Part 8. PRAIRIE RESTORATION

ONE DECADE OF RESEARCH IN PRAIRIE RESTORATION AT THE FERMI NATIONAL ACCELERATOR LABORATORY (FERMILAB) BATAVIA, ILLINOIS

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Abstract. During autumn of 1974, 181.2 kg (400 lb) of mixed prairie seeds were hand-collected from remnant prairies within 80.5 km (50 mi) of Fermilab and stratified at 5° C in a cooler during winter. In the first week of June 1975 these seeds were planted in 3.9 ha (9.6 a) of previously plowed and disked black agricultural soil within the accelerator ring (263 ha; 650 a) using a Nisbet drill. During the past ten years there have been twelve separate plantings (both spring and autumn), bringing the total area planted within the ring to 156 ha (385 a). Two additional plantings in 1984-1985 outside the ring added another 22.3 ha (5 5 a).

After experimenting with various types of agricultural equipment (Nesbit drill, hydromulcher, pull combine) these were abandoned in favor of equipment that was quicker and more efficient. Currently, using a front-mounted combine approximately 2265 to 4530 kg (5000-10,000 lb) of uncleaned mixed prairie seed are harvested in autumn, stored in an unheated barn during winter. In late June the seed is then sown in approximately 30 ha (75 a) of prepared land at the rate of about 4.3 kg/ha (40 lb/a) using an all-terrain spreader. Following this a cultipacker is used to compress the soil.

Restoration is now being accomplished by building a "prairie matrix" of late flowering grasses (*Andropogon, Sorghastrum, Spartina*) together with aggressive prairie forbs (*Coreopsis, Desmodium, Ratibida, Silphium*). This matrix can compete successfully with most weedy species, e.g., *Agropyron, Phalaris, Solidago*, producing a prairie sward that can be burned two or three years after initial planting. The planting area is then hand-sown with a "second wave" of prairie forbs and grasses, e.g., *Pedicularis, Petalostemum, Phlox, Sporobolus*, that do well once the weedy vegetation has been eliminated or greatly reduced. As the prairie improves, rarer species, such as, *Gentiana, Lilium* and *Habenaria*, will be introduced as seedlings to produce a community representative of the black soil Illinois prairie of pre-settlement times.

To date approximately 177.8 ha (440 a) have been planted both inside and outside of the accelerator ring, and eighty prairie and marsh species are now growing and reproducing on this restored prairie. The dominant grasses are *Andropogon gerardii* and *Sorghastrum nutans*, but other characteristic prairie grasses, such as, *Andropogon scoparius, Panicum virgatum, Spartina pectinata* and *Sporobolus heterolepis*, are increasing. With the exception of scattered patches of *Melilotus alba* and some clumps of *Solidago altissima*, the older plantings are relatively free of weedy vegetation.

INTRODUCTION

In pre-settlement times the northern two-thirds of Illinois - the Prairie State - was mainly covered with prairie, marsh and savanna. Using original surveys and the distribution of prairie soils, it is estimated that approximately 70% of the 145,000 square kilometers (56,000 square miles) or 103,000 sq km (40,000 sq mi) was prairie. Today no more than 13 sq km (5 sq mi) still exist along railroad rights-of-way, in pioneer cemeteries and on a few isolated tracts which have escaped the plow. Many of these remnants, especially the larger ones, are on poorer agricultural soils and do not represent the deep silt loam prairies that characterized most of the Illinois country.

With this in mind, prairie ecologists approached the administration of the Fermi Accelerator Laboratory (Fermilab) at Batavia, Illinois in August of 1972 about the feasibility of restoring an Illinois black silt-loam prairie on a portion of the laboratory's 2745 hectares (6800 a). After a number of discussions involving a series of proposals over a period of a year and a half, it was agreed that a prairie restoration project could be undertaken on land within the accelerator ring.

THE SITE

The ring is 2 km (1.2 mi) in diameter, 6.4 km (3.9 mi) in circumference and contains 314.2 ha (776.3 a). However, not all of the land is cultivable. A blacktop service road and a 15.2 meter (50 ft) moat containing water for cooling the ring magnets are adjacent to the inner side of the accelerator ring. In addition, inside the ring there is a large artificial lake used to replenish the water in the moat, a scattering of marshes and an open bur oak forest. Thus, the area available for prairie restoration is reduced to approximately 184 ha (455 a).

The land is almost flat, having a mean elevation of approximately 806.6 m (740 ft) with a variation of no more than 5.5 m (6 ft). It has been cultivated for more than a century and was mostly tiled. With the construction of the accelerator ring, many field tile lines were broken causing land to revert to the poor drainage characteristic of much of the pre-settlement Illinois prairies.

The ring soils were developed on a glacial outwash plain. Although seven soil types have been recognized in the most recent soil survey of the area (Mapes 1979), only three are widely found within the ring - Barrington and Mundelein silt loams and Drummer silty clay loam. The first two are deep, somewhat poorly drained, soils of uplands, having a silty loam surface layer and a silty clay loam subsoil. They developed in deposits of less than one meter (40 in) of silty material over calcareous silty or loam outwash. The Drummer silty clay loam is similar, having a deep, poorly drained, moderately permeable soil formed from silty clay outwash. The Barrington and Mundelein silt loams were associated with mesic prairie, while the Drummer silty clay loam formed under low prairie and marsh.

The original survey of the area was carried out in 1844 and showed the area covered with prairie. The surveyor's notes state "All rich, 1st rate prairie" and "Land, All rich and fit for cultivation." The extreme western portion of the ring is marked "timber" or "scattering timber" with the notes recording witness trees of white, red and bur oak "ten inches" in diameter. The area marked "scattering timber" has a transitional Wauconda silty loam with a gray A-layer. This would indicate that parts of the extreme western section of the ring were originally covered with savanna or prairie scrub. Such areas were often designated as "barrens" in the early 19th Century.

THE RING VEGETATION

Almost all of the original prairie within the ring was destroyed during the years of cultivation. Only along old fence rows and

in some of the ditches of abandoned country roads did a few prairie species survive, such as:

Andropogon gerardii (big bluestem grass)
Asclepias sullivantii (prairie milkweed)
Calamagrostis canadensis (blue-joint grass)
Lilium michiganese (Turk's cap lily)
Silphium terebinthinaceum (prairie dock)
Spartina pectinata (prairie cord grass)
Veronicastrum virginicum (Culver's root)

In the poorly drained areas, a few prairie marsh species were still found, such as:

Asclepias incarnata (swamp milkweed)
Carex hystricina (bottle brush sedge)
Carex lanuginosa (woolly sedge)
Lycopus americana (water horehound)
Lythrum alatum (winged loosestrife)
Lysimachia terrestris (swamp candles)
Mimulus ringens (monkey flower)
Senecio pauperculus balsamitae (ragwort)
Vernonia fasciculata (ironweed)

The land that would eventually be enclosed within the ring was retired from cultivation in 1970. Following a century of plowing and cultivation, the land lay fallow and secondary succession set in. After two or three years of an annual-biennial weed stage, an old-field community dominated by Eurasian perennial grasses and a few native perennial forbs established itself. Species present included:

Agropyron repens (quack grass)
Aster simplex (panicled aster)
Asclepias syriaca (common milkweed)
Bromous inermis (Hungarian brome grass)
Phalaris arundinacea (reed canary grass)
Poa pratensis (Kentucky blue grass)
Solidago altissima (tall goldenrod)

Since 1970 this ruderal old field community has maintained itself except that in certain areas a number of wood shrubs have invaded, especially along old fence rows. They are:

Acer negundo (box elder)
Cornus racemosa (gray dogwood)
Rhus glabra (smooth sumac)
Rosa multiflora (multiflora rose)
Rubus occidentalis (black raspberry)
Salix interior (sandbar willow)

In areas where there has been more severe disturbance of the soil, such as along the periphery of the moat, cottonwood trees (*Populus deltoides*) have formed small groves.

METHOD OF SEEDING

In the autumn of 1974, nearly a hundred volunteers collected seed from more than 70 species of prairie plants growing on remnant prairies within a 80.5 km (50 mi) radius of Fermilab. In February 1975 these seeds were cleaned using various sized screens. The resultant 181.2 kg (400 lb) of cleaned seed were then mixed with vermiculite in large plastic bags, moistened and stored in a cooler at 5° C for over four months. These cold-treated seeds were then taken from the cooler, spread out on a wooden floor and dried to remove excess moisture. They were planted during the first week of June 1975 using a Nisbet drill on previously prepared land. This land had been previously prepared for planting during the summer of 1974 when 3.9 ha (9.6 a) within the ring were plowed and disked. Two addition diskings were done in the spring of 1975.

Since that first seeding, there have been substantial modifications of planting techniques. The use of the Nisbet drill was discontinued after the first four sowings. This was partly because it planted in rows which are still visible a decade after planting, and partly because it was inefficient and time consuming especially when relatively large areas were planted (Table 1). It also required well-cleaned and thoroughly dried seeds to prevent clogging in the drill. A hydromulcher, using a slurry of seeds in water to spray onto the prepared soil, also proved unsatisfactory. This was because its excessive weight compacted the soil and also caused it to bog down in moist soil. During the past few years seeding has been done using a salt-spreader truck which scatters the mostly uncleaned seed onto the prepared soil. A further improvement, which is currently being used, has been the use of an all-terrain spreader with large balloon tires which distribute the weight of the vehicle more evenly, thus preventing soil compaction. It has a wider spreading arc than the salt-spreader and has a greater maneuverability over plowed and disked surfaces. A light harrow was used after sowing in the early plantings, but this was discontinued when no noticeable benefit was observed. Currently, a cultipacker is used before and after seeding to ensure good seed-to-soil contact. Mowing was done after some of the early plantings for weed control, but the practice has been generally discontinued because it frequently encourages the growth of heavier foliage closer to the ground. This in turn produces more intense shading which is deleterious to prairie seedlings.

Several plantings were done in autumn to increase the ease and efficiency of the restoration process (Table 1). However, this practice was discontinued because these autumnal plots had more islets of old field and weed vegetation than did those plots seeded in spring and early summer. Evidently disking the plots before late spring seeding inhibits weedy growth and encourages better survival of prairie seedlings.

Currently, from 2265 kg (5000 lb) to 4530 kg (10,000 lb) of seed are harvested from earlier plantings in autumn using a front-

TABLE 1. Fermi Prairie plot histories.

Plot	Date	Hectares	Acres	Method of Seeding
1	Spring '75	3.89	9.6	Nisbet Drill
2	Spring '76	4.17	10.3	Nisbet Drill
3	Spring '77	13.00	32.0	Nisbet Drill
4	Autumn '77	6.68	16.5	Nisbet Drill
5	Autumn '78	4.62	11.4	Saltspreader
6	Autumn '79	23.45	57.9	Hydroseeder
7	Spring '81	7.13	17.6	Hand
8	Autumn '81	17.58	43.4	Saltspreader
9	Autumn '82	22.52	55.6	Saltspreader
10	Spring '83	24.70	61.0	Saltspreader
11	Spring '84	16.20	40.0	All-Terrain Spreader
12	Spring '84	12.15	30.0	All-Terrain Spreader
TOTAL		156.09	385.3	

TABLE 2. Rate of seeding at Fermilab Prairie.

Plot	Seed (kg)	Hectares	Rate (kg/ha)	Seed (lb)	Acres	Rate (lb/a)
1	*181.2	3.9	46.6	*400	9.6	41.7
2	*108.7	4.2	27.1	*240	10.3	23.3
3	*203.8	13.0	15.7	*450	32.0	14.1
4	*154.1	6.7	23.1	*350	16.5	20.6
5	407.7	4.6	88.3	900	11.4	78.9
6	1359.0	23.5	57.9	3000	57.9	51.8
7	67.9	7.1	95.3	150	17.6	8.5
8	2718.0	17.6	154.6	6000	43.4	138.3
9	1259.3	22.5	55.9	2780	55.6	50.0
10	1359.0	24.7	55.0	3000	61.0	49.2
11	724.8	16.2	44.7	1600	40.0	40.0
12	543.6	12.2	44.8	1200	30.0	40.0
TOTAL	9087.1	156.2		20070	385.3	
AVERAGE			58.2			52.1

*cleaned seed

mounted combine (Table 2). This uncleaned seed, containing approximately one-third chaff, is spread onto a wooden floor of an unheated barn for drying and storage overwinter. To this harvested unclean seed there is mixed from 45 to 90 kg (100-200 lb) of partially cleaned seed, i.e., seed heads broken up and seeds stripped from corymbs and panicles. This partially cleaned seed is regularly collected elsewhere by volunteers. This is done (1) to increase the genetic diversity of the seed mix, (2) to augument those species having low populations on the restored prairie and (3) to introduce new species into the prairie.

The current planting regime is as follows:

1. In late summer an area to be seeded the following year has the vegetation mowed down to thirty centimeters or less and the soil plowed to a depth of at least twenty centimeters. Thus the alternate winter freezing and thawing kills some of the exposed weed roots and also weather levels the ground somewhat making further cultivation easier.
2. Toward the end of May, or as soon as it is possible to get into the field, the land is disked to smooth out the plow lines.
3. This is followed by a spring tooth harrowing to level the area and dislodge existing roots in the soil.
4. The soil is then cultipacked to provide a firm seed base.
5. Finally, the seed mix is then broadcast onto the prepared soil using an all-terrain spreader. After this the soil is again cultipacked to ensure good seed-to-soil contact.

SUCCESSIONAL CHANGES

Within a week after planting of the prairie seed, the seeds of annual weeds, which may have lain in the soil for years, germinate and initially dominate the tract. Among these are:

Amaranthus powellii (tall amaranth)
Amaranthus retroflexus (rough amaranth)
Ambrosia artemisiifolia elatior (common ragweed)
Ambrosia trifida (giant ragweed)
Chenopodium album (lamb's quarters)
Panicum capillare (old witch grass)
Setaria glauca (yellow foxtail grass)

Beneath these annual plants are rosettes of biennial weeds and seedlings of weedy perennials. Scattered through the planting in the shade of the dominant annual weeds are small depauperate seedlings of big bluestem (*Andropogon gerardii*), Indian grass (*Sorghastrum nutans*) and a few seedlings of some prairie forbs, including yellow cone flower (*Ratibida pinnata*), prairie dock (*Silphium terebinthinaceum*) and showy tick trefoil (*Desmodium canadense*).

In the second year flowering biennial weeds dominate the plot. In addition, some annual and perennial weed species occur scattered throughout the tract. The biennial and perennial weed species which appear during this second year include:

Brassica kaber pinnatifida (charlock)
Cirsium arvense (field thistle)
Cirsium vulgare (bull thistle)
Daucus carota (Queen Anne's lace)
Erigeron annus (annual fleabane)
Melilotus alba (white sweet clover)
Rumex crispus (curly dock)
Trifolium pratense (red clover)

During the second year the prairie grasses grow more vigorously and form small clumps. Some even produce short flowering culms and set seed. Notwithstanding the dominance of the weeds, below them clumps of prairie grass are manifestly evident throughout. In the late summer this lower sward of prairie grasses produces the russet hue so characteristic of the prairie. After the third year of growth this now relatively dense prairie carpet will support a fire. Typically, this burning is done in the spring of the fourth year.

Following the burning of this third year growth, the prairie grasses during the fourth year reach heights (2-2.5 m) that are to be found in native prairies. Indian grass (*S. nutans*) is dominant during the fourth year, but during subsequent years dominance changes to big bluestem (*A. gerardii*). Prairie forbs also become more conspicuous during this year. Drought and other unpredictable events can occasionally lengthen this succession by a year or two.

THE CONCEPT OF THE PRAIRIE MATRIX

Continuous observation of the emerging prairie on the seeded plots over the past decade has shown that relatively few prairie species are able to survive the intense competition of weedy vegetation. Even though large amounts of seed are used, many prairie species do not survive when sown directly onto plowed and disked soil. If they do, they almost always appear as isolated specimens scattered throughout the tract. On the other hand, there are some species that consistently survive this weedy competition. This is true regardless of the method and time of seeding, the occurrence of drought and other vagaries of nature. Thus, it appears that the prairie is able to establish itself in stages. The more aggressive species with wider ecological tolerances enter first and prepare the way for the other species with narrower tolerances. This first stage of aggressive prairie plants has been termed "prairie matrix" in this paper. It is seed from this matrix, collected from

plots seeded earlier along with seeds from species of the second stage, that has been used in the more recent plantings. Species characteristic of the matrix are:

Gramineae
Andropogon gerardii (big bluestem grass)
Panicum virgatum (switch grass)
Sorghastrum nutans (Indian grass)
Spartina pectinata (prairie cord grass)

Compositae
Coreopsis palmata (prairie coreopsis)
Coreopsis tripteris (tall coreopsis)
Echinacea pallida (purple coneflower)
Parthenium integrifolium (wild quinine)
Ratibida pinnata (yellow coneflower)
Silphium integrifolium (rosin weed)
Silphium laciniatum (compass plant)
Silphium terebinthinaceum (prairie doci)
Solidago gymnospermoides (grass-leaved goldenrod)
Solidago juncea (early goldenrod)
Solidago nemoralis (gray goldenrod)
Solidago riddellii (Riddell's goldenrod)
Solidago rigida (prairie goldenrod)

Leguminosae
Baptisia leucantha (white wild indigo)
Desmodium canadense (showy tick trefoil)
Desmodium illinoense (Illinois tick trefoil)
Lespedeza capitata (round-headed bush clover)

Other
Allium cernuum (nodding wild onion)
Carex bicknellii (prairie sedge)
Eryngium yuccifolium (rattlesnake master)
Monarda fistulosa (wild bergamot)

It is interesting to note that the species listed above as the first to become established in a restored prairie, are also the last to disappear when a prairie is degraded and destroyed. This is probably due to their competitive ability (Schramm 1976).

Over time species of the prairie matrix increase their dominance within the seeded tracts. None of the weedy species are capable of preventing this takeover. Certain species, such as, Hungarian brome grass (*Bromus inermis*) and reed canary grass (*Phalaris arundinacea*) are more resistant, but eventually they also succumb. It would seem that these matrix species have a competitive edge over the non-prairie ones. It is interesting to observe the aggressive growth of the matrix species year after year as they invade the surviving islets of old field and weed vegetation within the plantings. Characteristically, isolated clumps of *Sorghastrum* or *Andropogon* will invade and eventually replace established stands of *Agropyron*, *Bromus* and *Phalaris*. Throughout the developing prairie there are numerous clumps of the weedy tall goldenrod (*Solidago altissima*) which are reduced in stature and chlorotic in appearance which would seem to be the effect of heavy competition with matrix plants. Patches of field thistle (*Cirsium arvense*) and bull thistle (*C. vulgare*) disappear completely within a few years after being invaded by prairie vegetation.

Once this initial prairie matrix has gained dominance and can be burned regularly, the native plants that are less aggressive can be introduced either by seeding or by planting seedlings. Second stage plants include:

Amorpha canescens (lead plant)
Aster azureus (sky-blue aster)
Aster laevis (smooth blue aster)
Aster ericoides (heath aster)
Baptisia leucophaea (cream wild indigo)
Bromus kalmii (Kalm's brome grass)
Dodecatheon meadia (shooting stars)
Galium boreale (northern bedstraw)
Liatris aspera (button blazing star)
Liatris pycnostachya (prairie blazing star)
Liatris spicata (marsh blazing star)
Lobelia spicata (spiked lobelia)
Pedicularis canadensis (prairie betony)
Petalostemum candidum (white prairie clover)
Petalostemum purpureum (purple prairie clover)
Phlox pilosa (prairie phlox)
Phlox glaberrima interior (marsh phlox)
Physostegia virginiana (false dragonhead)
Potentilla arguta (prairie cinquefoil)
Pycnanthemum virginianum (mountain mint)
Sporobolus heterolepis (prairie dropseed grass)
Thalictrum dasycarpum (purple meadow rue)
Thalictrum revolutum (waxy meadow rue)

Some species, such as, prairie betony (*Pedicularis canadensis*), shooting stars (*Dodecatheon meadia*) and the prairie phloxes (*Phlox pilosa* and *P. glaberrima interior*) do especially well when seeded directly into the established prairie matrix. Others should be first grown in flats and then transferred as seedlings to Jiffy "rootmaster" pots for a full season of growth prior to transplanting into the matrix during May of the following year. At this time the danger of frost is over, the water table is high and the rains are dependable. Planting at other times usually brings less favorable survival.

SPECIES COMPOSITION OF THE FERMILAB PRAIRIE

From eleven years of planting annually there are now 156.2 hectares (385.2 a) of restored prairie within the accelerator ring containing 115 species of native plants (Table 3). Of these, more than two-thirds are mesic and wet prairie species. The remainder are those of marshes. With few exceptions, almost all of the prairie species (Table 4) have been introduced into the ring during these eleven years; whereas most of the marsh plants were already present on the site. In addition to these prairie and marsh species, there are still some herbaceous weeds (Table 5) and a few shrubs, such as, gray dogwood (*Cornus racemosa*) and black raspberry (*Rubus occidentalis*), scattered throughout the prairie.

The dominant species of grasses throughout the restoration areas are big bluestem (*A. gerardii*) and Indian grass (*S. nutans*). Switch grass (*Panicum virgatum*) is also widespread. Little bluestem (*Andropogon scoparius*) and prairie dropseed (*Sporobolus heterolepis*) are confined to the earliest planting (Plot 1), while prairie cord grass (*Spartina pectinata*) is found in four plots (Plots 1, 5, 6, and 11). These latter three species are actively increasing. Blue joint grass (*Calamagrostis canadensis*) is found in a few isolated clones along former fence rows in Plot 10. Only recently has an effort been made to collect seed of this species and thus to introduce it into suitable areas within the prairie.

The distribution of forbs within the prairie is sporadic. In general, the earliest plantings are not only richest in forb species, but they also have the largest populations of these species. On the other hand, the highest populations of weeds and their greatest diversity occurs in the more recent plantings (Tables 4 and 5). Most of these differences in forb distribution are attributable to the relative age of the plantings, but some are due in part to the varying amounts of forb seed collected in the various years and used for planting.

Even within a given plot there are spatially great differences in the variety and numbers of forbs. It is not unusual to have localized areas with a wide assortment of forb species with high populations of these species; whereas, other areas are devoid of forbs. This partly may be the result of differences in soil moisture when the seeds were germinating, but it may also be due to non-uniform sowing of the seed.

In general, all plots from the earliest to the most recent show increasing numbers of species and populations of these species. Each year, species not seen previously, are observed; it appears that the seeds of many species may lay dormant for years before

TABLE 4. Species composition of Fermilab Prairie.

Species	Plot 1	2	3	4	5	6	7	8	9	10	11	12
Allium cernuum	A											
Amorpha canescens						U						
Andropogon gerardii	A	A	A	A	A	C	C	C	C	C	C	C
Andropogon scoparius	C											
Anemone canadensis	R											
Apocynum sibiricum		A	C					U	U			
Asclepias incarnata		A	A			U		U	U			
Asclepias sullivantii	R	R										
Asclepias verticillata	C	C	C	C								
Aster laevis	R							R				
Aster novae-angliae		R	C	R	R			U	U			
Aster simplex		A	C	C	U	A	U	C	A	A		
Baptisia leucophaea	R											
Baptisia leucantha	C	U	U		R	C	R					
Bidens coronata			C									
Bromus kalmii	C											
Calamagrostis canadensis										R		
Carex bicknellii	C											
Coreopsis palmata	A	U	U			R		R				
Coreopsis tripteris	C	C	C	A	C	C	U	C	R	R		
Desmodium canadense	A	R	R	R	C	R	R	C		R		
Dodecatheon meadia	R	C										
Echinacea pallida	C	R	R									
Elymus canadensis	R			U					C			
Eoliobium coloratum						C						
Eryngium yuccifolium	U	C	C	U	U	U		C				
Galium boreale	U											
Galium obtusum	R											
Geum laciniatum						A		C				
Helianthus grosseserratus		C	C			C		A				
Helianthus mollis		U										
Heliopsis helianthoides	R	R	R	R	R	R		P				
Hypoxis hirsuta	R											
Leiocedza capitata	C	R					R					
Liatris aspera	R											
Liatris spicata	R					f						
Lilium michiganense								R	R			
Lithospermum canescens	R											
Lobelia spicata		C										
Lycopus americanus		R				C		A				
Mimulus ringens		R				U						
Monarda fistulosa	R	R	U	U	C	C	R	C		R		
Oxalis violacea	R											
Panicum virgatum	U	U	U	U	U	U			R	U		
Parthenium integrifolium	C	C	U									
Pedicularis canadensis	R	R										
Penthorum sedoides		U	U			U						
Petalostemum candidum	C		R			R						
Petalostemum purpureum	C		R					R				
Phlox glaberrima interior	R					U						
Physostegia virginiana	U	R	R	C								
Polygonum amphibium						C						
Polygonum coccineum						C						
Potentilla arguta	R		R									
Pycnanthemum virginianum	R					C		C				
Ratibida pinnata	C	C	C	A	C	A	U	C	C			
Rorippa islandica						C						
Rudbeckia hirta	U									U	C	C
Rudbeckia subtomentosa	U					U		U				
Senecio pauperculus						C						
Silphium integrifolium	C	C	C	U	U	R		U				
Silphium laciniatum	A	C	A	C	U	U						
Silphium terebinthinaceum	A	C	C	A	U	R		R		R		
Sisyrinchium albidum	R					C						
Solidago graminifolia						R						
Solidago riddellii								C				
Solidago rigida	R	R	R	A	U			A				
Sorghastrum nutans	A	A	A	A	A	A	A				C	C
Spartina pectinata	C				A	C					U	
Tephrosia intermedia						R				U	U	
Tradescantia bracteata	C											
Tradescantia ohiensis		C	C			C		C				
Thalictrum dasycarpum	U											
Thalictrum revolutum	R											
Tradescantia ohiensis	R			R	R							
Verbena hastata		U	U			C		U				
Vernonia fasciculata			U			R		U				
Veronicastrum virginicum	R			R								
Zizia aptera	R											
Zizia aurea	U											

TABLE 5. Weed composition of Fermilab Prairie.

Species	Plot 1	2	3	4	5	6	7	8	9	10	11	12
Abutilon theophrasti											A	A
Acnida altissima												U
Agropyron repens				C		C	C	C	A	C		
Amaranthus powellii												C
Amaranthus retroflexus											U	
Ambrosia artemisiifolia								A	A			
Ambrosia trifida	U	U						U				C
Asclepias syriaca		U					C		C	C	C	C
Aster pilosus		U		U	R	C	C	C	C	C	C	C
Aster sagittifolius				C	U	C				U		C
Bidens comosa											U	
Brassica kaber											U	
Chenopodium gerogsicides												C
Chenopodium album											U	
Chrysanthemum leucanthemum								R				
Cirsium arvense					R			C	U			C
Cirsium discolor				R								
Cirsium vulgare								C		A	C	C
Coronilla varia							C					
Cyperus esculentus								R			C	
Datura stramonium												U
Daucus carota				C		C	C		C		U	C
Echinochloa crusgalli											C	
Erigeron canadensis								C				
Eupatorium altissimum									U			
Eupatorium serotinum										U	U	
Euphorbia supina											R	C
Festuca elatior											U	
Hibiscus trionum											U	
Malva neglecta											U	
Melilotus alba	C	C		C	C	U	C	C	C	A		C
Oenothera biennis									C	A	U	C
Panicum capillare												C
Panicum dichotomiflorum												C
Pastinaca sativa								C				
Phalaris arundinacea			U	U				C				
Plantago major									U			
Poa pratensis	C			C	C	C		C	U			
Polygonum pensylvanicum												C
Potentilla norvegica								U		U		
Prunella vulgaris									U			
Rosa multiflorus									U			
Rubus occidentalis				U		R		C				
Rumex crispus								U	U	U	R	
Setaria glauca											U	C
Setaria viridis							C				A	C
Solanum nigrum							U		U		U	
Solidago altissima	C	C	C	C	C	C	C	C	A	A	R	
Sonchus uliginosus						U				C		C
Taraxacum officinale	U					U			U		R	C
Trifolium pratense							C			C	R	C
Trifolium repens							U					
Verbascum thapsus									U			

Legend:

A = Abundant, C = Common, U = Uncommon, R = Rare.

germination takes place; whereas, others in the plot may go undetected for years due to the lack of obvious growth or blooming. Some species, such as, wild quinine (*Parthenium integrifolium*) and shooting stars (*Dodecatheon meadia*), may take five or more years before they are first observed.

THE NEXT DECADE

During the next ten years enrichment of the Fermilab prairie will continue with the introduction of still more "second stage" plants, and, if possible, some of those of a still later "third stage." Plants of this last stage would include Mead's milkweed (*Asclepias meadii*), prairie gentian (*Gentiana puberula*) and prairie lily (*Lilium philadelphicum andinum*). One of the stumbling blocks to the introduction of these plants with narrower ecological tolerances is the lack of knowledge about their mycorrhizal requirements. Another is the possible presence of allelopathic compounds in the soil and their affect on the growth of these plants.

Additional efforts will also be made to enrich the marshes with sedges, such as, *Carex stricta*, and the dominant grasses, such as, blue-joint grass (*Calamagrostis canadensis*) and prairie cord grass (*Spartina pectinata*).

With the completion of the planting of areas available within the accelerator ring in 1985, the prairie matrix will be seeded into additional suitable tracts available outside of the ring over the next few years. This has already begun with the planting of approximately 80 ha (50 a) outside the ring in 1984 and 1985.

Following an expansion of land areas under restoration at Fermilab and subsequent species enrichment of all restoration areas, attention will be given to the re-establishment and subsequent increase in populations of prairie animal species. Some of this has already been taking place spontaneously over the past few years. Sandhill cranes and whistling swans are stopping at the marshes and lakes of Fermilab prairie on their annual migrations. There has been an increase in marsh hawks using the prairie for hunting purposes and upland sandpipers have nested on the land. The resident trumper swans recently introduced could become a nucleus for the re-establishment of this prairie bird in Illinois.

Studies are now underway on methods of introducing prairie invertebrates, including such uncommon and rare species as the prairie earthworm (*Diplocardia communis*), the dion skipper (*Atrytone dion*) and the yellow-winged grasshopper (*Arphia zanthoptera*).

Another decade of prairie restoration at Fermilab undoubtedly will yield much additional valuable information and provide many new challenges.

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PRAIRIE RESTORATIONS IN SOUTHWESTERN OHIO: VEGETATION AND SOIL CHARACTERISTICS AFTER TEN YEARS

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Abstract. Four reconstructed prairies in Butler County, Ohio were planted in 1974. Seed of two ecotypes was used and two seedbed hardnesses were employed in combination treatments. In 1980, two of the sites [Jericho and Ecology Research Center (ERC)] were compared for phytomass production and residual soil enzyme activity. The phytomass of the ERC, dominated by C4 grasses, was greater than the phytomass of Jericho, dominated by C3 grass species. Residual soil enzyme activity was greater at Jericho early in the 1980 growing season reflecting the earlier growth of the C3 species. Analysis of soil properties of all four prairies in 1984 revealed that the ERC and Wilson had soils of significantly higher bulk density, lower field capacity, and lower organic matter content, resulting in a drier habitat. This resulted in dominance of C4 grass species, significantly greater phytomass production, and greater density of C4 flowering culms than at the C3 dominated Jericho and Peffer sites.

INTRODUCTION

As interest in the tall grass prairie has increased over the past two decades, so has concern that management practices suitable for central and western portions of the true prairie may not be applicable to eastern prairies (Stuckey and Reese 1981). Furthermore, the relict prairies of the east are too small and too fragile to allow adequate experimentation to determine best management practices. Simulated or reconstructed prairies present opportunities to explore prairie species behavior in the eastern environment.

In 1974, undergraduate students at Miami University, under the supervision of the late Dr. Roger E. Wilson, established four prairie sites (0.4 ha each) in Butler County, Ohio. The sites were considered highly similar in soil (moderate to well drained Russell-Miamian-Wynn silt loams; Soil Survey of Butler County, Ohio) and climatic characteristics. The Peffer Park site, an abandoned agricultural field made into a recreation and education use area, had been mowed regularly and was in its fourth year of old-field succession in 1974. The Ecology Research Center (ERC) site had been farmed (the last crop was rye) and was in the third year of old-field succession in 1974. The Wilson site had been a timothy grass pasture and was in its fifth year of old-field succession in 1974. The Jericho site had been farmed (last crop was corn) and was in its sixth year of old-field succession in 1974. Each site was subdivided into four quadrants, to include combinations of two treatments. Two seedbed hardnesses were employed: final mean bulk density 1.19 g cm^{-3} (hard) and 0.87 g cm^{-3} (soft; Leibovitz 1974). The soft seedbed was prepared by plowing and disking, and the hard seedbed was prepared by plowing only. Seed of two ecotypes was purchased from Wilson seed farms in Polk, Nebraska (Table 1). Each site was planted uniformly with these species, keeping northern and southern ecotypes in separate quadrants, but including reed canary grass in both (Leibovitz 1974).

At the end of the first growing season, the study group reported qualitatively greater phytomass production of the hard seedbed treatments. No other information to assess the success of these plantings was collected until 1979 when phytomass production was measured on the ERC site. That prairie was burned in the spring of 1980; and in the fall of that year, phytomass production was measured on both the ERC and Jericho sites (Annala 1980). In the fall of 1983, a comprehensive burn regime was imposed on the ERC site. Subsequent comparative measures for use in this study were taken from the control (unburned) portions of this site. Peffer prairie was burned in the spring of 1981, but no quantitative measures were taken, and no further management practices have been applied. Finally, Wilson prairie was not studied or managed until 1984 when this current study began.

In 1984, the sites differed visibly. The ERC site had a well established, mixed stand of the tall grasses: big bluestem, switchgrass, and Indian grass. A considerable amount of little bluestem was also present. Tall Canada goldenrod had invaded most of the plots; and side oats grama had disappeared almost entirely. In midsummer, the quadrants of different seed sources were readily visible.

The Wilson site also showed a mixed stand of warm season grasses. Side oats grama was well established in the southwestern