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THE ESTABLISHMENT OF PRAIRIE SPECIES ALONG ROADSIDES

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Interim Report

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TO: H. L. Michael, Director
Joint Highway Research Project

FROM: Philip L. Carpenter

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Attached is an Interim Report on the HPR Part II Study titled "Techniques to Increase Survival of New Highway Plantings". This Interim Report is the first one on the portion of the study concerned with plant establishment by seeding. The Report is titled "The Establishment of Prairie Species Along Roadsides".

The Report is submitted for review and acceptance as partial fulfillment of the objectives of the Study. A very limited number of copies of the report will be published using color photographs in some of the illustrations as they better illustrate the points being discussed. All published copies will not have such prints as their inclusion makes the copies very costly.

An additional Interim Report and the Final Report will be available very soon on this portion of the Study.

Respectfully submitted,

Philip L. Carpenter/HLM

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16. Abstract

Seedings were conducted to test: the effectiveness of presoaking as a germination accelerator; the potential of using legumes, warm season grasses and prairie species in seeding mixtures; and the effect of fertilization on establishment of seed mixtures. Mixtures containing Eragrostis curvula and Medicago sativa performed the best. Presoaking enhanced the germination of many species. Fertilization initially reduced germination percentages, but adequate fertility levels were very important later in vegetation persistence.

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Highlight Summary

A field study was conducted on a newly cut highway slope in Vermillion County, Indiana. The purpose of the study was to better understand the potential use of prairie vegetation as a method to reduce mowing, fertilization, and maintenance costs, as well as to achieve an aesthetically pleasing landscape.

Individual species and seeding mixtures were tested. Also the influence of cold soaking treatments of seeds was compared for prairie species and standard highway species.

Cold soaking of seeds improved early germination of seven prairie species and two highway grass species. Length of stratification significantly affected germination levels, with maximum germination for seven prairie species occurring after 8 to 16 weeks cold soaking.

Differences were seen in initial germination of three cold soaked test species containing legumes, rapid cover species, cool-season species, and warm-season species. One week after seeding, numbers of seedlings per square meter were greatest for the two test mixtures containing cool-season species predominantly and either a tall prairie grass, *Panicum virgatum*, or short prairie grasses, *Andropogon scoparius* and *Sporobolus heterolepis*. By the second and fourth week numbers of seedlings per square meter of these two test mixes were not significantly different from the current and proposed highway mixes. However, germination of the prairie species test mix was lower than the other four mixes after two and four weeks. Fertilizer application at the time of seeding was detrimental to early germination of all five seed mixtures, but in the

second year a significant increase in above ground biomass production was noted with the fertilizer addition.

In the second year after seeding, mixtures containing warm season grasses and legumes (especially *Medicago sativa*) performed the best. The current and proposed highway mixes had very little growth, especially on plots which were not fertilized. Prairie forbs contributed only slightly to cover. Overall *Eragrostis curvula*, and the legumes *Medicago sativa*, *Lespedeza stipulacea*, and *Lotus corniculatus* looked very promising at this location after the second year.

Introduction

Numerous studies have shown that seed mixtures result in more productive stands than cover produced from pure seeding of one species (Kulfinski, 1957). The varied growth requirements of species in seed mixes due to differences in root quantity, root position in the soil, periodicity of growth and environmental requirements may at least partially explain increased yields of seed mixtures. The particularly higher productivity of grass-legume mixtures has been generally assumed to be a consequence of the ability of legumes to fix nitrogen, which is the most limiting nutrient in soils along Indiana highways. Thus it has been recommended that nitrogen fixing species be included in seed mixtures (Carpenter and Hensley, 1977).

Rapidity of early stages of establishment of a seed mixture depends on the differential germination and seedling growth of individual species or varieties in the mixture (Henderlong, 1971). Germination in turn depends on such factors as genetic differences, seed size, pretreatment and environmental conditions after planting. Under similar conditions certain species such as Lolium spp. (ryegrass) inherently show more rapid germination and seedling growth than other species such as Festuca rubra (red fescue). A presoaking treatment of many cover species has been found to accelerate germination (Larson, 1978; Young et al, 1977; Hesse, 1973; Keller and Black, 1968; Chippindale, 1934). Environmental conditions will then determine the degree to which genetic and pretreatment effects will affect germination rates. Hydroseeding can insure at least initially favorable moisture particularly important for presoaked seed (Young et al, 1977).

In Indiana the rate of cover establishment on highway slopes is often not achieved before severe erosion sets in (Carpenter and Hensley, 1977). It was the purpose of this study to develop and test the critical early establishment capabilities of new seed mixtures compared to a currently used mixture and a mixture proposed by the Indiana State Highway Department. Of particular interest were seeding techniques and mixtures which would allow establishment on slopes where initial seedings have failed without costly reworking of the slope. Eleven legumes and 19 grasses were tested individually and/or in mixtures on a west facing slope in west central Indiana. The five seed mixtures were tested with and without fertilizer application. Effects of presoaking on the rapidity of germination were evaluated for 18 species.

CHAPTER I

Review of Literature

Roadside Establishment

Successful establishment and maintenance of suitable vegetation along highways depends upon the adaptability of plant species to often unfavorable soil, climate and biotic conditions. The establishment period is a very critical stage in the highway planting process, with a minimum of three years considered necessary by the American Association of State Highway Officials. During that time appropriate management and cultural practices must be undertaken so that at the end of the period, the plants will be in an acceptable, vigorous growing condition (Anderson, 1969). Along roadsides establishment is often complicated by harsh environmental conditions. These unfavorable environmental factors include: poor growing media; heavy water runoff from surfaced roadways and steep backslopes; and rapid, extreme soil temperature changes (McDill, 1952; Foote and Kill, 1968).

Prairie vegetation has shown a potential for coping with unfavorable environmental conditions found along roadsides. Prairie species once covered approximately a billion acres in North America and occupied about 15% of Indiana (Curtis, 1959; Lemon, 1968; Betz, 1976). While most of this acreage has been lost to agriculture and urbanization, the use of warm-season perennial prairie vegetation has recently gained popularity in several midwestern states for difficult roadside environments (Landers, 1972; Cull, 1976; Nuzzo, 1978; Cattani, 1979). Once established, prairie had a very low maintenance requirement, was very stable, and extremely resistant to weed invasion (Dolling and Landers, 1969;

Aikman, 1960; Weaver and Flory, 1934). Mowing requirements were shown to be less for prairie plantings than conventional grass plantings (Dolling and Landers, 1969). Prairie species were successfully established on infertile soils (Robocker and Miller, 1955; Landers and Kowalski, 1968; Schramm and Kalvin, 1978). The root system of prairie species has aided in controlling soil erosion by almost completely occupying the upper soil layers and growing to depths of three to five feet (Sperry, 1935; Weaver and Darland, 1949; Aikman, 1960; Foote and Kill, 1968). While slumping has occurred on steep slopes planted with *Poa pratensis* L. (Kentucky bluegrass), prairie vegetation has held soil in place on similar slopes (Aikman, 1960). In addition, prairie vegetation has been a refuge for birds and wildlife (Dolling and Landers, 1969; Nichols and Entice, 1976). The year-round diversity in plant heights, textures, and colors of this once abundant indigenous vegetation has both scenic and educational values to the driving public (Rock, 1975; Ode, 1972; Morrison, 1975).

Seed Presoaking as a Germination Accelerator

In establishing vegetation along roadsides, it is important that germination and initial growth occur as rapidly as possible. Rapid early seedling growth increases the chances of successful establishment because favorable environmental conditions can be selected at seeding time, and the seedling allowed to take advantage of them. Thus, the critical period of initial establishment can be completed as fast as possible.

One method of accelerating germination of prairie and other cover crop species was by presoaking. Methods investigated have included presoaking of seed with water alone as well as mixed with moist soil or sand. Preconditioning temperatures have varied. When low temperatures are applied to seed in the imbibed state the process is called stratification (Roberts, 1972).

Several studies have found stratification to benefit germination by increasing the speed and percentage of germination. Blake (1935) found that overwinter stratification of seed from over 40 prairie forb and grass species resulted in greater total germination. Tolstead (1941) compared germination of seed after storage in moist sand with the containers placed either 6 inches below ground or about ground level to seed stored dry at room temperature. Responses of the native grass, forb and shrub species varied when germinated at 70°F on moist filter paper. The majority of the species germinated without low temperature treatment but germination was generally improved with the preconditioning. In another study, stratification of one to three months was required for improved germination percentages of 37 of 51 prairie species, and harmed only 7 species (Greene and Curtis, 1950).

Sorensen and Holden (1974) subjected seeds of 13 forbs to moist cold treatment by placing seed in a petri dish with moist filter paper for varying lengths of time. Of the 13 species, 31 percent germinated only after cold treatment, 23 percent increased in germination after cold treatment, 15 percent showed no effect from cold treatment and the cold presoaking harmed 31 percent of the species. Voigt (1977) found that a two-month startification of 20 forb species increased total germination for 75 percent and harmed no species tested.

The effects of stratification for 3 to 15 weeks on seven prairie forbs were studied under different germination conditions (Hesse, 1973). Stratification at $4^{\circ}C$ was better than dry storage at $4^{\circ}C$ or at room temperature for all species tested. The best time period of stratification was 6 to 15 weeks depending on the species.

Other studies have examined the effects of presoaking seed followed by drying before planting. Chippindale (1934) studied the effect of warm soaking ($22^{\circ}C$ for 17 hours) followed by drying ($15^{\circ}F$ for 24 hours) on 10 grass species. He found with most species that acceleration of germination resulted from presoaking, but the difference may be negligible under optimum soil conditions.

Larson (1978) examined the effect of presoaking and drying seed. He found germination of presoaked seed ($5^{\circ}C$, 28 days) was accelerated in cool soils ($15^{\circ}C$) for the cool-season grasses he tested. However total germination was not affected. A warm-season grass and two legumes did not show an accelerated germination, although an increase in the total number germinated was found for Coronilla varia L. (crownvetch). Larson (1978) also reported accelerated growth of three cool-season grasses and three legumes when presoaked (5^{o}C, 28 days) and dried, then grown in limed mine soil.

Effects of different drying techniques and presoaking temperatures were studied on four cool-season grasses (Anda and Beard, 1975). Seed was soaked for 6, 12, 24, 48, and 168 hours in distilled water at 5, 10, 15, 25, and $15/25^{o}$C. Drying treatments were air drying (23.9^{o}C) for 1 week and overdrying (45^{o}C) for 18 hours. Different combinations of soaking and drying were found to significantly benefit Agrostis palustris Hyds. 'Penncross', Festuca rubra L. 'Pennlawn' and Poa pratensis 'Merion'. Lolium perenne L. 'Manhattan' was not benefitted by any treatment compared to untreated seed. Oven drying was detrimental to germination of A. palustris, F. rubra, P. pratensis, and L. perenne when compared to air drying.

Both greenhouse and field studies have been conducted on the effects of presoaking of Agropyron spp. (crested wheatgrass) seed (Keller and Bleak, 1968; Bleak and Keller, 1974). Germination was faster for presoaked and dried wheatgrass seed, with the most effective treatment being 63^{o}F for 60 to 70 hours. In field trials, faster emergence occurred for treated seed (at 17^{o}C until five percent of the seed produced visible radicles) than dry seed of Agropyron spp. for the earliest planting dates. Faster emergence of wheatgrass did not result in more plants after 4 to 6 weeks nor a higher yield.

Another experiment by Keller and Bleak (1969) has examined the effects of presoaking and drying on initial shoot and root growth from seed of *Agropyron* spp. (crested wheatgrass complex). Presoaking treatments at 40, 63 and 82°F for 10 to 90 hours in ten hour increments were used. Seedlings from treated seed (63°F from 40 to 90 hours) harvested 3, 4 or 5 days after planting had roots averaging 19 mm longer and shoots averaging 15 mm longer than seedlings from untreated seed. Drying with warm air for two minutes had a small but consistent effect in delaying start of root growth. Roots of seedlings from untreated seed required 46 hours to reach the length attained by roots of seedlings from treated but not dried seed. Keller and Bleak concluded that roots from treated seed were still longer 3 days after seedling emergence and this may be the critical difference between survival and death in field conditions, because moisture near the surface may be rapidly depleted by high temperatures and low humidity.

Establishment of Prairie Vegetation by Seeding

Cultural practices to control weeds during the establishment of prairie species are very important, and have included plowing, stubble mulch, burning, mowing, herbicides and soil sterilization. A weed in this context may be defined as a plant growing at a location where it is not desired or its presence has or may have a detrimental effect (Foote and Kill, 1968). The need for cultural practices in order to control weeds seems dependent on site conditions. For example, Clements and Weaver (1924) found seed sown in areas with mature prairie vegetation resulted in very low establishment compared to prairie seed sown on denuded areas.

Stubble mulch alone or in combination with mowing has been tested for its value in prairie establishment by seeding. Cornelius (1946) tested four types of stubble in Kansas. He found in two-thirds of the years, better prairie grass establishment occurred with _Avena_ sp. (oat) stubble present. _Sorghum bicolor_ (L.) Moench. (sudangrass) and millet stubble were judged satisfactorily, and _Melitotus_ spp. (sweet clover) stubble determined to be the least satisfactory. Two clippings were required some years for weed control. Owensby and Anderson (1965) found no significant differences in total prairie vegetation establishment after the first growing season between three types of sorghum stubble mulch.

The growth responses of individual prairie species to different cultural practices was evaluated in southern Wisconsin (Robocker and Miller, 1955). Ten prairie grass species were seeded after plowing, double discing and harrowing on a field cropped the previous year with Sorghum bicolor (sudangrass). A similar seeding was done on a field dominated by Poa compressa L. (Canada bluegrass), Poa pratensis (Kentucky bluegrass) and Agropyron repens (L.) Beauvois (quackgrass). Plots were mowed either four times per year or once in mid-August. Mowing favored short grasses, i.e., Andropogon scoparius Michx. (little bluestem) and Bouteloua curtipendula (side-oats grama) and harmed the establishment of taller grasses, i.e., Panicum virgatum (switchgrass) and Andropogon gerardii (big bluestem).

Christiansen (1967) conducted a thorough review of prairie restoration. His studies included the effects of hand weeding, winter wheat cover crop, mowing, and spring versus fall planting. In a spring planting experiment with 2-month-stratified seed, weedfree plots produced the highest number of seedlings with weedy plots (never weeded) higher than cover crop plantings. Also, in a spring versus fall planting, overwinter losses were found to be higher on cover crop plots than weedy treatment plots.

Seeding studies along Iowa roadsides found perennial prairie grasses and forbs well established by the end of the third year without any mowing, spraying or cover crop (Landers and Kowalski, 1968). Ground preparation consisted of rototilling before seeding and dragging with a toothless harrow after seeding. Substantial establishment of prairie grasses occurred on a wide range of soils, even the most extreme sites. But competition from annual grasses was a problem on better soils.

A limited number of studies have investigated the use of herbicides in the establishment of prairie species. Atrazine, 2,4-D and mowing treatments were applied to upland and lowland prairie seeded sites in Iowa (Bragg and Sutherland, 1978). The results were dependent on species and location. A higher species diversity (including presence of forbs) occurred on mowed plots and 2,4-D-treated upland plots than on herbicide treated lowland plots. High concentrations of atrazine favored the establishment of Panicum virgatum (switchgrass). On upland sites 2,4-D was more effective than atrazine for the establishment of native grasses. Woehler and Martin (1976) found dichlobenil and glyphosate herbicides each favored establishment of certain grasses while both were detrimental to the establishment of forbs. Martin and Moomaw (1974) found Andropogon hallii Hack. (sand bluestem) and Andropogon scoparius (little bluestem) were tolerant of atrazine and simazine when compared to other grasses in their study. Glyphosate applied in late spring controlled only cool-season grasses, not the warm-season grasses present since they were not growing at the time of the herbicide application. Klingman (1974) indicated that glyphosate alone will not reduce volunteer grass plants from residual seed on treated plots nor would there be any effect of glyphosate on germination of seed sown in the area immediately after treatment.

Thus, in the successful establishment of prairie species some method of accelerated germination must be used, along with weed control. A moist-chill (stratification) treatment appears to hold promise of improving initial germination of some prairie species. Herbicides or the use of stubble controlled weeds, and allowed prairie species to establish.

CHAPTER II

Field Study on the Effects of Seed Presoaking and Seed Mixtures on the Initial Establishment of Prairie and Non-Prairie Species

Introduction

Field experiments were conducted on a west facing newly cut highway slope along Highway 63 just south of Interstate 74 in Vermillion county, Indiana. Three separate tests were conducted to evaluate individual species and seed mixtures. Individual species observations were only conducted the first year, while mixtures were observed for two years after establishment.

Materials and Methods

The site was brought to final grade the week of planting. No further slope preparation was made. Following slope preparation soil samples were taken to determine pH and fertilizer requirements (Appendix VI). Three test seeding mixes containing varying combinations of nitrogen fixing legumes, temporary rapid cover species, cool-season grasses and warm-season grasses were made along with a state highway proposed mixture and the currently used highway mixture (Table I). Seventeen species or varieties included in the five seed mixtures were individually tested at the same rates as in the mixtures (Appendices IV and V). Ten additional species or varieties were also selected for individual species evaluation based primarily on findings by Carpenter et al. (1977), and seeded at rates based on seed mixtures containing these species (Wheaton, 1965; Foote, 1967; Hottenstein, 1969; Soil Conservation Service, 1975; Soil Conservation Service, 1976) (Appendices IV and V).

Cold soaking pretreatment was initiated on March 21 and 22, and April 18, 1979 respectively for the 18 nonprairie grasses and legumes, 7 prairie species and prairie forb *Echinacea purpurea* (Table I, Appendices IV and V). Prior to pretreatment all seed but those of the prairie species were stored at room temperature (approximately 20-23^{o}C). Seed of the prairie species was airdried (15 to 18^{o}C) for about 65 days and after December 21 stored dry at 4^{o}C in one liter jars, with the exception of *Echinacea purpurea*. On March 21 and 22, seed lots of the 25 species to be presoaked were placed in polyethylene bags and enough tap water added to allow for seed imbibition (a volume in milliliters equal to half the

Table I. Five Trial Seed Mixtures and Seeding Rates (Kg ha)

Mixture / Species	Characteristics[1]	Seed Pretreatment[2]	Kg/ha[3]
Mixture 1. Tall Warm-Season/Cool-Season Mixture			
1. *Medicago sativa* L.	NF	W	5.1
2. *Coronilla varia* 'Penngift'	NF	W	11.2
3. *Lolium multiflorum* Lam.	RC CS	W	5.1
4. *Eragrostis curvula* (Schrad.) Nees.	RC WS	W	5.1
5. *Festuca elatior*	RC CS	W	39.3
6. *Lolium perenne*	RC CS	W	11.2
7. *Agrostis alba* L.	RC CS	W	16.8
8. *Panicum virgatum*	P WS	W	11.2
			105.0
Mixture 2. Short Warm-Season/Cool-Season Mixture			
1. *Medicago sativa*	NF	W	5.1
2. *Coronilla varia* 'Penngift'	NF	W	11.2
3. *Lolium multiflorum*	RC CS	W	5.1
4. *Eragrostis curvula*	RC WS	W	5.1
5. *Festuca elatior*	RC CS	W	39.3
6. *Lolium perenne*	RC CS	W	11.2
7. *Agrostis alba*	RC CS	W	16.8
8. *Andropogon scoparius*	P WS	W	22.4
9. *Sporobolus heterolepis* Gray.	P WS	W	5.1
			121.3
Mixture 3. Proposed Highway Mixture			
1. *Lolium multiflorum*	RC CS	D	11.2
2. *Festuca rubra*	CS	D	28.1
3. *Poa pratensis* 'Park'	CS	D	22.4
4. *Poa pratensis* 'Wabash'	CS	D	22.4
5. *Lolium perenne* 'Manhattan'	RC CS	D	28.1
			112.2
Mixture 4. Current Highway Mixture			
1. *Festuca elatior*	RC CS	D	44.9
2. *Lolium perenne*	RC CS	D	28.1
3. *Poa pratensis*	CS	D	11.2
4. *Lolium multiflorum*	RC CS	D	39.3
			123.5
Mixture 5. Prairie Mixture			
1. *Medicago sativa*	NF	W	5.1
2. *Petalostemum candidum* (Wild.) Michx.	NF P	W	7.6
3. *Petalostemum purpureum* (Vent.) Rydb.	NF P	W	7.6
4. *Amorpha canescens* Pursh	NF P	W	15.2
5. *Lolium multiflorum* Lam.	RC CS	W	5.1
6. *Eragrostis curvula*	RC WS	W	5.1
7. *Lolium perenne*	RC CS	W	22.4
8. *Andropogon scoparius*	P WS	W	22.4
9. *Andropogon gerardii*	P WS	W	22.4
10. *Sorghastrum nutans*	P WS	W	22.4
11. *Panicum virgatum*	P WS	W	3.4
			138.7

[1] NF = nitrogen fixer; RC = rapid cover; WS = warm-season grass; CS = cool-season grass; P = native prairie species

[2] W = stored wet at 4 C for 10 weeks prior to planting; D = stored dry at room temperature (approximately 20-23 C) until time of planting

[3] Kilogram weight based on dry seed

seed lot weight in grams). The presoaked seed lots were placed in dark storage at 4°C. The bags were rotated several times the first week to insure even imbibition of seed. Seed of Echinacea purpurea was placed in polyethylene bags between folded halves of Whatman #1 9 cm filter paper moistened with 1.5 ml of tap water and stored dark at 4°C after April 18. During the week prior to planting, seed lots required for individual field plots were weighed. The lots of soaked seed were returned to 4°C dark storage.

Three randomized complete block experiments were established at the highway site. In the first experiment the five test seed mixtures were randomly assigned to plots 4.6 x 1.5 meters, replicated four times. Randomly selected halves of each plot were fertilized. In the individual species experiment 14 grasses and 8 legumes were randomly assigned to 3.0 x 1.5 m fertilized plots, replicated three times. The treatments included stratified and dry seed of 18 species and dry seed of four additional species (Appendix IV). In a third experiment seed of four cold soaked warm-season prairie grasses, Andropogon gerardii, Andropogon scoparius, Sorghastrum nutans and Panicum virgatum with 3.2 g of Echinacea purpurea (purple coneflower) were sown on plots 1.5 x 1.5 m, replicated three times. No fertilizer was applied to these plots.

The planting for these three experiments was done on June 1, 1979. The surface soil was still moist from a rain 2 days earlier. A 12-12-12 fertilizer was applied to the plots to be fertilized at 800 pounds/acre (880 kg/ha). Seed was hand sown and lightly incorporated with a rake. All plots were straw mulched at two tons/acre (4400 kg/ha) and covered with erosion control netting.

Rapidity of germination was evaluated approximately once a week for the remainder of June. Numbers of seedlings of test species were recorded in randomly thrown $0.1m^2$ quadrats on all plots.

In the second year only the experiment involving seeding mixtures was continued, although, observations were periodically taken of the individual species plots. Road construction disturbed one replication, thus only the other three were used in the continuation of the study. Individual species plots which did not perform well were mowed and reseeded with the current highway mixture on June 20, 1980. They were remulched with wheat straw at 1.5 t/ha. During the beginning of August the highway department assumed normal maintenance procedures by mowing the plots.

Mixture performance was measured by taking fresh weights of above ground tissue. The samples were obtained on November 2, 1979, May 16, June 20, and September 6 of 1980, by randomly throwing a $0.1m^2$ quadrat and trimming the tissue at approximately 1 cm above the soil surface.

Results and Discussion

An analysis of variance of tested seed mixtures showed time, mixes and their interaction to be highly significant factors contributing to variations seen in numbers of seedlings between plots. The general, germination tended for all mixes to be slow the 1st week, increase dramatically by the 2nd week and level off by the 4th week. A mean separation test showed that week one germination rates were significantly less than those at weeks two and four while no significant change occurred between weeks two and four. The significance of the mix by time interaction indicates that timing of emergence was not the same for all species (Table II). The tall warm-season/cool-season and short warm-season/cool-season mix had the highest emergence during week one. The prairie, proposed highway, and current highway mixes increased at a much higher rate than the other two mixtures between the 1st and 2nd weeks.

Initially, fertilizer was significant only at .10 level, this low significance level was due probably to the small number of treatments and replicates rather than lack of actual differences (Table III). Seedling counts on fertilizer plots were consistently lower than on non-fertilized plots (Table II). Probably the moisture remaining from a 1.4-cm rain 2 days earlier dissolved but did not initially leach the fertilizer. This high surface salt content could have then damaged emerging seedlings. Dramatic differences in seedling counts the 1st week between nonfertilized and fertilized plots offers support to this explanation. Rains recorded at Covington, Indiana on June 8 (1.0 cm), 9 (0.4 cm), 10 (0.6 cm) and 12 (0.6 cm) decreased the surface salt concentration which allowed for germination increases on the fertilizer plots (Appendix VI).

Table II. Number of Seedlings/m^2 After One, Two and Four Weeks With and Without Fertilizer

	Weeks					
	1		2		4	
Seed Mix	Fertilizer	No Fertilizer	Fertilizer	No Fertilizer	Fertilizer	No Fertilizer
Mix 1	565.1	1113.0	2845.2	2979.0	2365.6	2790.6
Mix 2	354.4	1241.0	2018.8	3717.9	2687.3	3536.3
Mix 3	28.5	369.4	1617.0	3840.1	1935.7	3213.2
Mix 4	86.9	417.9	2433.0	3188.9	2581.2	2791.4
Mix 5	63.5	279.9	718.7	1033.6	1094.5	1065.6
Mean (wks)[1]	452.0 b		2439.2 a		2406.2 a	

[1]Tukey, .05

The significant interaction of mixtures and fertilizer indicated that the fertilizer effect was not the same for all mixtures.

Germination rates of individual species explained differences seen over time with different seed mixtures (Appendices IV and V). Cold-soaked seed of Agrostis alba and Festuca elatior had the highest germination level after 1 week and were both contained in the two mixtures with the highest germination the 1st week, Mixtures one and two (Table I). The only other species at the tested seeding rates to have more than 50 seedlings/m^2 after 1 week were cold soaked seed of Andropogon scoparius contained in Mixtures two and five, dry seed of Lolium multiflorum contained in the Mixtures three and four and Poa trivialis tested only on an individual species basis.

By the 2nd and 4th weeks only the germination level of Mixture five was significantly different from the germination levels of the other four mixes. Again individual species responses provide an explanation. Lolium multiflorum, Andropogon scoparius, Agrostis alba, and Festuca elatior increased five times or more by the 2nd week. During the second week germination of Lolium perenne, Poa pratensis, and Festuca rubra contained in either the current or proposed highway mixes increased at least tenfold. In contrast germination levels of the three prairie species, Andropogon giradii, Panicum virgatum and Sorghastrum nutans increased less than sevenfold.

The effect of fertilizer on presoaked seed is also better understood by examining the response of individual species. Seedling numbers were either increased or similar the 1st week when presoaked seed was compared to dry seed of the same species. This suggests that it is advisable to

Table III. Number of Seedlings/m^2 With and Without Fertilizers (Averaged Over one, Two and Four Weeks)

Seed Mixture	Fertilizer	No Fertilizer	Mean/Seed Mixture
Mix 1	1925.3	2294.2	2109.8 a*
Mix 2	1686.8	2831.9	2259.4 a
Mix 3	1193.8	2474.2	1834.0 a
Mix 4	1700.4	2132.8	1916.6 a
Mix 5	625.6	793.0	709.3 b
Mean/fertilizer treatment	1426.4 a**	2105.8 b	

*Tukey, .05

**Tukey, .10

plant presoaked seed if speed of germination is important (Appendix IV). The only three exceptions were Poa trivalis, Lolium multiflorum and Medicago sativa, where dry seed had higher emergence after 1 week than cold soaked seed of these species. However, the increased seedling numbers on the nonfertilized areas of seed mixture plots after 1 week suggests that the advantage of presoaking seed to increase germination was greater when fertilizer was not used.

Mixtures containing legumes and warm season grasses had the greatest fresh weight production (Table IV). In November 1979, the two way interaction between mixture and treatment was significant. The tall, warm season-cool season grass mixture (mix 1), when fertilized, was better than any other of the mixture-fertilizer combinations. The difference between this mixture and the short, warm season-cool season grass mixture (mix 2) was that it contained Panicum virgatum while the short, warm season-cool season grass mixture had Andropogon scoparius and Sporobolus heterolepis (Table I). The short, warm season-cool season grass mixture and the prairie mixture (mix 5) were the next best. All three mixtures contained warm season grasses and legumes whereas the other mixtures only contained cool season grasses, which required a high fertility level.

When shoot fresh weights were sampled again the next spring, the mixture effect was significant, with the mixtures ranked in the same order as the previous fall. In the better performing mixtures, Eragrostis curvula dominated the fertilized plots. Normally, E. curvula is not hardy in Indiana winters (Donahue and Bennett, 1975). On the better performing nonfertilized plots Medicago sativa was the dominant

Table IV. Mean Shoot Fresh Weights at the Covington Highway Site

Mixture		g/m² Sampling Date 11-2	5-16	6-20	9-6
Mix 1	Fertilized	660e*	350abc	830abc	990cd
	Unfertilized	60ab	270abc	260ab	520abc
Mix 2	Fertilized	440d	460c	1150bc	630bc
	Unfertilized	30ab	150ab	210a	420abc
Mix 3	Fertilized	140abc	40a	280ab	100ab
	Unfertilized	0a	10a	20a	30a
Mix 4	Fertilized	210bc	90ab	60a	100ab
	Unfertilized	0a	20a	30a	50a
Mix 5	Fertilized	300cd	160ab	1200c	800cd
	Unfertilized	20ab	370bc	450abc	1250d

*Means (grams/m^2) within a sampling date followed by the same letter are not signficantly different using the Duncan Multiple Range Test at the .05 level.

fertilized

nonfertilized

a. The tall, warm season-cool season grass mixture.

fertilized

nonfertilized

b. The current highway mixture.

Figure I. The persistence of vegetation on November 2, 1979.

a. The short, warm season-cool season grass mixture, fertilized.

b. The current highway mixture, fertilized.

Figure II. The performance of seed mixtures on June 20, 1980.

species. E. curvula is a good nurse crop for legumes because its erect habit permits considerable light penetration and E. curvula starts growth later in the spring (Woodruff and Baker, 1970). In June and September, all mixtures showed a similar response to fertilization with fertilized plots being significantly better than the nonfertilized plots (Figures I and II). The tall warm season-cool season grass mixture, the short warm season-cool season grass mixture and the prairie mixture were the best performing mixtures. There was an increase in shoot fresh weights from the May to June samples. The increase was due to Medicago sativa flowering and Eragrostis curvula starting to grow.

In September only the mixture effect was statistically significant, with the prairie mixture (mix 5) better than either the tall warm season-cool season grass mixtures and those better than the current or proposed highway mixtures. The cover from the prairie mixture contained mainly Medicago sativa, although each replication contained a few plants of the Petalostemum spp. The prairie mixture probably did the best because the prairie species included in it were less competitive with M. sativa. Besides containing Petalostemum spp. this mixture also included Amorpha canescens, Andropogon gerardii and Sorghastrum nutans which no other mixture had.

Conclusions

Tall, warm season-cool season and short, warm season-cool season mixtures appear to be promising seed mixtures for Indiana highway slopes where minimal slope preparation is mandated. These test mixtures showed greater germination levels, and hence better initial erosion control, after 1 week than the currently used mixture, the proposed mixture and the prairie mixture. After 4 weeks, cover provided by these two test mixes was not higher than that found with the proposed and current highway mixes.

The use of presoaked seed did result in higher germination levels compared to dry seed after 1 week.

The effects of fertilizer in this study were generally detrimental to early establishment of all species tested, whether seed was dry or presoaked, but later fertilizer was very important in ensuring adequate coverage. In seeding legumes, rates of fertilizer have to be controlled to favor them over the grasses in the mixture.

Prairie forbs did not contribute substantially to the cover obtained, and due to economic constraints they probably should not be used in mixtures except in special situations such as roadside rest areas, where an aesthetically pleasing landscape is important.

Warm season species have a great potential for use in seeding during late spring and early summer. Eragrostis curvula was especially promising because it is very tolerant of hot, dry summers (Perry et al., 1975). It may serve as a warm season cover crop.

Other species that deserve consideration for use in special situations are Lespedeza stipulacea and Lotus corniculatus. L. corniculatus has been used elsewhere and has relatively poor seedling vigor, along with an inability to establish during late summer and early fall (Laskey and Wakefield, 1978; Allinson, 1972).

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APPENDICES

Appendix I. Description of Prairie Species

Amorpha canescens Nutt., leadplant, is a legume found in dry to mesic prairies and sandy open woodland (Rock, 1975). The 46-91 cm shrub produces a dense violet flower spike on new wood from late June to July (Rock, 1975). It is a native species of Indiana (Deam, 1940).

Andropogon gerardii Muhl., big bluestem, is a warm-season perennial grass native to Indiana and other tall-grass areas (Deam, 1940; Schramm, 1976). It grows 122-244 cm tall, blooms in late summer, and turns a reddish cast after the first frosts (Rock, 1975; Schulenberg, 1972). The grass slowly forms sod (Rock, 1975).

Andropogon scoparius, little bluestem, is a 61 to 122 cm tall warm-season perennial grass native to Indiana. It is adapted to dry and moist prairies (Rock, 1975). Andropogon scoparius flowers in late summer and turns a reddish cast after fall frosts (Schulenberg, 1972; Rock, 1975). The grass never forms a sod (Rock, 1975).

Asclepias tuberosa, butterflyweed, produces attractive orange flower clusters from late June to late August (Rock, 1975). It is found in dry and sandy or gravelly prairies, and mesic prairies (Rock, 1975). It is native to Indiana (Deam, 1940).

Aster novae-angliae, New England aster, has a wide range of unshaded habitats. Before settlement it probably was best adapted to wet and mesic prairies (Swink, 1969). Native to Indiana it grows 30 to 122 cm tall and produces violet to red-purple flowers from August through October (Rock, 1975).

Aster sericeus Vent., silky aster, is found in dry to mesic prairies and is native to northern Indiana (Deam, 1940; Rock, 1975). It has highly ornamental foliage, grows 30 to 61 cm tall and has bright red-like flowers in mid September to early October (Rock, 1975).

Coreopsis palmata, prairie coreopsis, grows 46 to 91 cm tall, produces many yellow flowers in late June to late July and forms compact vegetative colonies (Schulenberg, 1972; Rock, 1975). It is adapted to mesic prairies and native to Indiana (Deam, 1940; Rock, 1975).

Echinacea purpurea, purple coneflower, is native to prairie and woodland habitats in Indiana (Deam, 1940). It grows 61 to 122 cm tall and produces reddish-purple flowers from late June through September (Rock, 1975).

Erynigum yuccifolium Michx., rattlesnake master, produces stiff yucca-like leaves and in early July to early August white global flower clusters (Rock, 1975). It grows in moist to dry prairies and is native to Indiana (Deam, 1940; Rock, 1975).

Helianthus occidentalis Riddell., western sunflower grows 30 to 90 cm tall and produces numerous yellow flowers from August through October (Rock, 1975). It is found in dry to mesic prairies and is native to Indiana (Deam, 1940; Rock, 1975).

Heliopsis helianthoides (L.) Sweet., false sunflower, is found throughout Indiana (Deam, 1940). It grows 61 to 152 cm tall and produces orange-yellow flowers early June through September in moist to mesic prairies and open woods (Rock, 1975).

Liatris aspera, rough blazingstar, is frequently found in dry prairie remnants of northwestern Indiana (Swink, 1969). It is adapted to mesic to dry sand soils, grows 46 to 122 cm tall and has numerous rose-purple flowers from mid August to late September (Rock, 1975).

Liatris pycnostachya Michx., prairie blazingstar, grows 61 to 122 cm tall in wet to dry prairies (Rock, 1975). It is found in northwestern Indiana (Swink, 1969). Its rose-lilac flower heads bloom from late July to early August (Rock, 1975).

Panicum virgatum, switchgrass, is a sod forming perennial grass which grows 100 to 150 cm tall (Heath et al., 1973). It is found in open woods, along shores, and in prairies where it blooms from late July to mid September (Rock, 1975). It is native to Indiana (Betz, 1976).

Petalostemum candidum, white prairie clover, is a legume found in dry to mesic, well-drained prairies (Rock, 1975). It produces long white flower heads from early July to early August and is native to Indiana (Rock, 1975; Betz, 1976).

Petalostemum purpureum, purple prairie clover, is a legume which is found in the same habitat and blooms during the same period as P. candidum. The flower heads of P. purpureum are violet to purple (Rock, 1975). The species is native to Indiana (Betz, 1976).

Ratibida pinnata (Vert.) Barrh., yellow coneflower, grows 91 to 122 cm tall, produces yellow flowers in July and August and usually forms large colonies (Deam, 1940; Rock, 1975). Ratibida pinnata is weedy in appearance until the planting becomes established and then is not a problem (Schulenberg, 1973). It is adapted to dry to wet prairies and dry woods (Rock, 1975).

Rudbeckia hirta L., blackeyed susan, prefers dry, poor acid soils but grows on a wide range of sites encompassing dry to wet prairies, open woodland and disturbed sites (Rock, 1975). It is native throughout Indiana, grows 30 to 91 cm tall and produces attractive orange to orange yellow flowers in July and August (Deam, 1940; Rock, 1975).

Silphium laciniatum L., compassplant, is native to prairie habitats in Indiana (Deam, 1940). It grows 122 to 244 cm tall in moist to dry prairies and produces yellow flower clusters late June to early August (Rock, 1975).

Silphium tetebinthinaceum Jacq., prairiedock, has large arrow-shaped leaves and produces a 152 to 213 cm tall flowering stalk with yellow flowers early July to early September (Rock, 1975). Its native habitat is dry to moist prairies (Rock, 1975). It is native to Indiana growing on a wide range of sites from the crest of a wooded sandstone ridge to a marsh (Deam, 1940).

Solidago rigida L., rigid goldenrod, grows 61 to 122 cm tall in dry to mesic prairies with neutral soil and produces yellow flowers during late August to early October (Rock, 1975). It is native to Indiana (Deam, 1940).

Solidago speciosa Nutt., showy goldenrod, is one of the showiest goldenrods producing dense yellow flower heads from August through October (Rock, 1975). It grows 61 to 183 cm tall in dry to mesic prairies and in open sandy woods (Rock, 1975). It is native to Indiana (Deam, 1940).

Sorghastrum nutans, Indiangrass, is a 91 to 152 cm tall warm-season prairie grass native to Indiana (Deam, 1940; Rock, 1975). It flowers late August to mid-September and turns a bronze color in the fall (Rock, 1975).

Sporobolus heterolepis Gray., prairie dropseed, is a 61 to 91 cm tall warm-season prairie grass which blooms in August (Rock, 1975). Although found in Indiana, Deam (1940) believed it moved into the state and was not originally native.

Appendix II. Effects of Different Time Length of Stratification on the Percent Germination of Seven Prairie Species After Five Days

Species / Treatment	0 wk wet	1 wk wet	2 wk wet	4 wk wet	8 wk wet	12 wk wet	16 wk wet	16 wk dry
Andropogon scoparius	1.5	11.5	10.5	8.5	19.0	22.0	16.5	1.0
Sorghastrum nutans	0.0	9.5	14.0	25.0	23.0	26.5	35.0	0.0
Asclepias tuberosa	0.0	0.0	0.0	0.5	0.0	0.0	2.0	0.0
Aster novae-argliae	0.5	0.0	0.0	0.0	1.0	1.0	3.5	0.0
Coreopsis palmata	0.0	3.0	1.5	3.5	15.0	17.5	23.0	0.0
Echinacea purpurea	2.0	5.5	9.5	7.0	30.0	30.0	21.5	0.0
Liatris aspera	0.0	0.0	0.0	0.5	4.5	20.0	17.0	0.5

Appendix III. Effects of Different Time Lengths of Stratification on the Percent Germination of Seven Prairie Species After Fourteen Days

Species / Treatment	0 wk wet	1 wk wet	2 wk wet	4 wk wet	8 wk wet	12 wk wet	16 wk wet	16 wk dry
Andropogon scoparius	3.0	23.0	19.5	13.5	27.5	33.0	22.5	2.0
Sorghastrum nutans	4.0	15.5	18.0	32.5	33.5	32.5	39.5	3.0
Asclepias tuberosa	8.0	26.5	27.0	21.5	24.0	9.0	10.5	1.5
Aster novae-angliae	2.5	1.0	2.0	1.0	5.5	2.5	6.5	1.0
Coreopsis palmata	0.5	8.0	9.5	25.5	26.5	25.0	30.0	0.0
Echinacea purpurea	34.5	39.5	50.0	53.0	64.0	68.0	49.0	21.5
Liatris aspera	1.0	4.5	5.0	5.5	33.5	39.5	24.0	1.5

Appendix IV. Seeding Rates and Germination Responses of Non-prairie Species at Highway 63 Experimental Plots

Species	Seeding Rate (kg/ha)[1]	Germination (Numbers of Seedlings/m²): Cold Soaked[2] 1 Week	Cold Soaked[2] 2 Weeks	Cold Soaked[2] 4 Weeks	Dry[3] 1 Week	Dry[3] 2 Weeks	Dry[3] 4 Weeks
Grasses							
Agrostis alba*	16.8	185.3	1394.4	832.4	1.1	2122.7	1320.4
Bromus inermis Leyss.	11.2	4.7	239.0	244.0	3.5	261.8	212.9
Dactylis glomerata L.	16.8	27.5	505.8	458.9	0.0	620.6	449.2
Eragrostic curvula*	7.3	2.4	277.2	167.3	3.6	1134.9	636.2
Festuca elatior*	39.3	86.1	1298.8	1002.1	3.6	905.3	805.9
Festuca rubra*	28.1	6.0	690.0	385.1	4.7	1370.6	444.9
Lolium multiflorum*	11.2	23.9	65.6	157.8	77.5	433.0	495.0
Lolium perenne*	11.2	49.9	434.1	373.0	20.1	473.5	401.8
Lolium perenne 'Manhattan'*	28.1				24.8	924.5	1507.0
Phalaris arundinacea L.	11.2	36.8	595.5	162.7	38.3	698.0	272.6
Poa pratensis*	11.2				1.1	71.6	186.2
Poa pratensis 'Park'*	22.4				15.4	1213.7	966.1
Poa pratensis 'Wabash"	22.4				4.7	526.1	510.8
Poa trivialis L.	29.2	89.1	2843.9	2899.1	133.8	2671.8	1918.3
Legumes							
Coronilla varia 'Emerald'	11.2	4.7	19.0	45.3	0.0	84.7	90.6
Coronilla varia 'Penngift'*	11.2	2.4	64.5	40.4	0.0	70.3	90.4
Lespedeza stipulacea Maxim.	16.8	7.2	45.5	38.0	0.0	281.1	298.2
Lotus corniculatus	5.1	2.4	27.5	11.8	2.4	80.1	54.9
Medicago sativa*	5.1	13.2	96.7	32.8	35.9	181.6	172.1
Trifolium hybridum L.	5.1	3.2	97.8	38.2	4.7	170.8	162.4
Trifolium pratense L.	5.1	7.1	32.2	31.0	3.5	83.6	122.0
Vicia villosa Roth.	16.3	0.0	1.1	0.0	1.1	45.4	47.7
Grasses $\bar{x}$		139.2	813.3	668.2	23.6	954.8	752.6
Legume $\bar{x}$		5.0	48.0	29.7	5.9	124.7	127.5

[1] Kilogram weight based on dry seed

[2] Seed stored at 4 C in the dark for 10 weeks prior to seeding

[3] Seed stored dry at room temperature (approximately 20-23 C) until time of seeding

* Included in one or more trial seed mixtures shown in Table V.

Appendix V. Seeding Rates and Germination Responses After One, Two and Four Weeks of Five Prairie Species at Highway 63 Experimental Plots

Species	Seeding Rate (kg/ha)	Germination (Numbers of Seedlings/m^2)		
		1 week	2 weeks	4 weeks
Grasses[1]				
Andropogon scoparius *	22.4	25.1	471.8	543.6
Andropogon gerardii *	22.4	71.8	333.7	554.4
Panicum virgatum *	11.2	14.3	238.6	200.9
Sorghastrum nutans *	22.4	32.3	192.0	500.6
Forb[2]				
Echinacea purpurea	13.8	1.0	33.8	29.2

[1] Seed stored moist at 4 C in the dark for 10 weeks prior to planting

[2] Seed stored moist at 4 C in the dark for 6 weeks prior to planting

* Included in one or more trial seed mixtures shown in Table V

Appendix VI. Selected Soil Properties of the Upper 10 Centimeter Soil Layer

Soil Sample Type	Data Collected[1]	pH	Phosphorous kg/ha	Potassium kg/m	NH_4^+ ppm	NO_3 ppm
Without fertilizer	5/31/79	6.2	20	176	4.8	3.1
With fertilizer	7/3/79	5.9	44	231	31.2	32.2
Without fertilizer	7/3/79	6.0	14	136	12.0	5.3
With fertilizer	5/13/79	5.9	28	160	--	--

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