THE INTRODUCTION OF SELECTED PRAIRIE FORBS INTO AN ESTABLISHED TALLGRASS PRAIRIE

by

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INTRODUCTION

Purpose

The purpose of this study is to determine which of a series of planting techniques is most successful in introducing individual forb species to the grass-dominated Fermilab Prairie Restoration Project. To achieve the long-range goal of having the restoration mimic the species composition of natural prairie communities, a forb enrichment program is necessary. The planting techniques studied include introducing forb seed and seedlings into the following treatments of the existing restoration sod: (1) a burn, (2) a burn followed by mowing, (3) a burn followed by soil scarification, and (4) a burn followed by removal of a portion of the sod mat.

Need for Restoration Forb Enrichment

Under current restoration practices, grasses dominate many plantings to a greater extent than they dominate natural prairies. One reason for this dominance is that many of the prairie grasses used, such as *Andropogon gerardii* and *Sorghastrum nutans*, develop more quickly than many forbs and, in turn, develop a renewable seed source which can seed into open areas where forb seed may be present, but not yet germinated. Grasses also have the ability to easily spread by vegetative means. Many recent restorations have been planted heavily to grasses because of their greater availability relative to forbs. Not only do commercial suppliers have greater quantities of prairie grass seed in stock, but

(not unrelatedly) the forb seed is more expensive. Grass seed is easily hand collected in large quantities in the wild, and it also can be easily harvested with a combine. Another factor contributing to the grass dominance in restorations is the fact that seed drills often used for large-scale plantings are set at a depth that is optimal for the grasses which make up the bulk of the seed mix. This results in the placement of seed at a depth too great for the optimal germination of many forb species, thus further reducing their numbers in the restoration (Clements and Weaver 1924, Christiansen 1967). Edmund, Musser, and Andrews (1957) state that optimal germination depth has been related to seed size and type of emergence.

Betz (1982) provides an additional explanation for grass dominance. He suggests that many forbs require a "prairie matrix" to survive. Such a "matrix" is often lacking in the early development of a prairie restoration. This idea follows one notion of plant succession theory, namely that early plant associations are necessary to create favorable environmental conditions for plants of later successional stages.

From observations seen at the Fermilab Prairie Restoration project, certain plants seem unable to compete in weedy Eurasian conditions. Plants, such as *Pedicularis canadensis*, do much better after prairie plants ("prairie matrix") have gained dominance.

The practice of improving the character and ecological integrity of prairie restorations through forb enrichment has many benefits. For example, a representative prairie is more valuable as a laboratory for researchers who want to know how the prairie ecosystem works. Similarly, a representative prairie is a valuable teaching aid for

introducing students to all levels of the ecosystem. "To most people the prairie is perhaps the least familiar of the major plant communities, largely because of the almost complete agricultural utilization of the original prairie lands" (Greene and Curtis 1953). The misunderstanding of what a prairie is can be remedied by the educational use of prairie restorations.

Forb enrichment also adds color and texture to the restoration, thus enhancing its aesthetic qualities. In many situations, for example, when prairies are planted in parks or on the grounds of buildings, the visual excitement created by displays of blooming forbs greatly increases the value and public acceptance of the restoration.

Establishment of Forbs in Nature.

Research has shown that prairie species can be established on many sites. In nature, the prairie withstood disturbances on both micro and macro scales. On the macro scale, drought and massive herds of herbivores caused damage to large areas. On the micro scale, digging by rodents, the creation of ant mounds, grazing and turf disturbances caused by individual animals removing patches of vegetation, and devastation by insects (locust swarms, for example), may have also caused serious damage to the prairie community. Prairie had the ability to recover from these disturbances through regrowth and new colonizations; therefore, it should be possible to emulate these recovery processes in creating restorations (Weaver 1954).

The study of intact and disturbed prairies may help us to understand how forbs establish naturally. This information can then be used to choose restoration establishment techniques. The potential for seedling establishment would seem to be always present, because many seeds are in the prairie soil; however most do not germinate (Blake 1935, Weaver and Mueller 1942). The annual production of prairie seed replenishes the seed supply in the ground that may have died or been eaten.

Some forbs seem to establish more readily than others. Shimek (1925) identified a group of prairie species as "prairie weeds," capable of taking advantage of disturbed sites. This group includes species that have high germination and establishment capabilities, and would be expected to survive in disturbance areas, such as *Ratibida pinnata*, *Helianthus grosseserratus* and *Solidago altissima*. The fact that many of the species are prevalent along railroad rights-of-way and roadside ditches reinforces the idea that they are important in the recovery from disturbances. Furthermore, Harper (1965) points out that any successful plant species must be an invader under certain circumstances. As an example, in the first few years invader species such as *Ratibida pinnata*, *Coreopsis tripteris*, *Helianthus grosseserratus*, and *Solidago altissima* are very prevalent, but after four or five years their numbers decline substantially.

The relationship between establishment from seed and prairie composition might appear to be a moot question, in the light that moist prairie species are perennial (Weaver 1954). The work of Steiger (1930), Blake (1935), and Weaver and Mueller (1942), attests to the

absence of seedlings in intact prairie. Blake's (1935) study of intact prairies revealed that, except for a few annual and short-lived perennials, germination consisted of small numbers of widely scattered individuals which frequently failed to survive. She attributed the lack of survival to heat and drought. The plants or seedlings that did survive the first summer were winterkilled. Blake (1935) also stated that vigorous seedlings which had attained the third or fourth leaf stage showed, during each of two successive seasons, a winter survival of 80 to 100 percent. Blake concluded that cool moist summers give the best germination. Competition in an intact prairie is much greater than under cultivated conditions (Christiansen 1967).

Establishment of Forbs in Restorations

The establishment of prairie species in restorations has received very little systematic attention (Christiansen and Landers 1966). Several prairie areas have been restored, such as Curtis and Greene Prairies at the University of Wisconsin-Madison Arboretum (Greene and Curtis 1953, Cottam and Wilson 1966), the Trelease Prairie near the University of Illinois-Urbana (Hadley and Kieckhefer 1963), the Morton Arboretum in Lisle, Illinois and the Fermilab Prairie Restoration Project in Batavia, Illinois; but most have not been analyzed rigorously in the intervening years to provide quantitative data on the performance of individual species and on the success of different re-establishment techniques in terms of a particular species or group of species. An exception to this would be two accounts by Blewett (1981) and Sperry (1982) of general trends of the successes of Curtis and Greene Prairies

at the University of Wisconsin-Madison.

Although much information exists on the establishment of prairie grasses (Booth 1941, Cornelius 1946, Pearse et al., 1948, Riegel 1944, Weaver 1954, Weaver and Mueller 1942, Weaver and Albertson 1944, and Weaver and Parland 1947), relatively few studies provide any valuable information for forb re-establishment data (Christiansen 1967).

One aspect of prairie forb establishment that has been looked at in some detail is seed germination. Germination of prairie forbs has been studied to a large extent in the laboratory.

Blake (1935) studied six common species in four different tests and found a large variation in germination rates: *Anemone cylindrica* 0 to 91%, *Amorpha canescens* 12-31%, *Echinacea pallida* 1.5 to 7%, *Lezpedeza capitata* 0-4%, *Petalostemum purpureum* 7 to 12%, and *Silphium laciniatum* 0-45%.

Greene and Curtis (1950) did several studies on germination, and also found a large fluctuation in rates: *Anemone cylindrica* 10-20%, *Baptisia leucantha* 10-18%, *Eryngium yuccifolium* 40-56%, *Liatris aspera* 29-48%, *Monarda fistulosa* 15%, *Parthenium integrifolium* 70%, *Petalostemum purpureum* 26%, *Potentilla arguta* 21%, *Ratibida pinnata* 7-60%, *Rudbeckia hirta* 0-40%, *Silphium integrifolium* 36-90%, *Silphium laciniatum* 25%, *Silphium terebinthinaceum* 34%, *Thalictrum dasycarpum* 6%, and *Vernonia fasciculata* 40%.

Generally these investigations revealed that stratification was beneficial to 70% of the species tested, ineffective for 17% and detrimental to germination of 13% of the species (Christiansen 1966).

Germination studies in the laboratory or greenhouse are helpful, but may not reflect what occurs under field conditions, where temperature may fluctuate, moisture is variable, and disease and predation may interfere. It is possible that variable temperatures, etc. in fact may increase forb germination from what is found under controlled laboratory conditions.

There are so many intangibles to successful germination, that it is difficult to determine which conditions are best for a particular situation. Germination rates are subject to change from year to year, in part because of changes in seed viability (Christiansen 1967). Germination studies to date at best can give an idea that, under certain conditions on a given year with a given seed source, a certain amount of success or failure can be achieved.

At least three extensive studies have looked at forb establishment techniques -- Blewett (1981), Christiansen (1967) and Greene and Curtis (1953). Blewett (1981) attempted to determine the success of the establishment of many prairie forbs at both the Curtis and the Greene Prairie Restorations in the University of Wisconsin Arboretum. He used data from inventories done at regular intervals over 40 years. The plantings were done using a variety of techniques including entire sod transplants of particular species, individual seedling transplants into tilled ground, broadcasting of seed into tilled ground and drilling seed into tilled ground. Burning was also used to promote re-establishment of prairie species, both grasses and forbs. Blewett's study does not compare the different methods of establishment; however, he concludes that all of the methods were successful to an extent.

Blewett also rated the success of individual forb species in the restorations. He formulated three categories to describe the behavior of different forbs: survivors, diminishers, and mixed reactors. Survivors are species that showed no significant decrease in numbers from the time of planting. These include such forbs as *Anemone cylindrica*, *Ratibida pinnata* and *Monarda fistulosa*. Diminishers are species that showed a significant decrease in numbers and include mainly weedy species such as *Agropyron repens*, *Lycopus americanus* and *Trifolium pratense*. Mixed reactors are species that showed large fluctuations in numbers. Examples of those are *Agrostos alba*, *Helianthus grosseserratus*, and *Silphium integrifolium*.

An extensive study carried out by Christiansen (1967) compared several prairie establishment techniques including planting prairie seed into different treatments; (a) weed-free, in which all weeds were removed by hand, (2) cover crop, (3) cover crop and mowed, (4) without cover crop, and (5) without cover crop and mowed. The cover crops of winter wheat were planted at both a light and a heavy density. The last four treatments had no weeds removed. Also, seedlings and sod transplants were done in both the spring and fall. Christiansen also planted seedlings into a plot dominated by *Bromus inermis* in both the spring and the fall.

Overall, Christiansen concluded that species can be established from seed in the cover crop, weedy and weed-free treatments. The mowing did not seem to show any general benefit towards establishment of plants from seed. The weed-free treatment was successful, but very laborious. The light cover crop showed the best results, then the weedy treatment,

and then the heavy cover crop treatment. It seemed that the greater the competition with other plants the less successful the treatment for both the seedling and seed treatments. The *Compositae* seemed to be the most vigorous species in all treatments, and could easily be established by broadcasting into burned plant material. (This was not true of all species.) Several species were influenced by the season they were planted. The trend was that spring flowering forbs did better in fall seed plantings, while summer and fall flowering species did better in the spring planting. Once a plant was established for a month or more it was likely to persist.

A study by Greene and Curtis (1953) on the University of Wisconsin-Madison Arboretum Prairies outlined their success with a variety of planting methods. Broadcasting seed in the fall on undisturbed soil surfaces was successful on open sod and on relatively closed sod, and unsuccessful on closed sod. Success was also obtained from broadcasting seed onto a scarified soil surface, spot planting on areas of animal disturbance, and broadcasting on a disced surface. According to Greene and Curtis (1953) species that were successful with these methods include: *Liatris aspera, Baptisia leucantha, Echinacea pallida, Eryngium yuccifolium, Monarda punctata, Penstemon digitalis, Petalostemum purpureum, Ratibida pinnata, Rudbeckia subtomentosa, Silphium integrifolium, Silphium laciniatum,* and *Silphium terebinthinaceum.*

From the literature, it is apparent that forb establishment with seeds or seedlings in a restoration may be done by assisting the species with a type of disturbance to reduce the competition of the other plants (Christiansen 1967, Greene and Curtis 1953, Shimek 1925).

METHODS

Laboratory History

The Fermi National Accelerator Laboratory, also known as Fermilab, is located near Batavia, Illinois, and is operated by Universities Research Association, Inc. (URA) of Washington, D.C. The research done at Fermilab is known as "high energy physics" or "particle physics." The laboratory consists of 2752 hectares of land with an accelerator that is one kilometer in diameter. For more information, consult *Fermilab Facts (1980)*.

Prairie Project Inception

The original idea for restoring a native Illinois prairie in the middle of the accelerator ring on the Fermilab site began in the summer of 1972 from discussions by Dr. Robert F. Betz and Dr. Floyd Swink of Northeastern Illinois University, Chicago, Illinois and the Morton Arboretum, Lisle, Illinois, respectively. At the time, Fermilab was negotiating with the Morton Arboretum for suggestions on how to improve the site. Many alternatives were discussed, but Dr. Betz suggested restoring the area to native Illinois tallgrass prairie.

The following fall at the Third Midwest Prairie Conference at Kansas State University, Manhattan, Kansas, Mr. Robert Jenkins of the Nature Conservancy suggested restoring a tallgrass prairie in Kansas. In a later discussion, Mr. Jenkins suggested to Dr. Betz that the nearby Fort Riley Military Reservation, a government-owned parcel of land, could be preserved with little effort. The mention of government-owned

land caused Dr. Betz to recall the Fermilab site. Mr. Jenkins was excited by the idea and told Dr. Betz to pursue it.

The following week, Dr. Betz approached the Fermilab site with Dr. Raymond Schulenburg of the Morton Arboretum and the late David Blenz of the Cook County Forest Preserves, and Fermilab showed interest in the project. The center of the main accelerator ring was chosen for a possible site. After Dr. Betz wrote a proposal to be sent to Fermilab, they informed him that they dealt mainly with organizations, and were not accustomed to dealing with individuals. For this reason, the Illinois Chapter of the Nature Conservancy was asked to submit the proposal. The proposal was accepted by Fermilab, and the project was underway!

Planting History

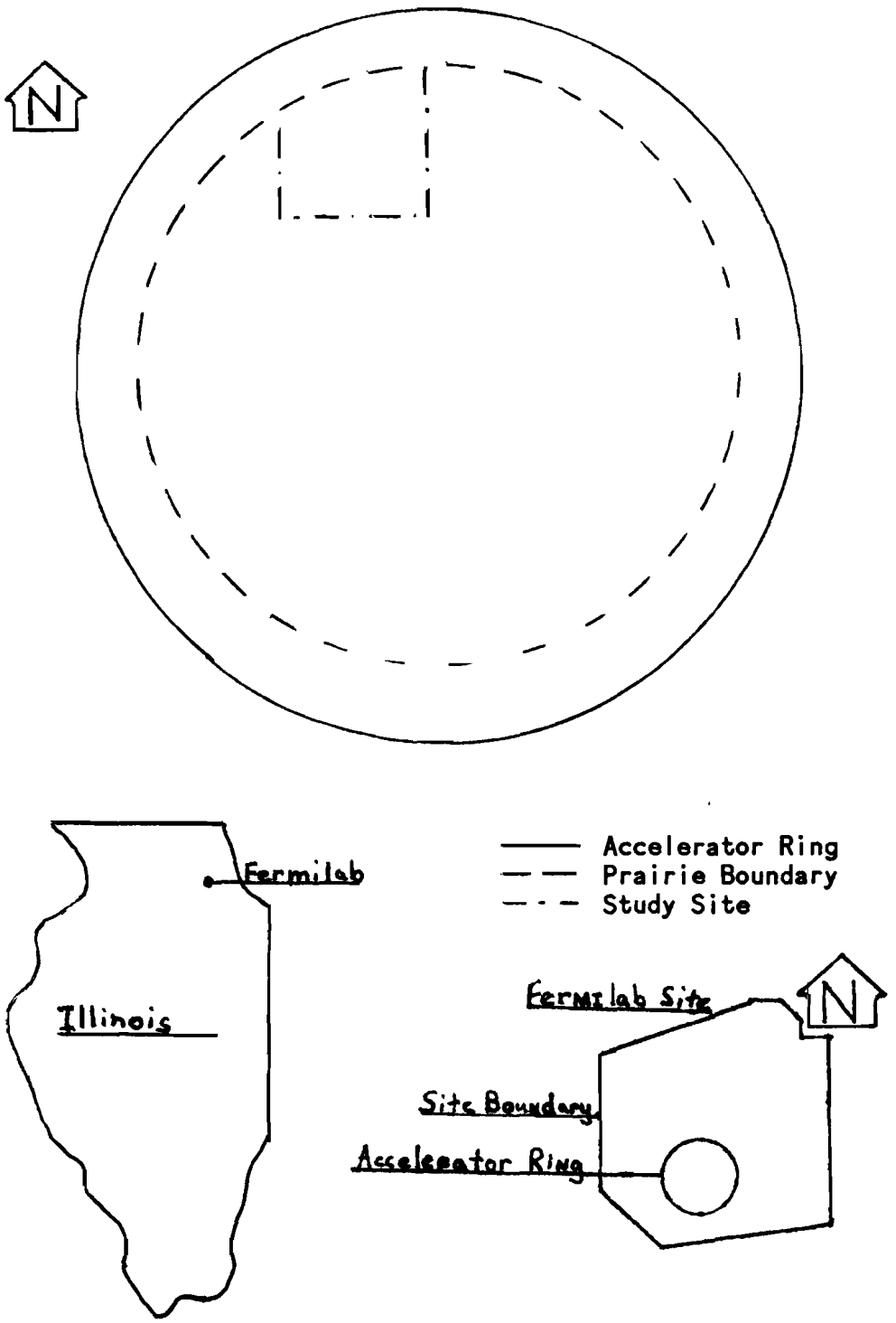
For details of the planting history, see Betz (1984). The prairie has been planted in sections, one of which (the spring 1977 planting site), was chosen for this study (see Figure 1).

Site Characteristics

The main physical characteristics of the study area are listed below:

1. Winds: prevailing from south southwest in the summer to north northeast in the winter.
2. Soil type: Wauconda silt loam, a prairie-forest transition mesic soil.
3. Slope: 0 to 1%.

Figure 1. Location of Study Site.



The accelerator ring vegetation prior to the beginning of the prairie restoration is found in Appendix I. Several communities were present, including marsh, old fields, pastures, and woods. Prior to restoration, the portion of the ring containing the study site (1977 spring planting) was old field, dominated by Eurasian grasses and forbs. The study site of approximately 12 hectares was planted using a Nisbet drill. The drilling of the seed was done in rows in an east-west direction at a rate of 13.6kg/acre (*Fermilab Prairie Project Newsletter*, 1981). The rows are a very evident character which visually dominates the area.

This planting was largely dominated by grass as of 1980, with an abundance of *Andropogon gerardii, Sorghastrum nutans* and some *Panicum virgatum*. Table 1 indicates the forb species present in the study area in 1980 and 1984 after this study was begun. None of the forbs were particularly abundant in 1980, making the site a good candidate for a forb enrichment program.

Appendix II lists the species found in all parts of the restoration as of 1980. Each planting is designated by the season and year planted. This information gives an indication of the vegetation of the area surrounding the study site.

Appendix III lists the species found in the entire Fermilab Site in 1984.

Table 1. Forb species found in 1977 Spring Planting.

Species	1980*	1984**
1. Apocynum sibiricum	U	A
2. Asclepias incarnata	C	C
3. Aster novae-angliae	-	C
4. Baptisia leucantha	-	R
5. Coreopsis palmata	-	R
6. Coreopsis tripteris	-	R
7. Desmodium canadense	-	R
8. Echinacea pallida	-	R
9. Eryngium yuccifolium	-	C
10. Heleopsis helianthoides	-	U
11. Helianthus grosseserratus	U	C
12. Lobelia spicata	-	R
13. Lycopus americanus	U	C
14. Lythrum alatum	U	C
15. Monarda fistulosa	-	U
16. Petalostemum candidum	-	R
17. Petalostemum purpureum	-	R
18. Potentilla arguta	-	R
19. Ratibida pinnata	U	C
20. Rudbeckia hirta	-	U
21. Rudbeckia subtomentosa	-	R
22. Silphium integrifolium	U	A
23. Silphium laciniatum	C	A
24. Silphium terebinthinaceum	U	A
25. Solidago rigida	-	C
26. Vernonia fasciculata	R	U
27. Zizea aurea	-	R

A = abundant C = common U = uncommon R = rare

*List compiled by Betz August 2, 1980.
**Compiled by Betz and Warkins October 1, 1984.

Formulation of Forb Species Mix

As one of the goals of this project is to create a prairie with a species composition similar to that of presettlement (natural) communities, forb species were chosen for this experiment by comparing a list of available seed with lists of prevalent species for wet-mesic and mesic prairies in *The Vegetation of Wisconsin* (Curtis 1959). These prairie types were chosen because of the site conditions. Although these lists are less applicable to Illinois than to Wisconsin, they probably provide a good indication of the composition of the original prairies. Using this method, 26 species were chosen (Table 2).

Table 2. Species planting rates.

Species	Aver.* Freq.	Rel. Freq. % of Plants
1. Allium cernuum	1%	0.3
2. Amorpha canescens	32%	8.4
3. Anemone cylindrica	5%	1.3
4. Baptisia leucantha** ***	1%	0.3
5. Coreopsis palmata	34%	8.9
6. Desmodium canadense**	5%	1.3
7. Echinacea pallida	1%	0.3
8. Eryngium yuccifolium	21%	5.5
9. Lespedeza capitata	18%	4.7
10. Liatris aspera	18%	4.7
11. Monarda fistulosa	22%	5.7
12. Oxypolis rigidior	4%	1.0
13. Parthenium integrifolium	1%	0.3
14. Penstemon digitalis	1%	0.3
15. Petalostemum purpureum**	7%	1.8
16. Potentilla arguta	13%	3.4
17. Ratibida pinnata	48%	12.5
18. Rudbeckia hirta	24%	6.3
19. Rudbeckia subtomentosa	1%	0.3
20. Silphium integrifolium	15%	3.9
21. Silphium laciniatum	8%	2.1
22. Silphium terebinthinaceum	31%	8.1
23. Thalictrum dasycarpum	16%	4.2
24. Tradescantia ohiensis	31%	8.1
25. Veronicastrum virginicum	17%	4.4
26. Zizia aurea	8%	2.1
		100.2

*From Curtis (1959).
**Inoculated.
***Scarified.

To mimic the relative abundances of forb species in natural prairies, prevalent species lists (Curtis 1959) were used as a guide for determining the planting proportions of the forbs. For each species included, a relative frequency statistic was calculated and used to determine the percentage of the total planting made up of that species. Relative frequency was calculated by dividing the average frequency of a species (Curtis 1959) by the sum of the average frequencies for all 26 species in the mix (Table 2). The number of seedlings or seeds used was determined by multiplying that relative frequency by the total number of seeds or seedlings desired. A forb density of 25 plants per square meter was chosen arbitrarily as the desired target. The relative frequency statistic is probably a poor representation of relative abundances, but was the best quantitative information available.

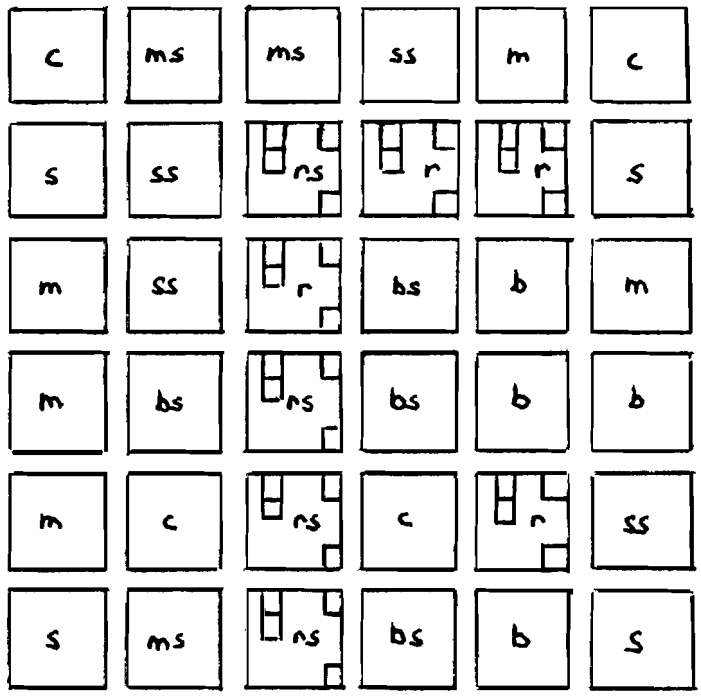
Experimental Design

The experimental design used for this study was a randomized block design consisting of 36 4.0X4.0m plots with a 1.0m buffer zone between each plot (Figure 2). The plots were located in an area that was visually homogeneous as to slope and vegetation. The buffer zones were included to avoid overlap of treatments and to provide an access to all plots without severe trampling.

The treatments consisted of:

1. a control (no forbs added, ground treatment a burn),
2. planting forb seeds after a burn,
3. planting forb seedlings after a burn,
4. planting forb seeds after a burn and then a mowing,

Figure 2. Plot Design.



c	control	bs	burn seedlings
b	burn seeding	ms	burn mow seedlings
m	burn mow seeding	ss	burn scarify seedlings
r	burn sod removal seeding	rs	burn sod removal seedlings
s	burn scarify seeding		

5. planting forb seedlings after a burn and then a mowing ,
6. planting forb seeds after a burn and then soil scarification,
7. planting forb seedlings after a burn and then soil scarification,
8. planting forb seeds after a burn and then removing sod plugs,
9. planting forb seedlings after a burn and then removing sod plugs.

The sod plug treatments were accomplished by using four randomly placed 1X1m quadrats within the appropriate plots. This was done as a labor-saving technique because of the time it took to accomplish the sod removal.

These treatments were chosen in an attempt to emulate natural disturbances in the prairie that may encourage seedling development and seed germination. Fire, of course, is one of the disturbances. Scarification mimics soil disturbances by walking animals such as buffalo and elk. Mowing mimics grazing by herbivores. The sod removal mimics burrowing animals and wallows formed by buffalo.

Work by Blewett (1981) and Christiansen (1967) indicated success by use of these treatments, as discussed above. These treatments inhibit the vigor of the grasses and enable the forb seedlings to compete for light and moisture.

Seed Rates

Seed was counted by hand and then placed into an appropriately marked bag, one per treatment. The sod plug removal treatment received only one-fourth the total amount of seed that the other plots received

because of the smaller area treated. A complete seed mix for a treatment was taken and arbitrarily divided into approximate one quarter sections (Table 3).

Table 3. Rates for seeds.*

Species	# Planted Per Plot	# Planted Per Sod Removal
1. Allium cernuum	1	1
2. Amorpha canescens	34	9
3. Anemone cylindrica	5	1
4. Baptisia leucantha	1	1
5. Coreopsis palmata	36	9
6. Desmodium canadense	5	1
7. Echinacea pallida	1	1
8. Eryngium yuccifolium	22	6
9. Lespedeza capitata	19	5
10. Liatris aspera	19	5
11. Monarda fistulosa	23	6
12. Oxypolis rigidior	4	1
13. Parthenium integrifolium	1	1
14. Penstemon digitalis	1	1
15. Petalostemum purpureum	7	2
16. Potentilla arguta	14	4
17. Ratibida pinnata	50	13
18. Rudbeckia hirta	25	6
19. Rudbeckia subtomentosa	1	1
20. Silphium integrifolium	16	4
21. Silphium laciniatum	8	2
22. Silphium terebinthinaceum	32	8
23. Thalictrum dasycarpum	17	4
24. Tradescantia ohiensis	32	8
25. Veronicastrum virginicum	18	5
26. Zizia aurea	8	2
	400	

*Arbitrarily chosen is the amount of 25 seeds/m^2 in 4mX4m plots which equals 400 seeds per plot.

Seed Treatment

The seed was hand-collected within an 80km radius of the study site during the fall of 1980. The seed was cold dry stratified for three months in an unheated garage. The appropriate species were scarified and inoculated (Table 2).

Seedling Establishment

A specific soil mix was used for the establishment of seedlings. First the soil had to be sterilized to rid the soil of unwanted seeds and disease organisms (pathogens). This was done by placing the soil in a commercial soil sterilizer at 82°C for four hours. This soil was then mixed at a ratio of two-thirds sterilized soil and one-third "Jiffy Plus" mix with a small amount of peat moss added to increase the water holding capacity. This mixture was placed in 10cm deep wooden and metal planting flats. The same planting procedure was used for all species. This procedure consisted of filling the flats with approximately 7.5cm of the soil mixture, then soaking the soil thoroughly with water. The seed was sprinkled over the moistened soil and covered with about one quarter of a centimeter of soil and moistened again. The flats were initially kept in a greenhouse.

Once the seedlings seemed sturdy enough to survive the outdoors (usually after two sets of true leaves had appeared), they were moved to a lathe house for at least one week before being planted into the prairie. The numbers of each species planted were based on relative frequencies as discussed above. During the propagation of the 26 species, half did not germinate. Table 4 indicates the species used and

their proportions. The proportions chosen do not necessarily comply with relative frequencies, but are an attempt to come as close as possible to the relative frequencies using the seeds that did germinate.

Table 4. Rates for Seedlings.

Species	# Planted Per Plot	# Planted Per Sod Removal Plot
1. Anemone cylindrica	12	4
2. Baptisia leucantha	4	4
3. Coreopsis palmata	40	8
4. Desmodium canadense	20	4
5. Echinacea pallida	52	12
6. Liatris aspera	8	4
7. Monarda fistulosa	4	4
8. Petalostemum purpureum	4	4
9. Potentilla arguta	56	12
10. Ratibida pinnata	68	16
11. Rudbeckia hirta	24	4
12. Rudbeckia subtomentosa	4	4
13. Zizia aurea	3	4
TOTALS	299	84

When planting the seedlings in the field, the seedlings would be readied by thoroughly soaking the flats. When planting, care was taken in trying to leave as much soil with the roots as possible. Planting of the seedlings was done by arbitrarily choosing a site and planting the seedlings in a hole created by using a trowel and then tamping the soil around the plants. Each specific site for each of the species emulates a random pattern as closely as possible.

Ground Treatment

All experimental plots were planted to seeds or seedlings following one of four ground-preparation treatments. All plots were burned in early April, 1981, during the annual burning of the entire restoration. Therefore, the burn was a pre-treatment for all plots.

The control treatment consisted of the burn and no introduction of seeds or seedlings.

The first treatment involved the burn only. Introduction of seeds and seedlings followed.

The second treatment involved repeated mowing of the established prairie grasses. The first mowing took place May 21, 1981. The mowing was done with a rotary blade at a height of about 2.5cm above the soil surface. A second mowing occurred on July 1, 1981 at a height of about 10cm. Clippings were not removed.

The third treatment consisted of a scarification of the soil surface. The first tilling, with a hand-operated rototiller, was done May 21, 1981, to the four seed plots. A second treatment of the four remaining plots was accomplished on July 1, 1981 using a rear-mounted

tiller on a small tractor. Tilling depth was two to four centimeters.

The fourth treatment involved removal of sod plugs. This was accomplished using a sod spade to remove four randomly placed 1X1m quadrats within the appropriate plots. A depth of approximately two centimeters was removed from the surface. Plants and soil were removed at this uniform depth. The four seed plots were treated May 22, 1981 and the four seedling plots on July 1 and 2, 1981.

Seed and Seedling Planting

The predetermined seed mix was hand broadcast over the appropriate plots May 22, 1981.

Seedlings were started in the greenhouse May 25, 1981 and planted between July 2 and July 30, 1981.

Field Data Collection

Field data were collected in early October, 1981, late June, 1981, October, 1982, June, 1983, October, 1983 and July, 1984. Data include counts of the forb species present in each plot as well as information on numbers of flowering individuals.

In 1981, one-half of the experimental plots were combined for seed before they could be sampled. This northern half was severely matted down and therefore very difficult to sample. As the 1981 data are incomplete, they will not be considered further.

Many difficulties arose concerning identification and recognition of forb seedlings during the data collection. For example, *Ratibida pinnata* and *Plantago major* can be difficult to differentiate in the

early stages of development. Similarly, distinguishing between *Potentilla arguta* and *Potentilla norvegica* was difficult until *Potentilla arguta* had developed the fourth and fifth leaves. For the purpose of this project, all *Potentillas* with three leaves were assumed to be *Potentilla norvegica*. It was also difficult to differentiate between the three young *Silphium* species. The problems of identification may have led to some errors in the data, but they are not assumed to be serious. The data collected in later years may contain fewer discrepancies because of an increased ability to correctly identify the seedlings. Because of the growth of the biomass of the prairie plants, observation of the individual seedlings was difficult at times. The mature prairie plants tended to obscure some of the smaller seedlings that may have been present. This may have caused the summer samples to have a greater number of individuals than the fall samples.

RESULTS AND DISCUSSION

In the following pages, the results will be presented as follows. First, the forb seeding experiments will be discussed, giving particular attention to the behavior of individual species. This will be followed by a discussion of the seedling experiments. Finally, all of the methods will be considered collectively in terms of their success in establishing individual forb species, as well as forbs considered as a whole.

Two factors need to be discussed before the results are presented, as they operate to complicate the analyses of the data. The first consideration is the fact that, although no forb plants were introduced to the control plots in this experiment, some appeared naturally. A total of six species were represented over the five samplings (Table 5). Five of these species may have developed from the original seeding mix, but one, *Baptisia leucantha*, was probably accidentally placed there by volunteers. In the June, 1984 sampling, only four species were present in the controls, and a general decrease in the number of individuals was observed. The fact that some species occurred in the control plots is important in interpreting the improvement or decline in forb numbers for the experimental treatments.

Table 5. Control (number of individuals found).

Species	Sampling Date				
	July 82	Oct 82	July 83	Oct 83	June 84
Baptisia leucantha	1	1	1	-	-
Eryngium yuccifolium	2	4	-	2	1
Ratibida pinnata	2	1	3	1	2
Silphium integrifolium	2	1	2	4	-
Silphium laciniatum	4	4	4	3	3
Silphium terebinthinaceum	-	-	-	-	1

The second consideration is the fact that during the course of the study some of the planted forb species flowered and set seed (Table 6). As a consequence, some of the increase in numbers shown by these species during the course of the experiment may be due to new recruits, and not to delayed establishment. This may effect the calculation of survival rates.

TABLE 6. SPECIES IN BLOOM

Table 6a. Flowering individuals for burn seeding treatment.

Species	July 82	Oct 82	July 83	Oct 83	June 84
Eryngium yuccifolium	-	1	2	-	-
Ratibida pinnata	-	3	2	-	2
Silphium integrifolium	-	-	2	1	-
Silphium laciniatum	-	2	2	-	-

Table 6b. Flowering individuals for burn mow seeding treatment.

Species	July 82	Oct 82	July 83	Oct 83	June 84
Ratibida pinnata	-	1	1	1	-
Silphium integrifolium	-	-	1	2	-
Silphium laciniatum	-	-	-	2	-

Table 6c. Flowering individuals for burn scarify seeding treatment.

Species	July 82	Oct 82	July 83	Oct 83	June 84
Eryngium yuccifolium	-	1	-	1	1
Ratibida pinnata	-	3	2	2	3
Silphium integrifolium	-	-	2	2	1
Silphium laciniatum	-	-	1	-	1

Table 6d. Flowering individuals for burn sod-removal seeding treatment.

Species	July 82	Oct 82	July 83	Oct 83	June 84
Silphium laciniatum	-	1	-	-	-

Table 6e. Flowering individuals for burn seedling treatment.

Species	July 82	Oct 82	July 83	Oct 83	June 84
Eryngium yuccifolium	-	-	-	1	-
Ratibida pinnata	-	-	1	2	2
Rudbeckia hirta	1	-	-	-	-
Silphium integrifolium	-	-	1	2	-

Table 6f. Flowering individuals for burn mow seedling treatment.

Species	July 82	Oct 82	July 83	Oct 83	June 84
Coreopsis palmata	-	1	-	-	-
Monarda fistulosa	-	-	-	1	-
Ratibida pinnata	-	4	1	4	4
Rudbeckia hirta	1	1	1	-	1
Rudbeckia subtomentosa	-	-	-	1	-
Silphium integrifolium	-	-	1	1	1
Silphium laciniatum	-	-	-	1	-

Table 6g. Flowering individuals for burn scarify seedling treatment.

Species	July 82	Oct 82	July 83	Oct 83	June 84
Coreopsis palmata	1	1	1	3	-
Monarda fistulosa	-	-	1	2	-
Ratibida pinnata	-	7	1	8	10
Rudbeckia hirta	7	1	5	1	-
Rudbeckia subtomentosa	-	-	-	2	-
Silphium integrifolium	-	-	2	1	1
Silphium laciniatum	-	1	-	1	-
Zizea aurea	-	2	-	2	2

Table 6h. Flowering individuals for burn sod-removal seedling treatments.

Species	July 82	Oct 82	July 83	Oct 83	June 84
Monarda fistulosa	-	-	-	1	-
Rudbeckia subtomentosa	-	-	-	1	1
Silphium laciniatum	-	-	-	1	-

Seeding Experiments

General Trends

A large majority of the species planted did not germinate, regardless of the treatment used. These included:

Allium cernuum
Amorpha canescens
Anemone cylindrica
Baptisia leucantha
Coreopsis palmata
Desmodium canadense
Lespedeza capitata
Liatris aspera
Oxypolis rigidior
Parthenium integrifolium
Penstemon digitalis
Petalostemum purpureum
Thalictrum dasycarpum
Tradescantia ohiensis
Veronicastrum virginicum
Zizea aurea

Four additional species were observed early in the experiment, but did not survive long enough to be observed in the final June, 1984 sample:

Echinacea pallida
Potentilla arguta
Rudbeckia hirta
Rudbeckia subtomentosa

These will be considered "observed unsuccessful" species.

Six species did appear to germinate under one or more treatment regimes, and survived to the conclusion of the experiment. These "successful" species are:

Eryngium yuccifolium
Monarda fistulosa
Ratibida pinnata
Silphium integrifolium
Silphium laciniatum
Silphium terebinthinaceum

The establishment rates of these species (number of individuals found in a sample, divided by the number of seeds planted, expressed as a percent) varied with treatment (see Table 7), but in general *Silphium laciniatum* was the most successful with rates ranging from 13 to 19%, and *Monarda fistulosa* and *Silphium terebinthinaceum* the least

Table 7. Percentage survival for individual species for June 1984.

Species	Burn	Burn Mow	Burn Scarify
Eryngium yuccifolium	9.1	1.1	4.6
Monarda fistulosa	-	1.1	2.2
Ratibida pinnata	4.5	1.0	5.0
Silphium integrifolium	7.8	10.9	6.3
Silphium laciniatum	18.8	12.5	12.5
Silphium terebinthinaceum	2.3	-	2.3

successful, with rates ranging from 1 to 2%. It is important to note that all but *Monarda* also appear in the control plots, hence these survival rates are probably high, in that some individuals may have been present prior to the experimental seeding. As will be seen later, there is evidence that such is the case.

Germination by Treatment

Table 7 presents the survival rates of the six "successful species" for three of the treatments as of June, 1984. (Again, the Burn Sod-Removal Treatment is not included.) With the exception of *Monarda fistulosa*, the species were successfully established in all three of the treatments. For two species, *Eryngium yuccifolium* and *Silphium laciniatum*, the rates were highest in the Burn Seeding Treatment. With the exception of *Silphium integrifolium*, rates were lowest in the Burn Mow Seeding Treatment. *Ratibida pinnata* achieved its highest survival in the Burn-Scarify Seeding Treatment. *Silphium integrifolium* had its highest rate in the Burn Mow Treatment.

Tables 8 to 11 present data for each species found in each treatment at the five sampling dates. Data include the number of individuals found and survival rates. Table 12 gives information on the percentage change shown in each treatment relative to the control, for all species combined. The results changed over the course of the experiment, with species appearing and disappearing from plots and the numbers of individuals also fluctuating. The Burn Scarify Seeding Treatment and the Burn Mow Seeding Treatment produced the greatest diversity, with nine and eight species appearing in one or more samples; the Burn Seeding Treatment contained five species, the Burn Sod-Removal

Seeding Treatment had six species. By the last sampling date in June, 1984, the Burn Scarify Seeding Treatment retained six species, the Burn Seeding Treatment and the Burn Mow Seeding Treatment each had five, and the Burn Sod-Removal Seeding Treatment had three species. In contrast, the control plots had four species.

In most instances, there were as many or more individuals found in the treatment plots as in the control for those species appearing in both. In terms of numbers of forb individuals, regardless of species, by June, 1984, the Burn Seeding Treatment had 31, the Burn Scarify Seeding Treatment had 27, and the Burn Mow Seeding Treatment had 15. These represent percent increases of 343%, 286%, and 114% over the control (seven individuals) (Table 12). None of the methods were significantly different from the others, however. (The Burn Sod-Removal Treatment is not included in this comparison, as the area covered is much smaller than that of the other treatments.)

These results need to be examined in relationship to the control for those seeded species which appeared there. Table 13 presents the percentage range relative to the control by species. *Ratibida pinnata* increased substantially in numbers under two treatments, Burn Seeding and Burn Scarify Seeding, but decreased under the Burn Mow Seeding Treatment. *Eryngium yuccifolium* increased only in the Burn Mow Treatment and showed no change in the Burn Scarify Seeding Treatment. It showed a large decrease in the Burn Mow Seeding Treatment. *Silphium integrifolium* showed a large increase in the Burn Mow Seeding Treatment with no change occurring in the Burn Scarify Seeding Treatment. A decrease was observed in the Burn Seeding Treatment. *Silphium*

laciniatum showed only a small increase in the Burn Seeding Treatment, with no change occurring in the Burn Mow Seeding and the Burn Scarify Seeding Treatments. *Silphium terebinthinaceum* was found in only the Burn Scarify Seeding Treatment with a substantial increase.

Table 8. Burn seeding treatment.

Species	July 82		Oct 82		July 83		Oct 83		June 84	
	#	%	#	%	#	%	#	%	#	%
Eryngium yuccifolium	-	-	5*	5.7	-	-	5*	5.7	8*	4.1
Ratibida pinnata	9*	4.5	8*	4.0	7*	3.5	8*	4.0	9*	4.5
Silphium integrifolium	8*	9.4	2*	3.1	6*	9.4	2	3.1	5*	7.8
Silphium laciniatum	5*	15.6	8*	2.5	3	9.4	5*	15.6	6*	13.8
Silphium terebinthinaceum	-	-	-	-	1*	0.1	-	0	3*	2.3
									31	

#Number found.
%Percent of establishment per number planted.
*Greater than number found in control.

Table 9. Burn mow seeding treatment.

Species	July 82		Oct 82		July 83		Oct 83		June 84	
	#	%	#	%	#	%	#	%	#	%
Echinacea pallida	2*	50	-	-	-	-	-	-	-	-
Eryngium yuccifolium	-	-	-	-	-	-	1	1.1	1†	1.1
Monarda fistulosa	-	-	-	-	-	-	-	-	1*	1.1
Ratibida pinnata	3*	1.5	2*	1.0	6*	3.0	1	0.5	2†	1.0
Rudbeckia hirta	1*	1.0	-	-	-	-	-	-	-	-
Silphium integrifolium	2	3	2*	3.1	1	1.6	2	3.1	7*	10.9
Silphium laciniatum	7*	21.9	7*	21.9	4	12.5	2	6.3	4*	12.5
Silphium terebinthinaceum	-	-	2*	1.6	1*	0.1	1*	0.1	-	-
									15	

#Number found.
%Percent of establishment per number planted.
*Greater than number found in control.
†Same as number found in control for 1984 June sampling.

Table 10. Burn scarify seeding treatment.

Species	July 82		Oct 82		July 83		Oct 83		June 84	
	#	%	#	%	#	%	#	%	#	%
Echinacea pallida	-	-	-	-	-	-	1*	25.0	-	-
Eryngium yuccifolium	3*	3.4	1	1.1	1*	1.1	2	2.3	4*	4.6
Monarda fistulosa	-	-	-	-	-	-	-	-	2*	2.2
Potentilla arguta	1*	1.3	-	-	-	-	-	-	-	-
Ratibida pinnata	9*	4.5	7*	3.5	9*	4.5	9*	4.5	10*	1.5
Rudbeckia hirta	2*	2.0	-	-	-	-	-	-	-	-
Silphium integrifolium	4*	6.3	5*	7.8	10*	15.6	3	4.7	4*	6.3
Silphium laciniatum	6*	18.8	3	9.4	2	6.3	6*	18.8	4*	12.5
Silphium terebinthinaceum	-	-	1*	0.1	-	-	-	-	3*	2.3
									27	

#Number found.
%Percent of establishment per number planted.
*Greater than number found in control.

Table 11. Burn sod removal seeding treatments.

Species	July 82		Oct 82		July 83		Oct 83		June 84	
	#	%	#	%	#	%	#	%	#	%
Ratibida pinnata	7*	14.0	2*	4.0	4*	8.0	3*	6.0	4*	8.0
Rudbeckia hirta	-	-	-	-	1*	16.0	-	-	-	-
Rudbeckia subtomentosa	1*	100.0	-	-	-	-	-	-	-	-
Silphium integrifolium	-	-	-	-	-	-	-	-	2*	6.3
Silphium laciniatum	2	25.0	2	25.0	-	-	1	12.5	2	25.0

#Number found (original data).
%Percent of establishment per number planted (multiplied by four).
*Greater than number found in control.

Table 12. Percentage of forb individuals over control.*

Treatment	July 82	Oct 82	July 83	Oct 83	June 84
Burn Seeding	100	109	75	100	343
Burn Mow Seeding	36	18	10	-20	114
Burn Scarify Seeding	127	55	120	110	286

*Percentage was calculated by determining the total number of individuals found minus the total found in the control, dividing this figure by the number found in control and multiplying the result by 100.

These results seem to follow the trends of other studies of germination of species in field conditions. A study by Peven (1985) had comparable results with the highest germination being 12.4 percent for *Silphium integrifolium* and no germination for seven species. Some of these species with no germination were in common with my results: *Allium cernuum, Lespedeza capitata, Liatris aspera, Tradescantia ohiensis* and *Veronicastrum virginicum*. Some successful species in common were *Monarda fistulosa, Ratibida pinnata* and *Silphium integrifolium*. *Rudbeckia hirta* and *Rudbeckia subtomentosa* germinated in this study but did not survive until June 1984. These species were successful in Peven (1985). In comparing the two studies, the results are very similar with many common species, with similar reactions of low germination or no germination.

Christiansen and Landers (1966) had success with several species in their seeding treatments. They had some success with eleven species that were used in this study. Species that were in common with ones used in thus study with successful results were *Ratibida pinnata, Eryngium yuccifolium,* and *Silphium laciniatum*. Their results were much higher than found in this study. Eight species were successful for that study but not for this study: *Anemone cylindrica, Baptisia leucantha, Desmodium canadense, Echinacea pallida, Lezpedeza capitata, Liatris aspera, Petalostemum purpureum* and *Potentilla arguta*. To summarize the results of the seeding experiments, no definite trends appeared for either a specific species or a specific treatment. Individual species did well for a specific treatment but showed no overall consistency through those treatments. Some species showed a tendency to fluctuate higher and then lower over the sampling periods. This is also true for

the different treatments, as they did not show a consistent improvement or decline for all species. (Table 13)

Table 13. Species change over control for seeding for June, 1984.

	Seed Burn	Seed Mow	Seed Scarify
Eryngium yuccifolium	100	-75	0
Ratibida pinnata	200	-33	233
Silphium integrifolium	-50	75	0
Silphium laciniatum	25	0	0
Silphium terebinthinaceum	-	-	200
Total % increase overall	275	-33	433

*Percentages determined from amount of increase or decrease in the number of individuals, as compared to the highest number of individuals found in all of the control samplings.

Seedling Experiments

General Trends

Of the thirteen species planted as seedlings, seven survived in one or more treatments to the June, 1984 sampling. Those which did not appear at any sampling date include:

Anemone cylindrica
Baptisia leucantha
Liatris aspera
Petalostemum purpureum

Two species survived at first, but had disappeared by June, 1984:

Potentilla arguta
Echinacea pallida

The successful species (those which remained by the June, 1984 sample) are:

Coreopsis palmata
Desmodium canadense
Monarda fistulosa
Ratibida pinnata
Rudbeckia hirta
Rudbeckia subtomentosa
Zizea aurea

The establishment rates varied, with *Zizea aurea* and *Monarda fistulosa* apparently being the most successful and *Coreopsis palmata, Rudbeckia hirta,* and *Desmodium canadense* the least successful species (Table 14).

As will be discussed later, the presence of plants on site prior to the experiment and the possibility of reproduction during the course of the experiment may account for rates in excess of 100%.

Table 14. Percentage survival for individual species for seedling treatment June, 1984.

Species	Burn	Burn Mow	Burn Scarify
Coreopsis palmata	-	-	2.5
Desmodium canadense	5.0	-	15.0
Monarda fistulosa	50.0	225.0	25.0
Ratibida pinnata	20.6	16.2	35.3
Rudbeckia hirta	-	4.2	-
Rudbeckia subtomentosa	-	25.0	50.0
Zizia aurea	100.0	125.0	300.0

Christiansen and Landers (1969) did something similar to this study, in that they took seedlings from intact remnant prairies and used them as transplants. In this study, plants were grown from seed. This can give some indication of what may be successful and we may be able to make some comparisons. Christiansen and Landers had very high success for the species used, getting over 30% survival for all species. *Zizea aurea, Desmodium canadense, Monarda fistulosa, Rudbeckia hirta, Rudbeckia subtomentosa, and Ratibida pinnata* were the only successful species the two studies had in common. Christiansen and Landers also had success with *Echinacea pallida, Liatris aspera, Silphium laciniatum, Anemone cylindrica, Silphium integrifolium, Thalictrum dasycarpum, Petalostemum purpureum, Lespedeza capitata,* and *Eryngium yuccifolium.* Christiansen and Landers also had very low numbers of transplants.

Their seedlings had a much more established root system than found in the seedlings in this study. This may have enabled the seedlings to compete for moisture more effectively. The type of root system the plant has may determine to some extend how successful the plant might be.

Seedling Survival by Treatment

Tables 15 to 18 present data for each species found in each treatment at the five sampling dates. Data include the number of individuals found and survival rates. The tables also include information on species found in the plots which were not planted there. Those results will be discussed separately.

Table 15. Burn seedling treatment.

Species	July 82		Oct 82		July 83		Oct 83		June 84	
	#	%	#	%	#	%	#	%	#	%
Desmodium canadense	1	5	-	-	-	-	-	-	1	5
Echinacea pallida	1	1.9	-	-	2	3.8	-	-	-	-
Eryngium yuccifolium	1	NP	4	NP	1	NP	3	NP	6	NP
Monarda fistulosa	-	-	-	-	-	-	2	50	2	50
Ratibida pinnata	5	7.3	10	14.7	4	5.9	9	13.2	14	20.6
Rudbeckia hirta	2	8.3	-	-	-	-	-	-	-	-
Silphium integrifolium	5	NP	5	NP	5	NP	3	NP	4	NP
Silphium laciniatum	2	NP	1	NP	-	-	-	-	-	-
Silphium terebinthinaceum	-	-	-	-	-	-	-	-	1	NP
Zizea aurea	-	-	3	100	-	-	4	130	3	100
									20	Planted Species

NP = Not planted.

#Number found.
%Percent of establishment per number planted.

Table 16. Burn mow seedling treatment.

Species	July 82		Oct 82		July 83		Oct 83		June 84	
	#	%	#	%	#	%	#	%	#	%
Coreopsis palmata	1	2.5	1	2.5	0	-	-	-	-	-
Desmodium canadense	1	5	1	5	1	5	-	-	-	-
Eryngium yuccifolium	1	NP	3	NP	0	NP	-	-	3	NP
Monarda fistulosa	3	75	1	25	3	75	1	25	9	225
Parthenium integrifolium	-	-	-	-	-	-	-	-	1	NP
Potentilla arguta	3	5.4	0	-	0	-	-	-	-	-
Ratibida pinnata	16	23.5	16	23.5	12	17.6	17	25	11	16.2
Rudbeckia hirta	2	8.3	1	4.2	1	4.2	-	-	1	4.2
Silphium integrifolium	10	NP	10	NP	11	NP	3	NP	9	NP
Silphium laciniatum	4	NP	4	NP	4	NP	3	NP	4	NP
Silphium terebinthinaceum	3	NP	0	NP	0	NP	-	-	-	-
Zizea aurea	3	100	3	100	2	67	4	125	4	125
									25	Planted Species

NP = Not planted.

.....

#Number found.

%Percent of establishment per number planted.

Table 17. Burn scarify seedling treatment.

Species	July 82		Oct 82		July 83		Oct 83		June 84	
	#	%	#	%	#	%	#	%	#	%
Coreopsis palmata	1	2.5	2	5	1	2.5	3	7.5	1	2.5
Desmodium canadense	7	3.5	5	25	2	1	-	-	3	15
Eryngium yuccifolium	-	-	-	-	-	-	1	NP	1	NP
Monarda fistulosa	4	100	2	50	3	75	4	100	1	25
Potentilla arguta	9	16	2	3.6	-	-	3	5.4	-	-
Ratibida pinnata	26	38.2	25	36.8	21	30.9	26	38.2	24	35.3
Rudbeckia hirta	7	2.9	1	4.2	5	20.8	1	4.2	-	-
Silphium integrifolium	3	NP	5	NP	7	NP	1	NP	13	NP
Silphium laciniatum	2	NP	4	NP	2	NP	6	NP	5	NP
Silphium terebinthinaceum	1	NP	1	NP	1	NP	10	NP	1	NP
Zizea aurea	5	167	6	200	6	200	5	87	9	300
									38	Planted Species

NP = Not planted.

#Number found.
%Percent of establishment per number planted.

Table 18. Burn sod removal seedling treatment.

Species	July 82		Oct 82		July 83		Oct 83		June 84	
	#	%	#	%	#	%	#	%	#	%
Eryngium yuccifolium	-	-	1	NP	-	-	-	-	-	-
Monarda fistulosa	3	75	2	50	3	75	1	25	1	25
Potentilla arguta	1	83	-	-	-	-	-	-	-	-
Ratibida pinnata	1	63	-	-	2	125	1	63	1	63
Rudbeckia subtomentosa	1	25	1	25	-	-	1	25	1	25
Silphium integrifolium	-	-	2	NP	1	NP	-	-	4	NP
Silphium laciniatum	1	NP	1	NP	1	NP	2	NP	5	NP
Zizea aurea	2	25	-	-	-	-	2	25	-	-
									3 Planted Species	

NP = Not planted.

.....

#Number found.
%Percent of establishment per number planted.

Considering only those species planted as seedlings, the results indicate that each treatment achieved some degree of success in forb establishment. As was the case with the seeding experiments discussed above, the results changed over time. Over the course of the experiment, the Burn Mow Seedling Treatment and Burn Scarify Seedling Treatment each contained seven planted species, the Burn Seedling Treatment six and the Burn Sod-Removal Treatment five. By June, 1984, the Burn Scarify Seedling Treatment had five planted species, the Burn Seedling and Burn Mow Seedling Treatments each had four, and the Burn Sod-Removal Seedling Treatment had three species. The Burn Scarify Seedling Treatment had 38 forb individuals, followed by the Burn Mow Seedling Treatment with 25, and the Burn Seedling Treatment with 20. These represent increases of 428%, 257%, and 287% over the seven forb individuals found in the control. (As before, the Burn Sod Removal Seedling data are not used for this comparison.)

Table 19 indicates the survival rates of the seedlings taken as a whole found at the different sampling dates. The highest rates were achieved in the Burn Scarify Seedling Treatment.

Monarda fistulosa and *Ratibida pinnata* survived at least until June 1984 in all four treatments, and *Zizea aurea* survived in all but the Burn Sod-Removal Seedling Treatment. The success of *Ratibida pinnata* has to be analyzed in relation to the Control. This planted species was also present on site in the Control, therefore indicating that it was present on site prior to the experiment. Because *Ratibida* was found in larger numbers on the experimental plots than in the Control Plot (Table 5), it can probably be assumed that some of the seedlings did survive.

Table 19. Percentage survival seedlings.*

Treatment	July 82	Oct 82	July 83	Oct 83	June 84
Burn	3.0	4.3	2.0	5.0	6.7
Burn Mow	10.0	8.0	6.4	7.7	8.7
Burn Scarify	20.4	15.4	13.0	14.7	13.8

*Percentage is calculated from the total number of planted species found in June 1984 divided by the total number planted for that treatment and multipled by 100.

Coreopsis palmata was found initially in the Burn Mow Seedling Treatment, but survived until 1984 only in the Burn Scarify Seedling Treatment. *Desmodium canadense* was found initially in the Burn Mow Seedling Treatment, but survived only in the Burn Seedling and Burn Scarify Treatments. *Rudbeckia hirta* was found initially in all but the Burn Sod Removal Seedling Treatment, but survived only in the Burn Mow Seedling Treatment. *Rudbeckia subtomentosa* only appeared in the Burn Sod Removal Treatment, where it was still found in June, 1984 (Table 18).

These species have to be analyzed in relationship with the control. Table 20 shows this relationship. *Eryngium yuccifolium* improved in only the Burn Seedling Treatment, while decreasing in number found in the Burn Mow Seedling and the Burn Scarify Seedling Treatments in comparison to Control. *Ratibida pinnata* increased substantially in all three seedling treatments, with the Burn Scarify Treatment being the most improved over Control. *Silphium integrifolium* stayed at the same level in the Burn Seedling Treatment, while it increased in both the Burn Mow Seedling and Burn Scarify Seedling Treatments in comparison to Control. *Silphium laciniatum* was not found in the Burn Mow Seedling Treatment. It showed no change over Control in the Burn Mow Seedling Treatment, while its increase was only minor over Control in the Burn Scarify Seeding Treatment. *Silphium terebinthinaceum* was not found in the Burn Mow Seedling Treatment, and showed no increase over Control in the Burn Seedling and the Burn Scarify Seedling Treatments.

Ratibida pinnata was the most successful species in all three treatments. Overall, *Monarda fistulosa* and *Zizea aurea* had comparable or even better success than *Ratibida pinnata*, but indicate percentages higher than 100% (Table 20), which may indicate reseeding of areas by flowering individuals or residual seed germination. *Coreopsis palmata* was the least successful of the surviving individuals.

Overall, the Burn Scarify Seedling Treatment is the most successful treatment in percentages (Table 19), with the Burn Seedling and Burn Mow Seedling Treatments being comparable in the limited success that they showed.

Table 20. Species change over control for seedlings for June 1984.

	Seedling Burn	Seedling Mow	Seedling Scarify
Eryngium yuccifolium	50	-25	-75
Ratibida pinnata	367	266	700
Silphium integrifolium	0	125	225
Silphium laciniatum	-	0	25
Silphium terebinthinaceum	0	-	0
Total % increase overall	433	366	875

*Percentages determined from amount of increase or decrease in the number of individuals, as compared to the highest number of individuals found in all of the control samplings.

Non-Planted Species in Seedling Experiments

Several species appeared in the seedling experimental plots which were not planted as seedlings. These include *Eryngium yuccifolium, Parthenium integrifolium, Silphium integrifolium, Silphium laciniatum* and *Silphium terebinthinaceum*. All of these species with the exception of *Parthenium integrifolium*, which was noted in June 1984 in the Burn Mow Seedling Treatment, also appear in the control plots, indicating their previous existence on site. By comparing the numbers of individuals found in each treatment with the numbers found in the control and those found in the seeding experiments, we can gain further insight into the results of the seeding experiments discussed above. If the numbers in the treatment plots show significant increases relative to the control, it is likely that the ground treatments caused the species to increase in number, perhaps by invasion from surrounding areas, or by the germination of residual seed. Similary, if the numbers found in the seedling plots are comparable to those found in the seeding plots, we will have to re-evaluate our assessment of the success of the seed germination results reported above.

As can be seen in Table 21, there is some slight evidence that the ground treatments used in the seeding and seedling experiments may have contributed to the success of the species found. For instance, in Table 21, *Silphium laciniatum* (with exception of the Burn Seedling Treatment) had almost identical numbers to the control, showing for that species no influence was had from the treatments. Similarly this is

Table 21. Number of individuals found (June 1984) versus highest number found in the control.

	*Control	Seed Burn	Seedling Burn	Seed Mow	Seedling Mow	Seed Scarify	Seedling Scarify
Eryngium yuccifolium	4	8	6	1	3	4	1
Silphium integrifolium	4	2	4	7	9	4	13
Silphium laciniatum	4	5	-	4	4	4	5
Silphium terebinthinaceum	1	-	1	-	-	3	1
TOTALS	13	15	11	12	16	15	20

*Highest number found through all sampling.
†Also planted as seedlings.

true for *Silphium terebinthinaceum*. *Eryngium yuccifolium* showed that the Burn Seedling Treatment and the Burn Seeding Treatment had slight increases in the number of species. The Burn Mow Seeding and the Burn Scarify Seedling may have had detrimental effects on the number of individuals. *Silphium integrifolium* showed large increases in the Burn Mow Seedlings, Burn Mow Seeding and the Burn Scarify Seedling Treatments. Overall, the species *Silphium integrifolium* may have been affected by the ground treatments.

From the date in Table 20 it appears as if the Scarify Treatment may have caused increases in species numbers. However, it is evident that the ground treatment, by itself, should have had controls set up to determine the success of the treatment, and not just a general unmanipulated control.

DISCUSSION AND RECOMMENDATIONS

Although the methods used in this project were successful to a small degree, many of the aspects of the project could be changed to improve the result.

The following suggestions are recommendations based upon my experience of five years in prairie restoration work. It is especially noted that all conditions and recommendations may only be true for the Northern Illinois area, and may need to be adapted to other climatic conditions and year-to-year variations in the weather. In order to make interpreting the results easier, the first thing that might be changed is the experimental design. The concept of simulating densities found in natural prairies was a good one, but when interpreting the results, many of the species were planted in such small numbers that any survival or non-survival could not be interpreted statistically.

Of the ground preparation methods tested, the one that is recommended for introducing both seeds and seedlings is the Burn Scarify Treatment. Although for the Seeding Treatment, the Burn Scarify Treatment did not have the highest percentage establishment, it showed the best overall establishment (See Table 7). For the seedlings, it was by far the best establishment method. In all seedling cases, this treatment was approximately twice as successful as the others (See Table 19)

All treatments give a degree of success, and can be used according to your own needs. Another important consideration is to determine which species interests you, and which choice of treatments would be best for that species. As found in the results, individual species do better with some treatments than with others.

One of the most important determining factors is the scale of the project. Your choice of ground preparation techniques may change according to the species you wish to favor. The Burn Sod-Removal Treatment allows only isolated improvements in species numbers with a large amount of labor. The other three treatments can be done on a more comprehensive scale in both small and large tracts of prairie. These three treatments differ in the amount of mechanical equipment required. The Burn Treatment requires burning equipment, such as flappers and back pack sprayers. The Mow Treatmment can be done by any type of rotary mower, these come in all types and sizes for your particular needs. Use of a cycle mower is not recommended, because the thatch left will require the removal of the debris. The rotary mower will chop up the thatch and prevent it from covering and shading the valuable plants underneath. The Scarifying Method can be done by hand-held rototillers or by discs pulled by tractors, depending on the scale of your needs.

Some suggestions for improving the seeding method are as follows:

1. The timing of the planting is very important, because need for moisture is of the utmost concern. Planting right after mowing, burning or scarifying would be ideal. Moisture during the first couple of weeks is critical for immediate success. In the Northern Illinois area, April 1st to June 1st in a

normal year is a good time to plant. Planting should also be gauged toward long-term moisture forecast.

2. After the planting of the seed a roller or other soil packing system will insure seed to soil contact. This treatment is especially necessary for the scarification method to improve germination percentages. It should also improve germination in the other methods.

3. Mowing may be a supplemental treatment for the Burn, Burn Scarify and Burn Sod-Removal Treatments, and could possibly improve the success for these methods when compared to the success found in this project, by increasing the seedlings ability to compete for light.

For the seedling treatments the following suggestions are recommended:

1. When growing the seedlings, you should choose an appropriate propagation technique so that you are ready to plant during late spring or early summer. When the seedlings have reached a state of at least two sets of true leaves, transplant them into a Root-Master System by Jiffy Products of America or a comparable system that consists of a long narrow tube. These are tubular containers, which direct the growth of roots downward rather than allowing them to spread laterally as conventional pots do. Seedlings with roots formed in this way seem to have better survival rates when they are transplanted in the spring. Leave the seedlings in the system until the following spring, so it can be determined whether that

particular cell has a live plant in it. Once this is determined, the seedlings can be transplanted into the established prairie, using the method or treatment chosen.

2. Be sure that ample moisture is available for the seedling after transplanting in the prairie. In most areas in Northern Illinois, this condition exists until about June 1st. If adequate rainfall does not occur, supplemental watering is suggested at the time of planting. The first couple of weeks are very critical to the survival of the plants.
3. As in the seeding recommendation, mowing of the other three methods may provide improved success, but be sure to mow above the height of the seedlings. Close monitoring of the seedling for light competition could be helpful in determining if this is necessary. The mowing should be done around the first week in July.

A follow-up study is now being conducted which utilizes some of the findings of this paper. Initiated in 1985, this study involves introducing five species of forb seedlings (Table 22) into an existing prairie near the site used for this thesis. Seedlings were started in 1984. Utilizing the propagation methods of Betz (1982), and then transplanting the seedlings into "Rootmaster Systems", they were then grown for one season outdoors. The following spring, the seedlings were planted into 4X4m plots with two different treatments: scarify and mow.

Table 22. Seedling survival rates.

	Scarify			Mow			Control		
	# p	% s	# f	# p	% s	# f	# p	% s	# f
Petalostemum purpureum	25	96	0	30	93	5	26	92	5
Petalostemum candidum	25	96	5	25	100	2	25	100	0
Amorpha canescens	25	84	0	25	100	0	25	100	0
Liatris pycnostachya	25	88	1	25	80	0	25	84	0
Coreopsis palmata	25	100	0	24	96	0	26	100	0

p = Number planted.
% s = Percent survival.
# f = Number flowering.

In addition, a control plot was set up, consisting of no ground treatment, but addition of seedlings. In most cases, 25 seedlings of each species were transplanted into the prairie sod (Table 22). Substantial rainfall occurred the day before and the day after the planting. Seedlings were planted into the plots on May 15 with no supplemental watering. Soil scarification occurred the day of the planting, and the mowing at a height of 1/4 meter with hand clippers occurred on July 23. The burning of the plots was done in April. The scarify plots were done with a hand held rototiller on the day of planting. Results have been very good for the methods used (See Table 22). The last sampling was done on July 12, 1985.

Overall, the ground treatments are both successful along with the control, with little difference between them. *Liatris pycnostachya* is the least successful species. Of course, the results are preliminary. They will be more definite after the seedlings go through their first winter. In the first experiment, losses occurred after the first year.

APPENDIX I: PLANTS OF THE ACCELERATOR RING - 1974

Prairie and Prairie Marsh

Andropogon gerardii (big bluestem grass)
Apocynum sibiricum (Indian hemp)
Asclepias sullivantii (prairie milkweed)
Asclepias verticillata (whorled milkweed)
Aster simplex (panicled aster)
Boehmeria cylindrica (false nettle)
Carex sp. (sedge)
Equisetum arvense (horsetail)
Erigeron philadelphicus (marsh fleabane)
Fragaria virginiana (wild strawberry)
Geum laciniatum v. *trichocarpum* (rough avens)
Glyceria striata (fowl meadow grass)
Gratiola neglecta (clammy hedge hyssop)
Helianthus grosseserratus (tall sunflower)
Juncus dudleyi (Dudley's rush)
Leersia oryzoides (rice cut grass)
Lemna minor (small duckweed)
Lilium michiganense (Turk's cap lily)
Lobelia spicata (pale-spiked lobelia)
Lycopus americanus (common water horehound)
Lysimachia ciliata (fringed loosestrife)
Lythrum alatum (winged loosestrife)
Monarda fistulosa (wild bergamot)
Penthorum sedoides (ditch stonecrop)
Potentilla simplex (common cinquefoil)
Prunella vulgaris v. lanceolata (self heal)
Ratibida pinnata (yellow cone flower)
Rosa carolina (wild rose)
Rudbeckia hirta (black-eyed Susan)
Saxifraga pensylvanica (swamp saxifrage)
Scirpus atrovirens (dark-green rush)
Scirpus lineatus (red bulrush)
Scutellaria lateriflora (mad-dog skullcap)
Senecio pauperculus v. balsamitae (balsam ragwort)
Silphium laciniatum (prairie compass plant)
Smilacina stellata (starry false Solomon's seal)
Solidago gigantea v. leiophylla (late goldenrod)
Spartina pectinata (prairie cord grass)
Sphenopholis intermedia (slender wedge grass)
Stachys palustris v. homotricha (woundwort)
Tradescantia ohiensis (spiderwort)
Typha latifolia (common cat-tail)
Verbena hastata (blue vervain)
Veronicastrum virginicum (Culver's root)
Viola papilionacea (common violet)
Zizea aurea (golden Alexanders)

Woods and Thickets

Acer negundo (box elder)
Acer saccharinum (silver maple)
Agastache nepetoides (yellow giant hyssop)
Agrimonia gryposepala (tall agrimony)
Allium tricoccum (wild leek)
Aster lateriflorus (side-flowering aster)
Aster sagittifolius v. drummondii (Drummond's aster)
Celastrus scandens (climbing bittersweet)
Cirsium altissimum (tall thistle)
Claytonia virginica (spring beauty)
Cornus oblique (blue-fruited dogwood)
Cornus racemosa (gray dogwood)
Cryptotaenia canadensis (honewort)
Ellisia nyctelea (Aunt Lucy)
Elymus villosus (silky wild rye)
Erythronium albidum (white trout lily)
Eupatorium rugosum (white snakeroot)
Fraxinus americana (white ash)
Fraxinus pennsylvanica v. subintegerrima (green ash)
Galium aparine (annual bedstraw)
Galium triflorum (sweet-scented bedstraw)
Geranium maculatum (wild geranium)
Geum canadense (white avens)
Hydrophyllum virginianum (Virginia waterleaf)
Impatiens capensis (orange jewelweed)
Juglans nigra (black walnut)
Lonicera tatarica (Tartarian honeysuckle)
Menispermum canadense (moonseed)
Morus alba (white mulberry)
Osmorhiza claytonii (Hairy sweet cicely)
Parthenocissus inserta (thicket creeper)
Podophyllum peltatum (May apple)
Polygonatum canaliculatum (Solomon's seal)
Populus deltoides (cottonwood)
Prunus americana (wild plum)
Prunus serotina (black cherry)
Prunus virginiana (choke cherry)
Pyrus communis (pear)
Pyrus malus (apple)
Quercus alba (white oak)
Quercus macrocarpa (bur oak)
Quercus rubra (red oak)
Ranunculus abortivus (small-flowered buttercup)
Rhus glabra (smooth sumac)
Rhus radicans (poison ivy)
Ribes americanum (wild black currant)
Ribes missouriense (wild gooseberry)
Rosa multiflora (Japanese rose)
Rubus allegheniensis (common raspberry)
Rubus occidentalis (black raspberry)
Salix interior (sandbar willow)
Sanicula gregaria (clustered black snakeroot)

Scrophularia marilandica (late figwort)
Smilacina racemosa (feathery false Solomon's seal)
Smilax lasioneura (common carrion flower)
Solidago altissima (tall goldenrod)
Tilia americana (basswood)
Tovara virginiana (woodland knotweed)
Trillium recurvatum (red trillium)
Ulmus americana (American elm)
Verbena urticifolia (white vervain)
Viola pensylvanica (smooth yellow violet)
Viola sororia (hairy wood violet)
Vitis riparia (riverbank grape)
Xanthoxylum americanum (prickly ash)

Weeds

**Agropyron repens* (qauck grass)
**Agrostis alba* (redtop)
**Alliaria officinalis* (garlic mustard)
Ambrosia artemisiifolia v. elatior (common ragweed)
Ambrosia trifida (giant ragweed)
**Arctium minus* (common burdock)
Asclepias syriaca (common milkweed)
Aster pilosus (hairy aster)
**Atriplex patula* (common orach)
**Barbarea vulgaris* (yellow rocket)
**Brassica kaber v. pinnatifida* (charlock)
**Brassica nigra* (black mustard)
**Bromus inermis* (Hungarian brome grass)
**Cerastium vulgatum* (mouse-ear chickweed)
**Cirsium arvense* (Canada thistle)
**Cirsium vulgare* (bull thistle)
**Dactylis glomerata* (orchard grass)
**Daucus carota* (Green Anne's lace)
Erigeron annuus (annual fleebane)
Eupatorium seriotinum (late boneset)
**Glechoma hederacea* (creeping Charlie)
**Hordeum jubatum* (squirrel-tail grass)
Lactuca biennis (tall blue lettuce)
**Leonurus cardiaca* (motherwort)
**Lychnis alba* (white campion)
**Medicago lupulina* (black medick)
**Melilotus alba* (white sweet clover)
**Melilotus officinalis* (yellow sweet clover)
**Nepeta cataria* (catnip)
Oxalis stricta (common wood sorrel)
**Pastinaca sativa* (wild parsnip)
**Phleum pratense (timothy)*
Physalis subglabrata (tall ground cherry)
Plantago rugelii (red-stalked plantain)
**Poa pratensis* (Kentucky blue grass)
**Polygonum convolvulus* (black bindweed)
**Potentilla recta* (sulfur cinquefoil)

**Rumex crispus* (curly dock)
**Sisymbrium officinale* (hedge mustard)
**Solanum dulcamara* (bittersweet nightshade)
**Sonchus uliginosus* (smooth sow thistle)
**Stellaria media* (common chickweed)
**Taraxacum officinale* (common dandelion)
**Tragopogon pratensis* (common goat's beard)
**Trifolium repens* (white clover)
**Verbascum thapsus* (common mullein)
Veronica peregrina (purslane speedwell)

*Introduced.

(List compiled by Betz-Schulenberg July 16, 1974.)

APPENDIX II: FERMILAB PRAIRIE

Spring 1975

Allium cernuum (nodding wild onion) - common
Andropogon gerardii (big bluestem grass) - abundant
Andropogon scoparius (little bluestem grass) - rare
Aster novae-angliae (New England aster) - uncommon
Baptisia leucantha (white wild indigo) - common
Carex bicknellii (prairie sedge) - uncommon
Bromus kalmii (prairie brome) - uncommon
Coreopsis palmata (prairie coreopsis) - common
Coreopsis tripteris (tall coreopsis) - common
Desmodium canadense (showy tick-trefoil) - very common
Echinacea pallida (purple cornflower) - common
Erigeron strigosus (daisy fleabane) - uncommon
Eryngium yuccifolium (rattlesnake master) - common
Lespedeza capitata (prairie bush-clover) - common
Liatris spicata (marsh blazing star) - uncommon
Panicum virgatum (switch grass) - common
Parthenium integrifolium (wild quinine) - uncommon
Petalostomum candidum (white prairie clover) -uncommon
Petalostemum purpureum (purple prairie clover) - uncommon
Physostegia virginiana (flase dragonhead) - uncommon
Potentilla arguta (prairie cinquefoil) - rare
Ratibida pinnata (yellow coneflower) - common
Rudbeckia subtomentosa (sweet black-eyed Susan) - uncommon
Silphium integrifolium (rosin weed) - common
Silphium laciniatum (compass plant) - common
Silphium terebinthinaceum (prairie dock) - common
Solidago gymnospermoides (goldenrod) - uncommon
Sorghastrum nutans (Indian grass) - abundant
Sporobolus heterolepis (prairie dropseed) - rare

Spring 1976

Andropogon gerardii (big bluestem grass) - abundant
Asclepias incarnata (marsh milkweed) - common
Coreopsis tripteris (tall coreopsis) - common
Desmodium canadense (showy tick-trefoil) - common
Erigeron strigosus (daisy fleabane) - uncommon
Eryngium yuccifolium (rattlesnake master) - uncommon
Helianthus mollis (downy sunflower) - uncommon
Heliopsis helianthoides (flase sunflower) - uncommon
Lespedeza capitata (prairie bush-clover) - uncommon
Liatris spicata (marsh blazing star) - uncommon
Ratibida pinnata (yellow coneflower) - uncommon
Rudbeckia subtomentosa (shweet black-eyed Susan) - uncommon
Silphium laciniatum (compass plant) - uncommon
Sorghastrum nutans (Indian grass) - abundant
Teucrium canadense (germander) - common

Spring 1977

Andropogon gerardii (big bluestem grass) - abundant
Apocynum sibiricum (Indian hemp) - uncommon
Asciepias incarnata (marsh milkweed) - common
Helianthus grosseserratus(tall sunflower) - uncommon
Lycopus americanus (water horehound) - uncommon
Lythrum alatum (winged loosestrife) - uncommon
Panicum virgatum (switch grass) - uncommon
Ratibida pinnata (yellow coneflower) - uncommon
Silphium integrifolium (rosin weed) - uncommon
Silphium laciniatum (compass plant) - common
Silphium terebinthinaceum (prairie dock) - uncommon
Sorghastrum nutans (Indian grass) - abundant
Vernonia fasciculata (common ironweed) - rare

Autumn 1977

Andropogon gerardii (big bluestem grass) - abundant
Apocynum sibiricum (Indian hemp) - uncommon
Coreopsis tripteris (tall coreopsis) - common
Desmodium canadense (showy tick-trefoil) - common
Erigeron strigosus (daisy fleabane) - uncommon
Ratibida pinnata (yellow coneflower) - common
Silphium laciniatum (compass plant) - common
Silphium terebinthinaceum (prairie dock) - uncommon
Solidago rigida (prairie goldenrod) - uncommon
Sorghastrum nutans (Indian grass) - abundant

Autumn 1978

Andropogon gerardii (big bluestem grass) - abundant
Asclepias incarnata (marsh milkweed) - uncommon
Coreopsis tripteris (tall coreopsis) - uncommon
Desmodium canadense (showy tick-trefoil) - uncommon
Sorghastrum nutans (Indian grass) - abundant

APPENDIX III: PLANTS AT FERMILAB

Prairie and Prairie Marsh Plants

Agrostis hyemalis (tickle grass)
Alisma subcordatum (water plantain)
Allium cernuum (nodding wild onion)
Andropogon gerardii (big bluestem grass)
Andropogon scoparius (Little bluestem grass)
Apocynum sibiricum (Indian hemp)
Asclepias incarnata (swamp milkweed)
Asclepias sullivantii (prairie milkweed)
Asclepias tuberosa (butterfly weed)
Asclepias verticillata (whorled milkweed)
Aster laevis (smooth blueaster)
Aster novae-angliae (New England aster)
Aster simplex (panicled aster)
Baptisia leucantha (white wild indigo)
Bidens coronata (swamp marigold)
Bromus kalmii (prairie brome grass)
Calamagrostis canadensis (Blue-joint grass)
Carex annectans xanthocarpa (sedge)
Carex bicknellii (prairie sedge)
Carex cristatella (sedge)
Carex hystricina (bottlebrush sedge)
Carex lanuginosa (woolly sedge)
Carex lupuliformis (sedge)
Carex scoparia (sedge)
Carex stipata (sedge)
Carex tribuloides (sedge)
Carex vulpinoides (fox sedge)
Coreopsis palmata (prairie coreopsis)
Coreopsis tripteris (tall coreopsis)
Cypripedium candidum (white lady's slipper)
Desmodium canadense (showy tick-trefoil)
Dodecatheon meadia (shooting stars)
Echinacea pallida (purple coneflower)
Eleocharis compressa (flat-stemmed spike rush)
Eleocharis smallii (spike rush)
Elymuscanadensis (Canada wild rye)
Epilobium coloratum (cinnamon willow herb)
Equisetum hyemale (scouring rush)
Erigeron philadelphicus (marsh fleabane)
Erigeron strigosus (daisy fleabane)
Eryngium yuccifolium (rattlesnake master)
Eupatorium maculatum (spotted Joe Pye weed)
Filipendula rubra (Queen-of-the-prairies)
Fragaria virginiana (wild strawberry)
Galium boreale (Northern bedstraw)
Galium obtusum (wild madder)
Geum laciniatum trichocarpum (rough avens)
Glyceria striata (fowl meadow grass)
Gratiola neglecta (clammy hedge hyssop)

Helianthus grosseserratus (tall sunflower)
Helianthus mollis (downy sunflower)
Heliopsis helianthoides (false sunflower)
Hypoxis hirsuta (yellow star grass)
Juncus dudleyi (Dudley's rush)
Juncus torreyi (Torrey's rush)
Leersia oryzoides (rice cut grass)
Lemna minor (small duckweed)
Lespedeza capitata (prairie bush clover)
Liatris aspera (blazine star)
Liatris spicata (marsh blazing star)
Lilium michiganense (Turk's cap lily)
Lithospermum canescens (hoary puccoon)
Lobelia siphilitica (great blue lobelia)
Lobelia spicata (pale-spiked lobelia)
Lycopus americanus (water horehound)
Lysimachia ciliata (fringed loosestrife)
Lysimachia terrestris (swamp candles)
Lythrum alatum (winged loosestrife)
Mentha arvensis villosa (wild mint)
Mimulus ringens (monkey flower)
Monarda fistulosa (wild bergamot)
Panicum virgatum (switch grass)
Parthenium integrifolium (wild quinine)
Pedicularis canadensis (prairie betony)
Penthorum sedoides (ditch stonecrop)
Petalostemum candidum (white prairie clover)
Petalostemum purpureum (purple prairie clover)
Physostegia virginiana (false dragonhead)
Polygonum amphibium atipulaceum (water knotweed)
Polygonum coccineum (water heartsease)
Potentilla arguta (prairie cinquefoil)
Prenanthes racemosa (glaucous white lettuce)
Pycnanthemum virginianum (common mountain mint)
Ratibida pinnata (yellow coneflower)
Rorippa islandica fernaldiana (marsh cress)
Rosa carolina (wild rose)
Rudbeckia hirta (black-eyed Susan)
Rudbeckia subtomentosa (sweet black-eyed Susan)
Saxifraga pensylvanica (swamp saxifrage)
Senecio pauperculus balsamitae (balsam ragwort)
Scirpus atrovirens (dark-green rush)
Scirpus acutus (hard-stemmed bulrush)
Scirpus cyperinus (wool grass)
Scirpus fluviatilis (river bulrush)
Scirpus lineatus (red bulrush)
Scirpus vallidus (great bulrush)
Scutellaria lateriflora (mad-dog skullcap)
Silphium integrifolium (rosin weed)
Silphium laciniatum (compass plant)
Silphium terebinthinaceum (prairie dock)
Sisyrinchium albidum (blue-eyed grass)
Solidago gigantea leiophylla (late goldenrod)
Solidago gymnospermoides (goldenrod)

Solidago riddellii (Riddell's goldenrod)
Solidago rigida (prairie goldenrod)
Sorghastrum nutans (Indian grass)
Spartina pectinata (prairie cord grass)
Sphenopholis intermedia (slender wedge grass)
Spiraea alba (meadowsweet)
Sporobolus heterolepis (prairie drowseed grass)
Stachys palustris homotricha (woundwort)
Teucrium canadense (germander)
Thalictrum dasycarpum (purple meadow rue)
Thalictrum revolutum (waxy meadow rue)
Tradescantia ohiensis (common spiderwort)
Typha latifolia (common cat-tail)
Verbena hastata (blue vervain)
Vernonia fasciculata (common ironweed)
Veronicastrum virginicum (Culver's root)
Viola papilionacea (common blue violet)
Viola pedatifida (prairie violet)
Zizia aurea (golden Alexanders)

Other Species of Plants

Abutilon theophrasti (velvet leaf)
Acalypha rhomboidea (three-seeded mercury)
Acer negundo (box elder)
Acer saccharinum (silver maple)
Achillea millefolium (yarrow)
Acnida altissima (water hemp)
Agastache nepetoides (yellow giant hyssop)
Agrimonia grypsosepala (tall agrimony)
Agropyron repens (quack grass)
Agrostis alba (redtop grass)
Alliaria officinalis (garlic mustard)
Allium canadense (wild onion)
Allium tricoccum (wild leek)
Amaranthus retroflexus (rough amaranth)
Ambrosia artemisiifolia elatior (common ragweed)
Ambrosia trifida (giant ragweed)
Amphicarpa bracteata (hog peanut)
Arctium minus (common burdock)
Asclepias syriaca (common milkweed)
Aster lateriflorus (side-flowering aster)
Aster pilosus (hairy aster)
Aster sagittifolium drummondii (Drummond's aster)
Atriplex patula (common orach)
Barbarea vulgaris (yellow rocket)
Boehmeria cylindrica (false nettle)
Botrychium virginianum (rattlesnake fern)
Brassica kaber pinnatifida (charlock)
Brassica nigra (black mustard)
Bromus inermis (Hungarian brome)
Bromus japonicus (Japanese chess)
Capsella bursa-pastoris (shepherd's purse)

Carex hirtifolia (hairy sedge)
Carex laxiflora (wood sedge)
Carex rosea (sedge)
Carya cordiformis (bitternut hickory)
Celastrum scandens (climbing bittersweet)
Celtis occidentalis (hackberry)
Cerastium vulgatum (mouse-ear chickweed)
Chenopodium album (lamb's quarters)
Chichorium intybus (chicory)
Circae quadrisulcata canadensis (enchanter's nightshade)
Cirsium altissimum (tall thistle)
Cirsium arvense (pasture thistle)
Cirsium discolor (field thistle)
Cirsium vulgare (bull thistle)
Claytonia virginica (spring beauty)
Convolvulus arvensis (field bindweed)
Convolvulus sepium (heldge bindweed)
Cornus oblique (blue-fruited dogwood)
Cornus racemosa (gray dogwood)
Cornilla varia (crown vetch)
Corylus americana (American hazelnut)
Crataegus sp. (hawthorn)
Cryptotaenia canadensis (nonewort)
Cyperus esculentus (chufa)
Dactylis glomerata (orchard grass)
Daucus carota (Queen Anne's lace)
Dentaria laciniata (toothwort)
Echinochloa crusgalli (barnyard grass)
Elaeagnus umbellata (oleaster)
Ellisia nyctelea (Aunt Lucy)
Equisetum arvense (horsetail)
Elymus villosus (silky wild rye)
Erigeron annus (annual fleabane)
Erigeron canadense (horseweed)
Erythronium albidum (white trout lily)
Eupatorium altissima (tall boneset)
Eupatorium rugosum (white snakeroot)
Eupatorium serotinum (late-flowering boneset)
Festuca elatior (meadow fescue)
Fraxinus americana (white ash)
Fraxinus americana f. iodocarpa (purple-fruited white ash)
Fraxinus pennsylvanica subintegerrima (green ash)
Galium aparine (annual bedstraw)
Galium triflorum (sweet-scented bedstraw)
Geranium maculatum (wild geranium)
Geum canadense (white avens)
Glechoma hederacea (ground ivy)
Hackelia virginiana (stickseed)
Hemerocallis fulva (orange day-lily)
Hieracium pratense (field hackweed)
Hordeum Jubatum (squirrel-tail grass)
Hydrophyllum virginianum (Virginia waterleaf)
Hypericum perforatum (common St. John's wort)
Impatiens capensis (orange touch-me-not)

Juglans nigra (black walnut)
Kochia scoparia (burning bush)
Lactuca biennis (tall blue lettuce)
Lactuca scariola (prickly lettuce)
Leonurus cardiaca (motherwort)
Lepedium campestre (field cress)
Lepedium densiflorum (small pepper-grass)
Llepedium virginicum (common peppergrass)
Lonicera tatarica (Tartarian honeysuckle)
Lychnis alba (white campion)
Lythrum salicaria (purpose loose-strife)
Medicago lupulina (black medick)
Medicago sativa (alfalfa)
Melilotus alba (white sweet clover)
Melilotus officinalis (yellow sweet clover)
Menispermum canadense (moonseed)
Morus alba (white mulberry)
Nepeta cataria (catnip)
Oenothera biennis (common evening primrose)
Osmorhiza claytonia (hairy sweet cicely)
Osmorhiza longistylis (smooth sweet cicely)
Oxalis europaea (tall wood sorrel)
Oxalis stricta (common wood sorrel)
Panicum capillare (old witch grass)
Parthenocissus quinquefolia (Virginian creeper)
Pastinaca sativa (wild parsnip)
Phlaris arundinacea (reed canary grass)
Phleum pratensis (timothy grass)
Physalis heterophylla (clammy ground-cherry)
Physalis subglabrata (tall ground-cherry)
Plantago major (common plantain)
Plantago rugelii (red-stalked plantain)
Poa compressa (Canada blue grass)
Poa pratensis (Kentucky blue grass)
Podophyllum peltatum (May apple)
Polygonatum canaliculatum (smooth Solomon's seal)
Polygonum convolvulus (black bindweed)
Polygonum erectum (erect knotweed)
Polygonum pensylvanicum laevigatum (Pennsylvania knotweed)
Polygonum persicaria (lady's thumb)
Populus deltoides (cottonwood)
Portulaca oleracea (purslane)
Potentilla norvegica (rough cinquefoil)
Potentilla recta (sulfur cinquefoil)
Prunella vulgaris lanceolata (self-heal)
Prunus americana (wild plum)
Prunus serotina (wild black cherry)
Prunus virginiana (choke cherry)
Pyrus communis (pear)
Pyrus malus (apple)
Quercua alba (white oak)
Quercus macrocarpa (bur oak)
Quercus rubra (red oak)
Ranunculus abortivus (small-flowered buttercup)

Ranunculus septentrionalis (swamp buttercup)
Rhus glabra (smooth sumac)
Rhus radicans (poison ivy)
Ribes americanum (wild black currant)
Ribes cynosbati (prickly wild gooseberry)
Ribes missouriense (wild gooseberry)
Rosa multiflora (multiflora rose)
Rubus allegheniensis (common blackberry)
Rubus occidentalis (black raspberry)
Rudbeckia triloba (brown-eyed Susan)
Rumex crispus (culy dock)
Salix amygdaloides (peach-leaved willow)
Salix discolor (pussy willow)
Salix glaucophylloides glaucophylla (blue-leaved willow)
Salix interior (sandbar willow)
Sambucus canadensis (elderberry)
Sanicula gregaria (clustered black snakeroot)
Scrophularia marilandica (late figwort)
Setaria glauca (yellow foxtail)
Silphium perforiatum (cup plant)
Sisymbrium altissimum (tumple mustard)
Smilacina racemosa (feathery false Solomon's seal)
Smilax ecirrhata (upright carrion flower)
Smilax lasioneura (common carrion flower)
Solanum carolinense (horse nettle)
Solanum dulcamara (bittersweet nightshade)
Solidage altissima (tall goldenrod)
Sonchus uliginosus (smooth sow thistle)
Stellaria media (common chickweed)
Taraxacum offininale (common dandelion)
Thalaspi arvense (penny cress)
Tilia americana (basswood)
Tovara virginiana (woodland knotweed)
Tragopogon pratensis (common goat's beard)
Trifolium hybridum (alskike clover)
Trifolium pratense (red clover)
Trifolium repens (white clover)
Trillium recurvatum (red trillium)
Ulmus americana (American elm)
Ulmus pumila (Siberian elm)
Verbascum blattaria (moth mullein)
Verbascum thapsus (common mullein)
Verbena urticifolia (white vervain)
Veronica peregrina (purslane speedweed)
Viburnum lentago (nannyberry)
Viola pensylvanica (smooth yellow violet)
Viola sororia (hairy wood violet)
Vitis riparia (riverbank grape)
Xanthoxylum americanum (prickly ash)

REFERENCES

Anderson, W.A., 1936, "Progress in the Regeneration of the Prairie at the Iowa Lakeside Laboratory," Iowa Academy of Science Proceedings 43: 87-93.

Betz, R.F., 1982, personal communication.

Betz, R.F., 1984, "Decade of Research," 9th North American Prairie Conference proceedings, Moorehead State University, Moorehead, Minnesota.

Blake, Agigail K., 1935, "Viability and Germination of Seeds and Early Life History of Prairie Plants," Ecological Monographs 5: 405-460.

Blewett, T.J., 1981, "An Ordination Study of Plant Spececies Ecology in the Arboretum Prairies," Ph.D. Thesis, University of Wisconsin-Madison.

Booth, W.E., 1941, "Regeneration of Abandoned Fields in Kansas and Oklahoma," American Journal of Botany 25: 415-422.

Christiansen, P.A., 1967, "Establishment of Prairie Species in Iowa by Seedlings and Transplanting," Ph.D. Thesis, Iowa State University of Science and Technology, Ames, Iowa.

Christiansen, P.A., and Landers, R.G., 1966, "Notes on Prairie Species in Iowa: I. Germination and Establishment of Several Species," Iowa Academy of Science Proceedings, 73: 51-59.

Christiansen, P.A. and Landers, R.G., 1969, "Notes on Prairie Species in Iowa: II. Establishment by Sod and Seedling Transplants," 76: 94-104.

Cornelius, Donald R., 1946, "Establishment of Some True Prairie Species"

Clements, Fredric E. and Weaver, J.E., 1924, "Experimental Vegetation," Carnegie Institute of Washington, Washington, D.C.

Cottam, Grant and Wilson, H. Cameron, 1966, "Germinating Dynamics on an Artificial Prairie," Ecology 47: 88-96.

Edmond, J.B., Musser, A.M., and Andrews, P.S., 1957, "Fundaments of Horticulture," McGraw-Hill Book Company, Inc., New York, New York.

Fermilab Prairie Project Newsletter, 1981, Fermi National Accelerator Laboratory, Vol. 1, No. 1-4.

Fermilab Facts, 1981, Fermi National Accelerator Laboratory.

Greene, H.C. and Curtis, S.T., 1950, "Germination Studies of Wisconsin Prairie Plants," American Midland Naturalist, 43: 186-194.

Greene, H.C. and Curtis, S.T., 1953, "The Reestablishment of Prairies in the University of Wisconsin Arboretum," Wildflower 29: 77-88.

Hadley, E.B. and Kreckhefer, B.J., 1963, Ecology 44: 389-395.

Harper, John L., 1965, "Establishment, Aggression, and Cohabitation in Weedy Species," H.G. Baker and C. Ledyard Stebbons, eds., Genetics of Colonizing Species, pp. 245-266, Academic Press, New York, New York.

Mayer, A.M. and Polyakoff-Mayber, A., 1963, "The Germination of Seeds," The Macmillan Company, New York, New York.

Peven, Robert, 1985, "Reclamation of Landfill Soils with Native Prairie Vegetation," University of Wisconsin-Madison, Masters Thesis.

Pearse, C. Kenneth, Plummer, A. Perry, and Savage, D.A., 1948, "Restoring the Range by Reseeding," I. Alfred Stefferad, ed., Gross, pp. 227-733, U.S. Government Printing Office.

Riegel, Andrew, 1944, "A Comparative Study of Natural and Artificial Revegetation of Land Retired from Cultivation at Hays, Kansas," Kansas Academy of Science Transactions 47: 195-214.

Shimek, B., 1925, "The Persistence of Prairie," University of Iowa Studies in Natural History 11, 5: 3-24.

Sperry, T.M., 1982, "Analysis of the University of Wisconsin-Madison Prairie Restoration Project," Proceedings of the Eighth North American Prairie Conference, pp. 140-147.

Steiger, T.L., 1930, "Structure of Prairie Vegetation," Ecology 11: 170-217.

Weaver, J.E., 1954, "A Seventeen Year Study of Plant Succession in Prairie," American Journal of Botany 41: 31-38.

Weaver, J.E., and Albertson, F.W., 1944, "Nature and Degree of Recovery of Grassland from the Great Drought of 1933 to 1940," Ecological Monographs 14: 343-379.

Weaver, J.E. and Parland, R.W., 1947, "A Method of Measuring Vigor of Range Grasses," Ecology 28: 146-162.

Weaver, J.E. and Mueller, Irene M., 1942, "Role of Seedlings in Recovery of Midwestern Ranges from Drought," Ecology 23: 275-294.