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The Effects of Seeding Time on Native Plant Establishment in a Prairie Reconstruction

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Final Report

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Executive Summary

The Iowa DOT is seeking ways to improve practices associated with revegetation projects to increase establishment of native grasses and forbs. One of these practices is to seed native grasses and forbs between Apr 01 - June 30 and between Aug. 01 - Aug. 31 (Iowa DOT 2001). We investigated seeding at different times during the growing season to determine the most appropriate seeding time for optimal establishment of prairie grasses and wildflowers.

In 2004, experimental plots were established in the right-of-way along Interstate 20 in Black Hawk County, Iowa. The experiment replicated a typical Iowa DOT re-vegetation prairie planting. All Iowa DOT specifications for a re-vegetation planting (site preparation, seeding, and mowing) were followed in the experiment. Prairie plant emergence, growth, and richness and weed growth and richness were compared in plots with four different seeding times: early-summer (June 15), mid-summer (July 29), late-summer (Sept. 13), and mid-fall (Oct. 31). Data was collected in 2005 and 2006. A summary of the results are as follows.

Prairie Plant Establishment:

* Early-summer seeding had the highest establishment of prairie plants among all seeding time treatments.
* Late-summer seeding resulted in the lowest establishment of prairie plants among all seeding times.

Prairie Plant Mortality:

* Early-summer seeding had the lowest prairie plant mortality among all seeding times.
* Late-summer seeding time had the highest prairie plant mortality among all seeding times.

Species Richness:

* Early-summer seeding had the highest species richness among all seeding times.
* Late-summer seeding resulted in lower species richness.

Plant Biomass:

* Early-summer seeding resulted in the highest prairie plant biomass among all seeding times.
* Late-summer seeding resulted in the lowest prairie plant biomass among all seeding times.
* Weed biomass was similar among all seeding time treatments.

Seeding time was found to have a significant impact on native plant emergence. Based upon the results from this experiment seeding prairie in summer should be done in early-summer to maximize prairie plant establishment, species richness, survival, and growth. Mid-summer and mid-fall seeding times had similar but lower prairie plant emergence than seeding in early-summer. Seeding prairie in late-summer is not recommended.

INTRODUCTION

The Iowa Department of Transportation (DOT) is currently planting native prairie grasses and forbs into interstate and highway rights-of-ways. Some of these plantings include "re-vegetation" projects. Re-vegetation plantings involve converting established non-native grass stands in the rights-of-ways to prairie plant plantings consisting of native grasses and forbs. The goal of this program is to create diverse native prairie plantings resistant to soil erosion and weedy invasion, improve water quality, enhance the landscape aesthetics, and to reduce long-term roadside vegetation maintenance costs. In re-vegetation projects, the non-native vegetation is killed with a herbicide and the prairie seed is planted into the killed sod with a no-till drill. The site is periodically mowed in the first two growing seasons to reduce weeds and stimulate the natives.

Choosing an optimal planting time can be complicated when planting prairie. Seed mixes for prairie plantings usually contain species with very different requirements for germination and establishment. Cool-season prairie grasses and some forbs readily germinate in cool, wet soils, whereas, warm-season prairie grasses and other forbs readily germinate in warmer soils. In addition, some forbs require over-winter fluctuations in soil temperatures and moisture to break seed dormancy and permit germination (Greene and Curtis 1950). Iowa DOT (2007) seeding specifications permit seeding prairie grasses and wildflowers between Apr 01 - June 30 or between Aug. 01 - Aug. 31. However, United States Department of Agriculture (USDA) - Iowa Natural Resources Conservation (NRCS) does not recommend seeding prairie grasses and wildflowers between Aug.01- Sept. 15 (Iowa NRCS 2003).

Seeding prairie grasses and wildflowers in late summer may be a problem for two reasons. First, August is typically the hottest and driest month during the growing season in Iowa (NOAA 2007). Exposing newly germinated prairie plants to these extreme conditions in late summer may increase seedling mortality (Meyer et al. 2002). Second, prairie plants that germinate in late summer may not grow large enough to survive over-winter (Williams et al. 2007). Both conditions in a prairie reconstruction can result in fewer native plants and an increased probability of weedy invasion.

The objectives of this study were to 1) assess and compare native plant emergence, and richness among four seeding time treatments and 2) assess and compare native plant and weed biomass among four seeding time treatments. The treatments were: early-summer (June 15), mid-summer (July 29), late-summer (Sept. 13), and mid fall (Oct. 31). All plots were seeded in 2004 with the same seed mixes (Table 4).

Results from this research project will provide information on the most appropriate time to seed for optimal establishment of native grasses and wildflowers during the summer months as well as determining if adequate establishment of native plants can be obtained at other times. This information can be used to revise or develop seeding time recommendations for re-vegetation projects.

METHODS AND MATERIALS

Site Description

Research plots were established in 2004 in the north and south right-of-way (ROW) of highway 20 between the Grundy County line and the Hwy. 63 exit in Black Hawk County, Cedar Falls Iowa. The experiment used a randomized block design. Three blocks were located in the north and three in the south ROW. Each block consisted of four 0.07 ha. plots. There were four seeding time treatments in the experiment: early-summer (June 15), mid-summer (July 29), late summer (Sept. 13), and mid-fall (Oct. 31). There were six replicates for each treatment.

Site Preparation and Seeding

The existing vegetation on the research sites consisted of stands of cool-season Eurasian pasture grasses that included smooth brome (*Bromus inermis*), tall fescue (*Festuca arundinacea*), Kentucky bluegrass (*Poa pratensis*), and orchardgrass (*Dactylis glomerata*). In 2004, the vegetation was mowed in mid-April (4" high) and sprayed with a non-selective herbicide (glyphosate) in early May.

The seed mix for the experiment included 63 prairie species (Table 2). All seed was tested for viability by an independent seed-testing lab. Seeding rate for each species was calculated based upon by pure live seed (PLS) and seed weight estimates of Henderson and Kern (1999). Seed was mixed and bagged for each plot. Equal amounts of clay chips were also added to each bag and mixed thoroughly to improve the flow of seed through the no-till drill.

The plots were seeded at scheduled seeding time treatments in 2004 with a no-till seed drill and mowed in early July and August in both 2004 and 2005. Every attempt was made to follow Iowa DOT seeding specifications for re-vegetation projects.

Vegetation Sampling

The vegetation was sampled in mid September of 2005 and 2006. Two random 15 meter transects were established in each plot. Each transect extended from the delineator post to the fence line near the back of the ROW. This was done to sample the entire ROW profile (foreslope, bottom, and backslope). At 1 meter intervals, the vegetation was sampled using a 0.10 m^2 quadrat frame. Within the quadrat frame, all native seedlings were identified and counted and all weed species were identified. In addition, five quadrats from each transect were chosen at random for biomass sampling in 2006. Native grasses, forbs, and weeds were clipped at ground level and bagged by plant group. Bags were oven dried (60^oc) for three days and weighed.

Data Analysis

The data were analyzed using a analysis of variance (ANOVA) with two factors: block and seeding rate. The model included six blocks, and four seeding time factors (June 15, July 29, Sept. 13, and Oct. 31). Skewness (g1) and kurtosis (g2) were calculated for all data sets. A student's t-test (alpha = 0.05, with infinite degrees of freedom) was conducted to determine if the data had significant skew or kurtosis from zero (Wilkinson 1989). The data was square-root transformed to run the ANOVA. A Tukey's protected test for pairwise comparisons was used to compare means among the seeding rate treatments.

RESULTS and DISCUSSION

Effects on Native Plant Emergence

Seeding time had significant effects on native plant emergence. Early-summer (June 15) seeded plots fared the best and late-summer (Sept. 13) seeded plots fared the worst in the experiment. There were 2.2 times more prairie plants in the early-summer seeded plots over plots seeded in late-summer (Table 1). Both prairie grass and forb emergence was significantly lower in plots seeded late-summer as compared to early-summer seeded plots (Table 3). Big bluestem (*Andropogon gerardii*) and Canada wild rye (*Elymus canadensis*) fared the worst (Table 4). No big bluestem plants and only two Canada wild rye plants were detected in late-summer seeded plots (Table 4). This was very evident by the end of the growing season in 2006. Flowering prairie grasses and forbs were much more abundant in spring seeded plots than in plots seeded late-summer (Figure 1). Prairie plant emergence was not significantly different between mid-fall and mid-summer seeding time treatments (Table 1). It appears that seeding prairie in the summer months should be done early in the summer to maximize plant emergence.

Effects on Native Plant Mortality

Seeding time may have contributed to prairie plant mortality. Prairie plant mortality from 2005 end of growing season to end of 2006 growing season was evident across all seeding time treatments, however, the highest mortality was in plots seeded late-summer. The number of prairie plants in plots seeded early-summer went from 3.85 to 3.39 plants/m^2 (12% mortality) as compared to 26% mortality (2.03 to 1.51 plants/m^2) in plots seeded late-summer (Table 1). Competition from non-native plants may have contributed to prairie plant mortality. Tall fescue (*Festuca arundinacea*) and bird's foot trefoil (*Lotus corniculatus*) were observed in all research plots. It appeared that one spring application of glyphosate was ineffective at killing the established vegetation (Figure 1). Winter-kill may also have contributed to prairie plant mortality. In early October of 2004, many new germinants of prairie plants were observed in plots that were seeded late-summer of that year (Figure 2). It is possible that many of those plants didn't have enough root energy to survive over their first winter.

Effects on Species Richness

Early-summer seeded plots had more native species than all other seeding time treatments (Table 1). The later the seeding time in summer, the fewer native species that emerged (Table 1). Late-summer seeded plots had the lowest native species richness among all other seeding time treatments (Table 1). Native species richness was not significantly different among mid-summer, and mid-fall seeding time treatments (Table 1). It is clear that seeding prairie in late-summer could result in a planting low in species richness. Due to so few plants being detected in quadrat samples for many of the species, there was no clear pattern of a single or a group of species favored by seeding treatment over another (Table 4).

In 2006, the numbers of weed species were similar across all seeding time treatments (Table 1). Seeding time did not appear to affect the number of weed species that were measured in the experiment.

Plant Biomass

In 2006, native plant biomass was highest in plots seeded in early-summer and lowest in plots seeded in late-summer (Table 2). There was a trend of decreased native plant biomass as seeding time extended through the summer (Table 2). This trend may be due the number of growing days and competition by non-native plants. Prairie plants that were seeded in the early-summer had more days to grow and develop in the first year than the plants that were seeded in late-summer. In year two, competition from non-native plants may have further suppressed growth, having a greater effect on the younger prairie plants that were seeded in late-summer of the previous year.

Weed biomass was similar among all seeding time treatments (Table 2). It appears that prairie plant growth had little effect on the growth of weeds in the experiment. Poor weed control may be responsible for this result. Weeds that quickly re-invaded the plots may have been superior competitors for resources severely curtailing native plant growth throughout the experiment.

CONCLUSION

Seeding time played a critical role in prairie plant establishment. Seeding later in summer reduced prairie plant establishment. In this experiment, seeding in late-summer was the worst time to plant prairie. Seeding in late-summer reduced prairie plant emergence, species richness, and growth. Based upon results from this experiment, seeding prairie in early-summer will maximize emergence, species richness, survival, and growth of prairie plants. Seeding prairie in late-summer is not recommended.

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Table 1. Mean number of plants per m^2 and standard deviations of plants sampled in September 2005 and 2006. Means were square root transformed and the plant groups analyzed separately with a one-way ANOVA. Different letters are significantly ($p<0.05$) different based on a Tukey HSD test for each group. Reported means were not back-transformed.

	------------------Seeding Time Treatments----------------				
Plant Group (Year)	Jun 15 (s.d.)	Jul 29 (s.d.)	Sept 13 (s.d.)	Oct 31 (s.d.)	p-value
Native Seedlings (2005)	3.85 (0.539)^{a}	2.78 (0.615)^{b}	2.03 (1.060)^{b}	2.66 (0.639)^{b}	0.001
Native Seedlings (2006)	3.39 (0.770)^{a}	2.48 (0.626)^{b}	1.51 (0.496)^{c}	2.23 (0.726)^{b}	0.001
Native Species (2005)	2.78 (0.310)^{a}	2.00 (0.319)^{b}	1.65 (0.746)^{b}	2.07 (0.415)^{b}	0.001
Native Species (2006)	2.55 (0.393)^{a}	1.89 (0.397)^{b}	1.36 (0.393)^{c}	1.79 (0.584)^{bc}	0.001
Weed Species (2005)	2.55 (0.321)^{a}	2.74 (0.309)^{ab}	2.86 (0.197)^{b}	2.79 (0.160)^{ab}	0.032
Weed Species (2006)	2.30 (0.381)	2.46 (0.295)	2.55 (0.363)	2.51 (0.286)	0.250

Table 2. Mean biomass (grams-dry weight per $0.1m^2$) and standard deviations of plant groups sampled in September of 2006. Means were square root transformed and the plant groups analyzed separately with a one-way ANOVA. Different letters are significantly ($p<0.05$) different based on a Tukey HSD test for each group. Reported means were not back-transformed.

	------------------Seeding Time Treatments-----------------				
Plant Group	Jun 15 (s.d.)	Jul 29 (s.d.)	Sept 13 (s.d.)	Oct 31 (s.d.)	p-value
Total Natives	3.25 (1.673)^{a}	2.06 (1.498)^{ab}	0.97 (1.290)^{b}	1.10 (1.063)^{b}	0.03
Native Grass	2.52 (1.624)	0.91 (0.847)	0.83 (1.321)	0.79 (1.112)	0.07
Native Forbs	1.83 (1.112)	1.46 (1.747)	0.33 (0.302)	0.37 (0.660)	0.06
Total Weeds	6.06 (1.013)	6.08 (1.133)	6.86 (1.555)	5.98 (1.041)	0.56

Table 3. Mean numbers per m^2 and standard deviations of prairie grasses and forbs sampled in September 2005 and 2006. Means were square root transformed and the plant groups analyzed separately with a one-way ANOVA. Different letters are significantly ($p<0.05$) different based on a Tukey HSD test for each group. Reported means were not back-transformed.

	------------------Seeding Time Treatments-----------------				
Plant Group (Year)	Jun 15 (s.d.)	Jul 29 (s.d.)	Sept 13 (s.d.)	Oct 31 (s.d.)	p-value
Grasses (2005)	2.33 (0.285)[a]	1.27 (0.517)[b]	1.06 (0.734)[b]	1.46 (0.533)[b]	0.001
Forbs (2005)	3.04 (0.628)[a]	2.19 (0.627)[b]	1.59 (1.054)[b]	2.13 (0.749)[b]	0.001
Grasses (2006)	1.85 (0.638)[a]	1.31 (0.545)[a]	0.62 (0.494)[b]	1.40 (0.417)[a]	0.001
Forbs (2006)	2.77 (0.768)[a]	1.95 (0.863)[b]	1.26 (0.566)[b]	1.62 (0.855)[b]	0.001

Table 4. Total prairie plants sampled in 2005 and 2006.

	SEEDING RATE	SEEDING TIME TREATMENTS (n=180)							
		June		July		September		October	
GRASSES	seeds/sq. meter	2005	2006	2005	2006	2005	2006	2005	2006
Andropogon gerardii	1	16	15	2	4	1	0	0	1
Bouteloua curtipendula	1	8	5	2	0	0	0	0	0
Calamagrostis canadensis	1	0	0	0	0	0	0	0	0
Elymus canadensis	1	41	23	23	15	16	2	7	10
Koeleria macrantha	1	0	0	0	0	0	0	0	0
Panicum virgatum	0.5	20	14	25	14	22	9	33	23
Schizachyrium scoparius	1	1	2	0	2	0	0	0	1
Sorghastrum nutans	1	5	6	0	0	0	0	0	0
Spartina pectinata	1	0	2	0	0	0	0	0	2
Sporobolus asper	0.5	8	1	0	1	0	0	2	0
Sporobolus heterolepis	0.75	0	0	0	0	0	0	0	0
Stipa spartea	0.25	0	0	0	0	0	0	0	0
FORBS									
Allium canadense	0.5	0	0	0	0	0	0	0	0
Amorpha canescens	1	0	0	0	0	0	0	0	0
Anemone cylindrica	1	1	0	0	0	2	0	1	1
Artemisia ludoviciana	1	4	5	0	0	0	0	0	3
Asclepias incarnata	1	4	0	6	0	6	0	6	2
Asclepias tuberosa	0.25	2	5	1	1	0	0	0	0
Aster ericoides	1	0	0	0	0	0	0	2	0
Aster laevis	1	0	0	0	0	0	0	0	0

Aster novae-angliae	1	1	2	0	0	2	0	1	4
Aster sericeus	1	0	0	0	0	0	0	0	0
Astragalus canadensis	1	2	1	0	1	0	0	0	0
Baptisia leucantha	0.1	0	0	0	1	0	0	0	0
Cassia fasiculata	1	11	13	3	1	1	0	8	0
Coreopsis palmata	0.1	0	0	0	0	0	0	0	0
Dalea candida	1	6	7	0	0	0	0	0	0
Dalea purpurea	1	3	8	1	0	0	0	0	2
Desmodium canadense	0.1	6	2	0	1	0	0	1	0
Echinacea pallida	1	2	0	0	0	1	1	5	1
Erynigium yuccifolium	1	0	1	0	0	0	0	0	0
Eupatorium altissimum	2	1	2	0	0	1	0	0	2
Helenium autumnale	4	2	0	2	2	0	2	0	4
Helianthus grosseserratus	0.1	2	8	1	7	0	1	1	1
Helianthus laetiflorus	0.25	12	18	2	1	2	0	0	0
Heliopsis helianthoides	1	15	23	1	14	11	7	17	9
Lespedeza capitata	1	3	0	0	0	0	0	0	0
Liatris aspera	1	0	0	1	1	0	0	0	0
Liatris ligulistylis	0.5	0	0	0	0	0	0	0	0
Liatris pycnostachya	1	1	0	0	0	0	0	0	0
Lobelia siphilitica	1	0	0	0	0	0	0	1	0
Monarda fistulosa	2	17	13	5	12	2	6	3	9
Parthenium integrifolium	0.5	0	0	0	0	0	0	0	0
Penstemon digitalis	1	2	0	0	1	0	0	0	0
Penstemon grandiflorus	1	1	0	0	0	0	0	0	0
Phlox pilosa	0.2	0	0	0	0	0	0	0	0
Pycnanthemum virginianum	5	1	1	0	0	0	0	0	0
Ratibida pinnata	1	7	11	5	5	5	10	6	3
Rosa spp.	0.05	0	0	0	0	0	0	0	0
Rudbeckia hirta	1	50	4	45	23	5	1	12	4
Rudbeckia subtomentosa	1	2	7	4	2	6	1	5	2
Silphium integrifolium	0.1	1	2	0	0	0	0	0	0
Silphium laciniatum	0.01	0	0	0	0	0	0	0	0
Solidago graminifolia	1	0	0	0	1	0	0	0	0
Solidago nemoralis	1	0	1	1	0	0	0	0	0
Solidago rigida	1	7	3	5	4	8	0	12	4
Solidago speciosa	1	0	0	0	0	0	0	0	0
Tradescantia ohiensis	1	0	1	0	0	0	0	0	0
Verbena hastata	3	0	0	0	2	0	0	0	0
Verbina stricta	1	1	0	2	0	3	0	3	0
Vernonia fasciculata	1	2	2	0	0	0	0	1	0
Veronicastrum virginicum	1	0	0	0	0	0	0	0	0
Zizia aurea	1	4	8	2	1	9	4	6	6
TOTAL	61.76	272	216	139	117	103	44	133	94

Table 5. Weed species that were present in quadrat samples in September 2006.

Genus-Species	Common Name	Origin
Acer negundo	Box Elder	Native
Amaranthus retroflexus	Pigweed	Exotic
Ambrosia artemisiifolia	Common Ragweed	Native

Asclepias syriaca	Common Milkweed	Native
Bidens spp.	Beggar-Ticks	Native
Bromus inermis	Smooth Brome	Exotic
Cirsium arvense	Canada Thistle	Exotic
Cirsium vulgare	Bull Thistle	Exotic
Convolvulus arvensis	European Bindweed	Exotic
Conyza canadensis	Horseweed	Native
Cornus racemosa	Gray Dogwood	Native
Cornus stolonifera	Red-Osier Dogwood	Native
Coronilla varia	Crown Vetch	Exotic
Cyperus esculentus	Yellow Nutsedge	Native
Dactylis glomerata	Orchard Grass	Exotic
Daucus carota	Queen Anne's Lace	Exotic
Echinochloa crusgalli	Barnyard Grass	Exotic
Elytrigia repens	Quackgrass	Exotic
Erigeron annuus	Annual Fleabane	Native
Euphorbia spp.	Spurge sp.	Native
Festuca arundinacea	Tall Fescue	Exotic
Glechoma hederacea	Creeping Charlie	Exotic
Lactuca serriola	Prickly Lettuce	Native
Leonurus cardiaca	Motherwort	Exotic
Lotus corniculatus	Bird's-Foot Trefoil	Exotic
Matricaria matricarioides	Pineapple Weed	Exotic
Melilotus spp.	Sweet Clover	Exotic
Morus spp.	Mulberry sp.	Native
Oenothera biennis	Common Evening Primrose	Native
Parthenocissus quinquefolia	Virginia Creeper	Native
Pastinaca sativa	Wild Parsnip	Exotic
Phalaris arundinacea	Reed Canary Grass	Exotic
Physalis heterophylla	Clammy Ground Cherry	Native
Physalis virginiana	Virginia Ground Cherry	Native
Plantago rugelii	Common Plantain	Exotic
Poa pratensis	Kentucky Bluegrass	Exotic
Polygonum spp.	Smartweed sp.	Native
Potentilla simplex	Common Cinquefoil	Native
Rumex crispus	Curly Dock	Exotic
Salix spp.	Willow sp.	Native
Setaria spp.	Foxtail sp.	Exotic
Solanum carolinense	Horse Nettle	Native
Solidago canadensis	Canada Goldenrod	Native
Sonchus oleraceus	Common Sow Thistle	Exotic
Taraxacum officinale	Common Dandylion	Exotic
Trifolium pratense	Red Clover	Exotic

Ulmus rubra	Slippery Elm	Native
Urtica dioica	Stinging Nettle	Native
Viola pratincola	Common Blue Violet	Native
Vitis spp.	Grape sp.	Native