment of rating values and abundance of plant species in the seedling transplant area from 1984-87. Nomenclature is from Swink and Wilhelm (1979).

Numerical rating	Recorded taxa	Number of plants			
		1984	1985	1986	1987
-1	<i>Abutilon theophrasti</i>	21	40	3	0
0	<i>Acalypha rhomboidea</i>	0	1	0	0
-2	<i>Agropyron repens</i>	7	31	29	13
-1	<i>Amaranthus retroflexus</i>	8	0	0	0
0	<i>Ambrosia artemisiifolia</i>	23	428	85	22
10	<i>Amorpha canescens</i>	0	3	2	6
4	<i>Andropogon gerardi</i> ^a	3	5	1	1
0	<i>Anthemis cotula</i>	0	0	1	0
-3	<i>Arctium minus</i>	1	3	2	4
0	<i>Atriplex patula</i>	3	5	0	0
4	<i>Aster novae-angliae</i>	0	0	0	1
1	<i>A. pilosus</i>	0	4	30	65
*	<i>Avena sativa</i>	59	0	0	0
8	<i>Baptisia leucantha</i>	0	3	3	3
15	<i>B. leucophaea</i>	1	1	3	5
1	<i>Barbarea vulgaris</i>	14	1	0	0
-1	<i>Brassica kaber</i>	5	1	0	0
1	<i>Cerastium vulgatum</i>	8	0	0	0
1	<i>Chenopodium album</i>	89	17	0	0
1	<i>Cichorium intybus</i>	0	8	9	0

Table 5. continued

Numerical rating	Recorded taxa	Number of plants			
		1984	1985	1986	1987
-3	<i>Cirsium arvense</i>	9	16	56	48
-3	<i>C. vulgare</i>	1	9	46	14
8	<i>Coreopsis palmata</i>	3	10	17	24
5	<i>C. tripteris</i> ^a	0	1	1	1
1	<i>Cyperus strigosus</i>	26	0	0	0
1	<i>Dactylis glomerata</i>	1	0	0	0
1	<i>Daucus carota</i>	8	16	267	122
8	<i>Echinacea pallida</i>	17	17	18	17
0	<i>Echinochloa crusgalli</i>	36	2	0	0
0	<i>Erigeron canadensis</i>	0	9	6	2
9	<i>Eryngium yuccifolium</i>	7	9	5	6
-1	<i>Euphorbia supina</i>	5	0	0	0
1	<i>Festuca elatior</i>	3	2	3	1
2	<i>Helianthus grosseserratus</i>	3	0	0	0
0	<i>Hibiscus trionum</i>	10	14	3	0
-1	<i>Hordeum jubatum</i>	0	5	23	9
-1	<i>Lactuca scariola</i>	0	1	0	0
0	<i>Lepidium virginicum</i>	1	2	2	0
6	<i>Liatis pycnostachya</i>	0	8	1	2
-2	<i>Lychnis alba</i>	0	0	0	1
-2	<i>Melilotus sp.</i>	1	1	1	0
0	<i>Oxalis stricta</i>	1	4	4	0
1	<i>Oenothera biennis</i>	0	0	3	4
7	<i>Parthenium integrifolium</i>	7	4	6	5
4	<i>Penstemon digitalis</i>	0	2	2	1
15	<i>Petalostemum candidum</i>	14	15	18	26
9	<i>P. purpureum</i>	6	14	18	23
1	<i>Phleum pratense</i>	0	0	1	0
0	<i>Plantago major</i>	8	14	6	18
0	<i>P. rugelii</i>	2	3	0	0
0	<i>Poa pratensis</i>	10	9	4	0
0	<i>Polygonum pensylvanicum</i>	11	5	0	0
2	<i>Populus deltoides</i>	11	3	3	1
9	<i>Potentilla arguta</i>	8	6	6	7
0	<i>P. norvegica</i>	3	2	2	0
4	<i>Ratibida pinnata</i> ^a	3	1	0	0
5	<i>Rorippa islandica fernaldiana</i>	2	0	0	0
1	<i>Rudbeckia hirta</i> ^a	1	1	13	4
-1	<i>Rumex crispus</i>	6	6	8	7
-1	<i>Setaria faberii</i>	19	0	2	0
0	<i>S. glauca</i>	61	33	6	0
-1	<i>S. viridis</i>	15	49	12	1
5	<i>Silphium laciniatum</i> ^a	1	3	1	1
-1	<i>Solanum americanum</i>	7	1	0	0
1	<i>Solidago altissima</i>	0	0	10	11
4	<i>S. rigida</i>	17	10	29	45
-2	<i>Sonchus uliginosus</i>	3	53	15	0
9	<i>Sporobolus heterolepis</i>	155	196	203	189
0	<i>Taraxacum officinale</i>	108	42	79	7
1	<i>Trifolium hybridum</i>	12	12	8	2
1	<i>T. pratense</i>	4	8	4	2
1	<i>T. repens</i>	11	7	58	9
1	<i>Verbascum thapsus</i>	4	4	2	1
4	<i>Verbena stricta</i>	1	1	1	1
-1	<i>Xanthium americanum</i>	0	0	0	2

N (Number of recorded taxa) 54 58 52 42
 I (Rating Index) 14.29 17.46 18.31 20.83

^a Seeds of *A. gerardi*, *C. tripteris*, *R. pinnata*, *R. hirta*, and *S. laciniatum* from seed broadcast mixture became established in seedling transplant area.

* No numerical rating

There was a slow but steady decline of weed species and consistent increase in coverage of native prairie species for both the seed broadcast and seedling transplant areas during the first four years of assessment. Weeds occurred spontaneously from the 7 to 10 cm of black soil used to top-dress the area, the clay and rubble subsoil, the adjacent marsh vegetation, and the oat and wheat straw mulch that was scattered on both the broadcast and transplant areas. Our results are similar to those reported by others (Dale and Smith 1983, Woehler and Martin 1983). Both restoration areas have progressed toward prairie states in the absence of weed removal and fire.

At the end of four years, the seedling transplant area contained 19 prairie species with an average numerical rating of 7.52. The seed broadcast area contained 22 prairie species with an average numerical rating of 6.50. After the first four years, neither restoration area was significantly different ($p > .05$) in the overall quality of prairie present ($X^2 = 0.074$; Goodness of Fit, Zar 1984).

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