PRAIRIE RESTORATION: A TWENTY-FIVE YEAR PERSPECTIVE ON ESTABLISHMENT AND MANAGEMENT

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Abstract. Conclusions drawn from twenty-five years of prairie restoration experience are reviewed. Fire management of various prairie habitats, need for more frequent burning, benefits of early spring burns, and effects of fire are discussed. Grass-forb competition, cold-damp seed conditioning, watering, and seed quality are also considered. Differential conditioning of grass and forbs is described and advocated. Mosaic planting procedure is described and evaluated. Weed control by germination and scratch-out of the top-most portion of the weed seed bank and its relationship to time of planting is reviewed. A scheme of developmental stages for prairie restoration is proposed with dominant species, descriptive attributes, competitive processes, and approximate duration of the various stages described and discussed. Forbs are grouped in overlapping assemblages of occurrence in this successional stage framework, with staying-power and quality indicated. Concern is voiced about the monocultural switch grass syndrome and the use of inappropriate prairie grass ecotypes in wildlife habitat plantings and roadside prairies. The importance of burning and proper seed mixes for roadside restorations is discussed with specific mixes suggested.

INTRODUCTION

Natural areas restoration is a realm of ecology destined to become the single most important environmental effort of the future. With the demise of tropical rain forests, the clear-cutting of ancient old growth forests of the Pacific northwest, and the continued cutting of oak-hickory stands in the Midwest for firewood and industrial pallets, to name a few examples, it is becoming increasingly clear that preservation efforts cannot begin to keep up with the destruction. Unfortunately, some of these habitats, once destroyed, cannot be restored in a single lifetime or even several lifetimes. Restoration ecology for many of these habitats is in its infancy.

This is not true for prairie restoration. We know quite a bit about this process. Unfortunately, with all the current interest in and efforts at restoration, what we know is not being used. Current literature is too vague and noncommittal about how to restore a prairie. On the one hand there are papers by scientists, whose cautious, experimental, and scholarly approach is little help in guiding the practical process of establishing a prairie planting. Then there are brochures by commercial companies selling prairies. Some are well done and quite informative; others are misleading or actually damaging. Additionally, some publications by public agencies are so general and noncommittal that they do not guide the new restorationist to a practical and realistic process that will result in the best prairie planting possible under the given circumstances.

Because of this, I decided to review and discuss what I have learned in more than 25 years of prairie restoration. It has been mainly a process of trial and error. The initial work was done on the Knox College Biological Field Station, located 20 miles east of Galesburg, Knox County, in west-central Illinois. After many years of experimental planting at the field station, I began commercial plantings at state parks and wildlife areas, federal refuges, public and private school grounds, and private projects of all kinds, including Conservation Reserve Program (CRP) plantings for farmers in Illinois, Iowa, and Indiana. I currently do about 25 prairie plantings a year. I am still learning and adjusting my restoration process as I begin new plantings, evaluate already established projects, and watch the oldest plantings on the Knox Field Station and elsewhere.

I do not "know it all" when it come to prairie restoration, but I have found it necessary to be somewhat dogmatic and outspoken to get key points across. New restorationists do not seem to learn from the mistakes of others. I guess it's human nature, but they love to go off on their own and make their own mistakes. But prairie restoration takes long enough to do using correct procedures; why extend the process by repeating past errors. My main goal has always been to find the most practical way to restore a true prairie. The process is not all that difficult if done properly. Some points emphasized here have been made in past publications (Schramm 1978) but need re-emphasizing. Others, such as the proposed successional stages of prairie restoration, are new and undoubtedly will be revised or added to in the future.

This paper applies primarily to the high rainfall regions of the tallgrass prairie. Some points may apply to restoration in the dryer Great Plains region, but I have had no restoration experience in those regions.

The models for restoration are the prairie remnants. I have looked at prairie remnants all over the Midwest. I have talked at length and gone into the field with some of the most knowledgeable prairie botanists to try to understand what constitutes a good, true prairie. This is elusive information. My most important mentors in this process have been Dr. Robert Betz of Northeastern Illinois University and Ray Schulenburg, formerly of the Morton Arboretum, both of whom gave me important insights into what constitutes true, quality prairie. Dr. Robert Livingston, formerly of the University of Massachusetts, introduced me to and helped me key out my first prairie grasses, and Aldo Leopold introduced me to my first prairie wildflowers when I was a young boy. So, to the new restorationist I say, much has gone on before, and I urge you to profit by the experience of others.

FIRE MANAGEMENT

One would think that by now, fire would be universally accepted and vigorously applied in all restoration and management efforts, but fire is still being used too conservatively. Many prairie preserves are not burned often enough or thoroughly enough or at the right time. Hill prairies and glade prairies are being lost to eastern redcedar (*Juniperus virginiana*) and other woody plant invasion through lack of coordinated, dedicated efforts to burn them at the right time.

These recommendations apply mostly to the high rainfall regions of the tallgrass prairie, where, in normal years, post-burn productivity is enhanced by adequate spring and summer rainfall.

When To Burn And The Effects of Fire

There is only one time to burn — early spring. There are usually several days to a week or more of ideal burning weather during March and one must be poised and ready. If you miss it, you can run into trouble getting the burn done later. Occasionally, these ideal conditions occur in February, but you need some sunny conditions, warming, and a moderate breeze to burn efficiently. We like to have all burning completed by mid-April.

Early spring burning leaves winter cover for wildlife. More important, it clears away accumulated litter and produces black ash, which in combination with sunlight warms the soil and stimulates early prairie plant growth at a time of maximum moisture. In effect, this lengthens the growing season for warm-season prairie plants. Litter removal appears to be the primary factor in beneficial response of prairie to burning (Anderson 1982; Knapp and Seastedt 1986).

A common misconception is that the primary advantage of burning is killing or suppressing non-prairie species, thereby releasing the prairie species from competition. There is some suppression, but the main effect of a properly timed fire, is to stimulate the prairie species which then outcompete the non-prairie species. This misconception about fire suppression of non-prairie species has led people to burn later in the spring or in early summer, believing they are killing cool-season, non-native forbs and grasses when, in reality, they are stressing the warm-season natives that are just entering peak growth. Fall burns, after the prairie has gone dormant, do not suppress the prairie but do lack the advantage of the sudden ground-warming effect that a spring burn produces because ash from a fall burn is washed away by winter precipitation.

That ash provides a nutrient boost is an older idea that has been very hard to demonstrate (Old 1969). The role of fire in mineral cycling and increasing or decreasing available nitrogen(N) is still not clear. Old (1969) reports higher N levels in plants from burned areas while Seastedt and Remundo (1990) conclude that frequent burning creates conditions for severe N limitation to plant productivity. Recent reviews (Collins and Wallace 1990) emphasize that there is still much to learn about the effects of burning, but one thing is obvious—prairies in high rainfall areas, restorations and remnants included, greatly improve with regular burning.

Frequency of Burning

Remnants.

How frequently the original prairies burned does not have much bearing on determining frequencies for management. Most remnants have been neglected or abused by grazing, haying, and other disturbances and currently need regular burning to regain their original quality. For a typical remnant, half the area should be burned each year, providing unburned, survival refugia for possible endemic insect life history stages. Lack of knowledge about prairie insects calls for this conservative approach. After a decade, if recovery and improvements are evident, an every three-to-four year burn for each half of the remnant can be scheduled. Other studies have concluded that a three-year burning interval was necessary to maintain grass dominance and the species diversity typical of native prairie (Kucera and Koelling 1964; Kucera 1970).

Restorations.

Restorations are a different matter entirely. Prairie restoration is, plainly and simply, a process of manipulating perennial, herbaceous plant succession. All restorations, during the first decade or so, need burning every year to speed up establishment and seral progression of prairie plant succession. There is no need to worry about the survival of endemic insects because, in most instances, they are not present yet (Selser and Schramm 1992). The idea, circulated some years ago, that one should not burn the first spring after planting, is incorrect. Restorations develop and improve more quickly if burned every year for at least five years, including the spring after the first year's growth. The one exception is on steep slopes where severe erosion may have exposed the new root systems and fire could damage the vulnerable meristem of these hemicryptophytes.

The first year or two, it is sometimes difficult to get a good burn. Annual weeds, such as foxtail (*Setartia* sp.), and old witch grass (*Panicum capillare*), are usually present and may aid in providing fuel for these all-important first burns. With regard to long-term, continuous burning, the best prairie plots on the Knox College field station are those that have been burned every year for over two decades. As with the remnants, after a restoration is well-established and progressing nicely, alternate year burns on one half of the area would be prudent with the hope of encouraging insect endemics. In any event, after the first two decades, portions of a restoration should be burned at least once every three to four years to encourage progression to a climax equilibrium.

Burning of Special Kinds of Prairies

Hill and glade prairies.

The loess and limestone hill prairies of the Midwest and the glade prairies of the Ozarks are in serious trouble from lack of burning. The problem is that most of these sites have been severely overgrazed, allowing invasion of prickly woody plants, such as eastern redcedar, that are avoided by livestock. Eastern redcedar is the single, most serious threat to these xeric prairie remnants, but burning can solve the problem. Fortunately, eastern redcedar is very fire-sensitive. Seedlings are usually killed outright by one or more burns. Even larger trees can crown-out from a ground fire and be killed. Burning hill prairies and glades is not easy, but it is essential.

Sand prairies.

We are just learning about the effects of burning sand prairies. My personal observations Big River State Forest in Henderson County in west-central Illinois indicate a rapid improvement in the vigor of the prairie species—dominant grasses little bluestem (*Andropogon scoparius*) and June grass (*Koeleria cristata*) and a number of sand prairie forbs. The rare sand forb, giant penstemon, (*Penstemon grandiflorus*) is thriving and increasing with the new fire management program. Furthermore, there was a definite suppression of the prickly-pear cactus (*Opuntia rafinesquii*), a grazing-disturbance, successional species that dislikes fire. Where cactus is well established, it will take several burns to really knock it out.

Savannas.

There is current great interest in savanna ecology, preservation, and management (see this proceedings). It is fire that created savannas the world over. All the true prairie plants and savanna-specific species appear to thrive under a rigorous burning regime. A word of caution—in savannas that have not been burned for some time, great care should be exercised to prevent the fire from burning up into the inner hollows of old burr oaks, white oaks, and hickories. In old trees, which may not have been subjected to fire for many years, such inner-core burning can weaken and topple them, thus, losing a key feature that makes a savanna.

Mowing and Grazing versus Burning

Some think mowing or grazing can substitute for burning. This is wishful thinking. Mowing and grazing are special kinds of disturbance that result in incomplete litter removal and, depending on when they occur, may suppress photosynthetic productivity. Betz (1989) found annual mowing of hay prairies completely suppressed the reproduction of Mead's milkweed (*Asclepias meadii*). Grazing by large ungulates was a naturally occurring process in climax, temperate grasslands that, because of migratory and nomadic movements, probably had only transient and localized effects on the vegetation. Grazing by native ungulates is now being studied at the Konsa Prairie in Kansas, and important new insight into this process should be forthcoming.

If you think you are in a situation where you cannot burn, do something to reverse the situation or don't get involved in prairie. If you try prairie without fire, you'll have poor results and a negative impact on the prairie movement.

GRASS-FORB COMPETITION

Perhaps the most important insight gained in over two decades of prairie restoration is in regard to grass-forb competition. In the early years, we worried about the non-prairie weeds out-competing the prairie (see Control of Non-native Weed Competition below), but we soon learned that, by the vigorous and regular use of fire, the prairie would eventually win over the weeds. The more serious problem was the prairie competing with the prairie. Ultimately, competition between grasses and forbs determined the nature of the stand, and this, in turn, was determined by what went into the ground the initial day of the planting. To phrase this another way, "What you plant is what you get!". So we began to work on solutions for this grass-forb competition and came up with mosaic planting and differential seed conditioning.

MOSAIC PLANTING

The Case For

Mosaic planting is the simplest and most reliable way to prevent tall grasses from overpowering forbs in later stages of prairie plant succession. It involves inserting one or more forb plantings into a general prairie planting. This procedure has been so successful, I almost always use it. Also, I feel this more closely approaches the original prairie. Tallgrass prairie was not a uniform stand. To the contrary, the remnants that are our models are all different. Some are grass dominated; others are forb dominated; still others consist of mixed patches of forbs and grasses, in various combinations throughout the remnant. A restoration should try to duplicate this mosaic. With few exceptions and regardless of the intended use of the stand, a diverse mosaic provides the best habitat. One of the underlying principles of modern Ecology is that diversity is associated with the stability of many healthy, natural ecosystems. Wildlife managers have long recognized that wildlife of all kinds are drawn to and thrive in a diverse mosaic of habitat types. This diversity is part of the esthetic beauty of a quality prairie. Mosaic planting is a step in the direction of trying to duplicate what we observe in nature.

The Procedure

In mosaic planting, one or more areas of the planting are loaded with a forb mix while reducing tall grasses to only a pound per acre rate or less. Because they develop slowly and present no competitive threat to the forbs, little bluestem and prairie dropseed (*Sporobolus heterolepis*) can be used quite liberally in such mixes. These forb-dense sections can be placed in sites that I call viewing areas — in the foreground, near a trail, or next to a road. In background areas, the taller grasses can be increased to four to eight pounds, still including many forbs in the mix. In another area, a dense planting of ten to fourteen pounds of tall grasses per acre can be applied with some of the more competitive forbs still included. The final result, if done properly, is a diverse prairie landscape that is pleasing to the eye and is suited to a wide variety of uses. This approach can be used on areas of all sizes. I use a specially modified Nisbet rangeland grass drill on all sites, even those less than one acre, and by drilling round and round over the selected portions of the site, I can achieve the desired mosaic placement of the various mixes.

The process is not an exact science; no two mosaic plantings are alike. Wilson (1970) pointed out that planting with a Nisbet drill is an art. Mosaic planting is, likewise, somewhat of an art form, with the drill being the brush, the seed mixes the paint, and the operator the artist. With some experience, the operator can arrive at a site and quickly determine where the best viewing areas for forbs will be and where the denser grass stands should be placed. The result, though variable from site to site, is an acceptable facsimile of what we believe the original prairie was like.

SEED CONDITIONING

Cold-damp conditioning, or stratification, has long been recognized as necessary for breaking dormancy of dry seed and assuring prompt germination (Schramm 1978), which is critical for quick establishment. All prairie forbs, except legumes, can profit from cold-damp treatment. The smaller the seed, the shorter the time required. Tiny seeds of spring-blooming species, such as shooting stars (*Dodecatheon meadia*), alum root (*Heuchera richardsonii*), and pale-spiked lobelia (*Lobelia spicata*), need only one to two weeks. A few of the softer, larger seeds such as the milkweeds (butterfly weed *Asclepias tuberosa* and the various green milkweed species), likewise require only two to three weeks of cold-damp to germinated freely. But most of the prairie forbs successfully used in current restoration, such as the silphiums, coneflowers, blazing stars, and rattlesnake master, need six to eight weeks of cold-damp to germinate promptly. A few toughies with hard seed coats or perhaps more complex conditioning chemistry need longer periods to break dormancy. I have found that the hard, grey, rock-like seeds of spiderwort (*Tradescantia ohiensis*) need four to six months of cold-damp. New Jersey Tea (*Ceanothus americanus*) was found to give maximum germination (70%) only after boiling water treatment of one to two minutes followed by six months cold-damp conditioning (Schramm and Johnson 1981). Legumes germinate readily without cold-damp treatment if they are lightly scarified by scratching in a sandpaper box, moistened, and inoculated with the appropriate *Rhizobium* bacterium.

Moisture and Temperature

Some restorationists treat their seed with cold only, but for really quick germination, the seeds must be moistened, but only slightly! It takes very little dampening to achieve complete conditioning. Do not get the seed wet. This makes it difficult to handle later. One part water, by volume, to fifty parts seed is adequate. Do not add other substances such as sand or vermiculite. They are unnecessary and will foul up your planting devices. For small amounts of the tiniest seeds, a little potting soil may be added, but most prairie seed has enough chaff to hold the moisture needed for conditioning. The ideal temperature for conditioning is just above freezing, one to two degrees C.

DIFFERENTIAL CONDITIONING

In recent years, I have used a differential seed conditioning to help counteract the problem of prairie grasses out-competing forbs. In addition to reducing rates of grass seeding, I leave the grass somewhat more dormant than the forbs. This is accomplished by cold-damp conditioning the forbs (legumes excepted) while leaving the grasses dry. Then, when these two groups are mixed together and planted, given adequate moisture in the soil, the forbs will germinated almost immediately while the grasses will delay from one to three weeks. In mixed plantings, this gives the forbs an advantage over the grasses at this initial stage of establishment. The grass seed is open-air dried on the floor of an enclosed building for four to five weeks, then bagged in plastic bags to retain some moisture, and stored in cool or cold (either works well) conditions. The resultant seed will store well without molding, has some degree of dormancy, but will germinate more rapidly than grass seed that has been dried completely and stored in the open mesh bags used by most commercial producers.

MOISTURE FOR GERMINATION

Recent experience has shown that extra precipitation or watering can greatly enhance initial germination and seedling establishment. Experiments with extra watering, even in normal rainfall years, on newly planted prairie gardens and other small plots with available irrigation have resulted in quick establishment and increased growth. No matter how wet the year, if you can water thoroughly right after planting, by all means, do so. After that initial heavy soaking, water once a week for several weeks for really good establishment, especially of the forbs.

QUALITY OF SEED

It is imperative to use the best seed you can find. A few seeds sown in flats, watered, and germinated after proper conditioning can tell you much about the future success of your planting. Jim Wilson (1970) discussed this at the first prairie conference. He pointed out that even though it germinates, live seed from a batch with low percentage germination is weak seed, and we have found this to be very much the case. Whether you harvest your own grass or buy from a supplier, take an individual seed, pinch it gently at the base with the nails of the thumb and forefinger, and squeeze the kernel out of the glume and lemma. If it is fat and filled out, you've probably got a good product that will result in good stand establishment. The same holds true for forb seed. Get a magnifying glass or dissecting scope and spend some time studying your seed. It is worth the effort.

CONTROL OF NON-NATIVE WEED COMPETITION

Non-native weed competition remains the most unpredictable variable in restoration planting. Much has been written about this (Schramm 1970 and 1978, Wilson 1970). Earlier in this paper, I made the statement that "What you plant is what you get," but the final product is also influenced by the amount of annual weed competition at the very beginning of the restoration. Some prairie species can compete at this early succession stage, and others cannot. So control weeds as much as possible before the actual planting. Many projects are not as good as they might be because of poor planning and timing of site preparation—working the ground and getting those annual weed seeds of the shallow, surface seed bank germinated and scratched out.

Site Preparation Is The Key

Perennial root situations.

If there is perennial vegetation present (pasture sod, hay fields, lawns, etc.), the site should be plowed or tilled in the fall so that frost can kill any perennial grass or forb roots during the winter. If the site is fallow from previous farming and has only annual weeds present, ground preparation can wait until the following spring.

Spring site preparation without chemicals.

Before planting, disc and harrow the site as early as the ground can be worked. Harrowing (or other final leveling) is essential for smooth, even ground. Then, in future years, one can walk in the plot without stumbling on rough ground. After the ground is harrowed smooth, wait two or more weeks until some weeds have come up. Then use a harrow, harrowgator, cultimulcher, or similar implement to scratch out the germinating weeds. Do this two or more times during April, May, and into June, if necessary, so several generations of weed seeds can germinate. Of course, it is impossible to eliminate all weeds, but this repeated shallow working will reduce much of the potential weed competition. The key point is to work just the surface of the soil. If the site is deeply worked by rototilling or deep discing, the procedure is defeated by bringing up more weed seeds from the deeper part of the seed bank. You are at the mercy of not only the equipment operator but also the weather.

Spring site preparation using Round-up.

Another alternative is chemical treatment. Two or more weeks after the site is disced and harrowed to a smooth surface, the emerging weed seedlings are treated with Round-up, a non-residual, short-term, broad-spectrum herbicide. This herbicide, available from elevators and farm supplies stores, is sprayed on actively growing weeds at the 2 to 5 inch stage, using a 1.0% to 1.5% solution on annuals and a 2.0% solution for perennials. Two or, ideally, three treatments are desirable, depending on the weed problem. After Round-up treatment, do not rework the ground; this will only bring up more weed seeds. Six or more days after the last Round-up treatment, the prairie can be planted into the firm, weed-free seed bed. A good prairie seed drill can cut the seed in without any more tilling. In some projects excellent results have been obtained by combining one or more mechanical scratch-outs with a final Round-up treatment.

All site preparation calls for planning, proper timing, proper equipment, and, most of all, the operator's commitment to follow the plan. One can still get prairie establishment without doing the site preparation perfectly, but many prairie projects could be greatly improved by commitment to this part of the process.

The problem of fall plantings.

By now, it is obvious that late spring or early summer is the best planting time because it allows one to get control of annual weeds. Conversely, a fall planting presents numerous problems in this regard. First, prairie seed will be dormant over winter, during which time animals will consume some of that precious and expensive seed. In addition, the cool-season weeds have not only the fall, but the long, cool spring to germinate. Warm-season prairie seeds need damp, hot soil to germinate, and by the time such conditions occur in late May, the annual weeds have a big advantage. Prairie restoration is a plant successional race with many participants competing for the lead. Don't let the annual weeds get that lead.

DEVELOPMENTAL STAGES OF RESTORATION SUCCESSION

A thorough understanding of plant succession is important to successful prairie restoration. With the earlier restorations now in

Table 1. A proposed scheme for developmental stages in prairie restoration.

Stage #	*Plant name*	*Descriptive name*	*Years*
I	***Rudbeckia* stage** (blackeyed susans)	**Initial downgrow, weedy stage**	**1-3**
II	***Ratibida-Heliopsis* stage** (yellow cone flower, false sunflower, rosenweed)	**Intense competitive, stand establishment stage**	**2-5**
III	***Eryngium-Silphium* stage** (rattlesnake master, compass plant, prairie clover, prairie dock)	**Closeout stage**	**6-12**
IV	***Amorpha-Sporobolus* stage** (lead plant, dropseed, culver's root)	**Longterm Adjustment stage**	**13-20+**

Table 2. Developmental stage amplitude of prairie plant species

SP=Staying Power SP+=Staying Power Plus CS=Competition Sensitive A=Aggressive

	Stage I Stage II Stage III Stage IV
Composites	
Blk-Eyed Susan (*Rudbeckia hirta*)	----------->
Yellow Cone Flower (*Ratibida pinnata*)	-------------->
False Sunflower (*Heliopsis helianthoides*)	----------------->
RosinWeed (*Silphium integrifolium*)	---------------->
Compass Plant (*Silphium laciniatum*)	----------------->SP+
Prairie Dock (*Silphium terebinthinaceum*)	----------------------->SP
Cup Plant (*Silphium perfoliatum*)	------------Wet Mesic----------->
Stiff Goldenrod (*Solidago rigida*)	----------------------->SP
Showy Goldenrod (*Solidago speciosa*)	----------------------->
Old Field Goldenrod (*Solidago nemoralis*)	------------------------>SP+
Rough White Lettuce (*Prenanthes aspera*)	----Dry Mesic------>
Smooth White Lettuce (*Prenanthes racemosa*)	----Wet Mesic------>
New England Aster (*Aster novae-angliae*)	---------Wet Mesic-------->
Prairie Blazing Star (*Liatris pycnostacya*)	------------------------>CS
Rough Blazing Star (*Liatris aspera*)	----------------------->
Pale Purple Cone Flower (*Echinacea pallida*)	------------------------------>
Purple Cone Flower (*Echinacea purpurea*)	-----------Savanna------->
Wild Quinine (*Parthenium integrifolium*)	------------------>
Prairie Coreopsis (*Coreopsis palmata*)	---------------->
Heath Aster (*Aster ericoides*)	----------------------->
Sky-blue Aster (*Aster azureus*)	-------------------->
Smooth Aster (*Aster laevis*)	-------------------->
Grasses	
Switch Grass (*Panicum virgatum*)	------------------------------------->A+
Big Bluestem (*Andropogon gerardii*)	----------------------------->A
Indian Grass (*Sorghastrum nutans*)	------------------------------->SP
Little Bluestem (*Andropogon scoparius*)	------------>SP
Prairie Dropseed (*Sporobolus heterolepis*)	------------>SP
Legumes	
Showy Tick Trefoil(*Desmodium canadense*)	---------------------------------->SP
Illinois Tick Trefoil (*Desmodium illinoense*)	----------------------->SP
Round-headed Bush Clover (*Lespedeza capitata*)	--------Dry to Wet Mesic----->SP
Purple Prairie Clover (*Petalostemum purpureum*)	----Dry Mesic----->SP
White Prairie Clover (*Petalostemum candidum*)	----------Mesic------->SP
White False Indigo (*Baptisia leucantha*)	---------------------->SP
Cream False Indigo (*Baptisia leucophaea*)	----------->CS
Lead Plant (*Amorpha canescens*)	----------->CS
Umbels	
Rattlesnake Master (*Eryngium yuccifolium*)	-------------------->SP+
Golden Alexanders (*Zizia aurea*)	-------Wet Mesic------>
Mints	
Mountain Mint (*Pycnanthemum virginianum*)	----------------------->
Wild Bergamot (*Monarda fistulosa*)	--------------------------->
Others	
Culvers Root (*Veronicastrum virginicum*)	---------------->SP+
New Jersey Tea (*Ceanothus americanus*)	------------------->
Prairie Cinquefoil (*Potentilla arguta*)	------------------>
Spiderwort (*Tradescantia ohiensis*)	------------------->SP+
Yellow Gentian (*Gentiana flavida*)	------------------>SP
Bottle Gentian (*Gentiana andrewsii*)	---------Wet Mesic------->
Prairie Gentian (*Gentiana puberula*)	-------->
Penstemon (*Penstemon digitalis*)	----------------------->
Butterfly Weed (*Asclepias tuberosa*)	----------------->CS

Nomenclature after Jones, 1971

their third and in some cases forth decade, we are in a better position to understand and describe successional stages of this process. Based on two decades of observations at the Knox College field station and various other restorations in Illinois and Iowa, I propose the following successional stages in prairie establishment. It is not in final form or complete by any means, but is offered as an initial format to be developed and added to as additional years of observations increase our insights into prairie community developmental processes.

I have divided the succession process into stages that are identified by a stage number, a plant-(or plants) stage name, and a descriptive name (Table 1). An approximate number of years covered by the stage is also proposed. This time element is the most variable part of the proposal and differs depending on weed competition and the nature of the restoration. A more detailed scheme (Table 2) presents most of the prairie species I have worked with, showing where they fit into this successional progression. The dotted, amplitude arrows indicate where in the progression, each species becomes an obvious part of the community. The term staying-power, introduced here, is a useful characteristic denoting the ability of a species to persist and even to increase as the community develops and matures. The ability of a prairie species to persist and eventually spread depends on whether that species is in the optimum part of its ecological amplitude as expressed both by habitat and associated species. It also depends on the seed dispersal mechanism of the species. Our understanding of these associations and characteristics, is still in its infancy.

Discussion Of The Stages

Stage I.

Stage I, the *Rudbeckia* Stage, or the **Initial Downgrow Weedy Stage,** lasts two to three years after planting and is characterized by the dominance of prairie annuals, such as black-eyed susans (*Rudbeckia hirta*); the non-native annual weeds, such as foxtail grass (*Setaria sp.*), old witch grass(*Panicum capillare*), velvet leaf (*Abutilon theophrasti*), lamb's quarter (*Chenopodium album*), pigweed (*Amaranthus sp.*), and the native ragweed species (*Ambrosia sp.*). Because new prairie plantings look so messy and un-prairie like, this stage gives a bad impression to the uninitiated. This is the time when the prairie species are "growing down" rather than up (Wilson 1970). Three to four weeks after germinating, a prairie grass species such as big bluestem (*Andropogon gerardii*) and a prairie forb such as compass plant (*Silphium laciniatum*) may be only one to two inches tall, but the roots will have grown more than a foot into the soil. At the end of the first growing season, prairie species may still have only six inch, wispy tops buried in the foxtail and difficult to even find, but the roots will be well established, two or more feet deep. This is when the new restorationist must apply those two necessary ingredients, patience and fire, if the project is to succeed. Just how much the annual weeds dominate this first stage is extremely variable and unpredictable (Schramm 1978). It depends on how much weed seed was in the surface seed bank and how successful weed control procedures were (see Weed Control above).

Stage II.

Stage II, the *Ratibida-Heliopsis* Stage, is named after yellow cone flower (*Ratibida pinnata*) and oxeye, or false sunflower (*Heliopsis helianthoides*), two prairie species typical of this second stage of development. Other species prominent during this stage are rosenweed (*Silphium integrifolium*) and others listed in Table 2. This is also the **Intense Competitive, Stand Establishment Stage,** referring to the intense, competitive processes that are going on among the prairie species themselves as they vie for space and resources during this phase of community development. This is the first really colorful stage, with the dominant, yellow-flowered species making an impressive and pleasing display. This stage begins in the second or third year and may last three to four years or longer as the prairie matrix (Betz 1986) becomes evident (see discussion below). The larger grasses also become prominent, and it is apparent if too much grass has been used or if the grass seeding rate has been properly balanced against the forb seeding rate. Species with staying-power are not yet dominant but show here and there; the competitive processes that will determine the final nature of the stand are well under way. Most annual weeds are gone. Velvet leaf disappears the second year. Annual fleabane (*Erigeron annus*) disappears the fourth or fifth year. More persistent, perennial, non-prairie weeds, such as tall goldenrod (*Solidago altissima*), are still present and seem to be holding their own. Annuals, such as little ragweed (*Ambrosia artemisiifolia*), are, by now, reduced to miniature stature — still growing but like bonsai plants tucked into the prairie matrix. The colorful prairie annual, black-eyed susan is still re-seeding itself but has moved to the edge of the stand.

Stage III.

Stage III, the *Eryngium-Silphium* stage, is named after rattlesnake master (*Eryngium yuccifolium*), compass plant (*Silphium laciniatum*), and prairie dock (*Silphium terebinthinacium*), which now begin to flower for the first time. Purple and white prairie clovers (*Petalostemum purpureum* and *P. candidum*) are also evident and flower regularly. In this **Closeout Stage**, most of the annual weeds have been eliminated (the ragweeds are gone and the perennial tall goldenrod clones are being suppressed) and the dominant prairie forbs of Stage II are being pushed to the edge of the stand. This movement-to-the-edge phenomenon is not entirely new—in Stage II we saw the movement of black-eyed susans to the edge as the perennial species increased their toehold. Stage III persists six to twelve years or longer, during which time the stand may be evaluated with regard to what species have been successfully established and what can be expected in the future. At this point, the staying-power forbs, such as spiderwort (*Tradescantia ohiensis*), Culver's Root (*Veronicastrum virginicum*), rattlesnake master, the climax silphiums (compass plant and prairie dock), prairie cinquefoil (*Potentilla arguta*), sky-blue aster (*Aster azureus*), and others, are really coming into their own.

Stage IV.

Stage IV is the final stage described in this proposal but is probably not the final stage of this process. This is the **Long-term Adjustment Stage,** or the *Amorpha-Sporobolus* Stage, named after lead plant (*Amorpha canescens*) and prairie dropseed (*Sporobolus heterolepis*), which finally begin to flower and make a real showing, if present. This stage, in older restorations, reveals much regarding staying-power of various species. In the center of the stand, closeout of the more successional prairie species has been completed and long-term adjustment has begun among the remaining, more mature, climax community species. The time frame proposed is thirteen to twenty or more years. Thirty, forty, or more years are possible. The limits, if any, on this stage will be determined by future observations.

Discussion

Betz (1986) has presented valuable insight into and a detailed description of plant succession during the first decade of a prairie planting at the Fermilab in Batavia, Illinois. In this discussion, he introduced the concept of the prairie matrix, an assemblage of more aggressive, competition-tolerant prairie species that, with regular burning, establish early and constitute the primary competitive force that suppresses and eventually eliminates the non-prairie weed species. In my scheme, Betz's matrix is well-established by the end of Stage II and has closed out the non-prairie weeds by the end of Stage III. Betz suggested that later, more competition-sensitive prairie species may be added to this matrix assemblage. I agree, although in some of our restorations, competition-sensitive species survived being planted at the outset and eventually came into their own in Stage IV.

One of the curious occurrences observed in many restorations is that each year, even into the second decade (or well into Stage III), new species appear. These species were in the original seed mix but did not appear until years after the initial planting. Betz (1986) observed this, and we have seen it a number of times. We do not know whether the seeds lay dormant for a number of years or germinate but remain inconspicuous, buried in the vigorous growth of the more aggressive, successional species. I suspect the latter is, generally, the case. Our work with conditioning and germination suggests that even the hardest seeds, such as the legumes and spiderwort would germinate by the third year.

Sperry (1983) gave additional insight into the late stages of prairie restoration in his analysis of the oldest restored prairie in the eastern tallgrass region, started in the 1930s at the University of Wisconsin Arboretum in Madison (the Knox College project is the second oldest restoration, started in 1955). Many of the forbs that Sperry reported persisting in the Wisconsin restoration also persisted in the Knox College prairie and other restorations I have planted. These are the species I designated as having staying-power. Sperry reported that some quality species did not spread, or actually decreased, in the Wisconsin restoration. I do not know the exact burning history of that project, but I do know there have been several interims of infrequent fire that, I suspect, limited establishment and spread of some species.

My attempt to formalize successional stages in prairie restoration obviously has its limits of usefulness. Experienced restorationists may take issue with my choice of species used to characterize the stages. No two restorations are exactly alike. The time frame may be greatly protracted in some establishments because of local adverse conditions, or it may be greatly accelerated because of reduced weed competition, ideal moisture, particularly good seed, or a host of other reasons. Prairie restoration is still more of an art than a science and is at the mercy of many variables that we are still learning to control. But stages do exist, and this proposed scheme may facilitate talking about the processes and comparing observations. I hope this will help new restorationists understand and evaluate what is happening in their projects.

Mix Composition Decisions

It is hoped that the Successional Stages and associated plant lists will be useful in determining mix compositions for new restorations, but if seed is available and costs are not prohibitive, there is nothing wrong with including Stage III and IV species in the initial planting. Sometimes they do quite well for reasons we cannot explain. For most quality forbs, the more seed planted, the better the results. We still strongly advise against planting the really weedy species of sunflowers (*Helianthus mollis. H. grosseserratus,* etc.) because of their vegetative spreading and allelopathic properties (Schramm 1978).

THE ECOTYPE PROBLEM

At the first prairie conference, held at Knox College in 1968, no concern was voiced about the source of seeds for local restorations. We were all so caught up with the urge to restore, planting methods, limited seed availability, etc., that no one was really thinking about the genetics or purity of restoration. But two years later, at the Wisconsin prairie conference, Jerry Schwartzmeier voiced great concern over preservation of local gene pools. We can all thank Jerry for calling this to our attention; it was a timely warning that most of us took to heart. Biologists and other knowledgeable people from many of the disciplines and agencies interested in using prairie plantings responded immediately and in a positive way to this concern. It was well known that naturally selected ecotypes, or genetic variants adapted to local conditions, existed within species of prairie grasses and forbs. It made common sense to most of us to use local seed sources. First, if the prairie planting is to be a restoration, then we should try to restore what was there originally. Second, we should be concerned with the preservation of local gene pools as part of the vast genetic diversity of this once wide-spread plant community. And finally, natural selection has already determined that these local genotypes are the ones that are best suited to local conditions.

Thus, the purist approach was initiated. Judging from my contacts with hundreds of restorationists over the last two decades, more than 90% take this approach. To the vast majority, whether or not to use local strains is not even a debatable issue.

However, there are a few commercial suppliers of prairie seed that have done a great disservice to the movement, misleading newcomers and some state agencies by maintaining that its perfectly acceptable to use seed from distant regions. Their argument is, quite simply, that it is not practical to use local seed. They maintain there is not enough local ecotype seed available, or it is too expensive. In fact, they use large volumes, can buy wholesale more cheaply from western producers, and make more money in the resale of these inappropriate varieties. They also make being a purist sound like an extremist approach taken by only a few. Limited availability may have been a problem initially but not today. If done properly, it takes only three years for a stand of the larger grasses to be harvestable for commercial sale of seed. More than two decades of restoration with local ecotypes have amply proved the vigor and suitability of local genetic varieties.

The sad result of the non-purist approach is that considerable quantities of western varieties of big bluestem, Indian grass, switch grass, and little bluestem have been planted in the Midwest, particularly on interstate and local road right-of-ways. This has happened because several state departments of transportation have been misled or were simply not aware of the problem and the options available. State and federal agencies, such as departments of conservation, departments of natural resources and the Fish and Wildlife Service that have insisted on local ecotypes on state parks, state wildlife areas, and federal refuges are to be commended.

It is not too late to take a stand. I urge anyone involved in prairie establishment to use reasonably local seed. Grass seed varieties are the worst problem. Frequently, beginning restorationists are not aware that many of the named varieties or strains of big bluestem, Indian grass, little bluestem, and switch grass, which are readily available in large quantities from the big seed producers of Kansas, Nebraska and Missouri, were selected and developed by the Soil Conservation Service and originated in the southern Great Plains. Since they are proven, vigorous varieties, they do well in the Midwest, but they are quite different from strains that evolved here and, in the minds of many, are not appropriate for use here. Contrary to what some might have us believe, for natural ecosystems, we really cannot improve on local natural selection.

And how local is local? I am not an extremist about local limits. As I stated in an earlier paper (Schramm 1978), two hundred miles is a reasonable distance to work within, but east-west rainfall regimes are a better guideline. For instance, western Illinois seed would not be appropriate for western Iowa, but it would be for western Indiana. Undoubtedly, in the original, vast, contiguous tracts of prairie, seeds of many species were dispersed great distances by animal fur, feathers, and droppings and by wind. The tiny postage stamp remnant gene pools left today were once part of a more connected genetic system. Thus, the case can be made for mixing prairie clover seed from a remnant in Chicago with prairie clover seed from Springfield and planting them with local seeds in a new restoration in Peoria. By working within reasonable distance limits in similar climatic regimes, we can preserve local genes and also do some mixing to maintain or recreate the genetic variety that must have been present in the original prairie.

THE MONOCULTURAL SWITCH GRASS SYNDROME

There has been a disturbing development in some areas of the Midwest, particularly in Iowa and Missouri, where projects are proclaimed to be prairie projects but are primarily monocultural stands of switch grass (*Panicum virgatum*). Somehow, the idea that big bluestem and Indian grass are difficult or slow to establish has resulted in excessive use of switch grass. It is quick and easy, but a closed, monocultural community with no diversity is exactly what we were trying to get away from when we turned to the natives. These stands have none of the positive attributes of the original prairie and are not even reasonable prairie facsimiles. For wildlife managers who have had good success with switch grass as roosting cover, I have observed that pheasants and quail prefer mixed stands of big bluestem and Indian grass to switch grass for winter roosting cover.

ROADSIDE PRAIRIES

Planting prairies along roadsides is finally becoming accepted. Long before the commercial people even knew about prairie, prairie biologists had been saying that prairie vegetation is a natural for roadsides. Low maintenance, erosion control, wildlife cover, beauty, and permanence, all contribute to its suitability. Unfortunately, people newly involved in this transformation are making many of the same mistakes that other new restorationist have been making. This is not an area for experimentation. Weedy failures on public land, there for everyone to see, are the worst kind of public relations for prairie restoration. Plead with all those involved in roadside management: "If you are going to do a prairie, do it correctly!"

Burning On Roadsides

First, be prepared to burn. Like all restorations, roadside prairies must be burned if they are to succeed and flourish. Without burning, the result is a weedy mess that will not get better with time. Such abortive attempts not only give prairie a bad name, but are a waste of the taxpayers' dollars. To be sure, there are a few prairie stands, mostly grasses, that have been established on roadsides without fire, mainly on sites where the worst possible subsoil provided a low-nutrient medium where non-prairie plants cannot compete. In the absence of competition from non-prairie weeds, the prairie plants succeeded. But even these stands could have been much better and would have developed much more rapidly with the proper use of fire.

The concern for public safety and traffic control during the burn and smoky conditions is a valid one. However, traffic is slowed and diverted regularly for repairs on roadways, sometimes for extended periods. Roadside burns need only brief periods of traffic control. Appropriate legislation and public education may be needed to clarify liability matters and to set the scene for safe fire management. These have been worked out for road repairs, and the same can be done for burning.

Planting Mixes For Roadsides

As in all other aspects of roadside restorations, an approach should be taken that is sure to succeed. This means use species and seed in the planting mix that are sure to successfully establish in a reasonably short period of time. A new restorationist may see a native stand of little bluestem growing on a steep road bank out in the country and conclude that that is the species to use in a comparable site on a new freeway. The problem is that little bluestem is very slow to establish; much more so than, say Indian grass. That country road bank stand may have been there for fifty or more years. A better approach would be to use the taller, more easily established grasses as the basic mix with a liberal amount of little bluestem thrown in. In time, it will contribute substantially to the overall, long-term stabilization of the new road bank site.

Roadside mixes should contain substantial amounts of the large grasses—by this we mean big bluestem and Indian grass. We know these species, if done properly, will grow on almost any site. Indian grass particularly, is an ideal grass for roadsides. It is slightly more xeric adapted than big bluestem. It establishes and flowers just a little bit faster and is an excellent choice for road banks, even steep ones. An all-purpose, ideal grass mix, pure live seed, for roadsides contains 60% Indian grass, 25% big bluestem, 10% little bluestem, and 5% switch grass. Another good basic road mix is 40% Indian grass, 40% big bluestem, 15% little bluestem, 5% switch grass. Or the switch grass can be left out entirely with no harm done. If it is included, use very sparingly.

Forb mixes for roadsides, like the grasses, should include species known to do well, such as the dominant species of Stages II and III. The more competitive and staying-power forbs can be included in the grass mixes to increase diversity. Mosaic planting can be done in cloverleafs and rest areas to assure a showy flower display.

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