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THE EFFECTS OF ANNUAL RYE ON NATIVE PLANT ESTABLISHMENT WHEN SEEDED AS A NURSE CROP IN A PRAIRIE RECONSTRUCTION

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Abstract: Iowa Department of Transportation (DOT) utilizes annual rye (*Lolium multiflorum*) as a nurse crop (seeded with prairie grasses and forbs) to reduce weeds in new prairie reconstructions. Their seed mixes include annual rye at a seeding rate of 5.6 kg/ha (5.0 lbs/ac). We hypothesized that planting annual rye with the prairie seed would reduce weed growth and also reduce prairie plant establishment. In 2004, experimental plots were established in the right-of-way along U.S. 20 in Black Hawk County. Plots were sprayed with glyphosate to kill the established non-native cool-season grasses in late spring 2004 and seeded with annual rye and prairie grasses/forbs in early June 2004. Prairie plant emergence, growth, richness, and weed growth were compared at three different seeding rates of annual rye: No Rye (control), Rye (5.6 kg/ha - 5.0 lbs/ac), and 2x Rye (11.2 kg/ha - 10.0 lbs/ac). Data were collected in 2004 and 2005. Native plant establishment was reduced by 22.0% and 36.5% in Rye and 2x Rye plots, respectively, as compared with the No Rye controls. The addition of annual rye reduced weed growth up to 40.7% in the first year; however, weed growth in Year 2 was 13.3% and 15.8% higher in Rye and 2x Rye plots than the weed growth in control plots. Based upon the results of this experiment, we concluded that seeding annual rye as a nurse crop with the prairie seed will decrease native plant establishment and only temporarily reduce weed growth. It is recommended that annual rye be excluded as a nurse crop in prairie reconstructions.

Key Words / Search Terms: annual rye, nurse crop, prairie reconstruction

INTRODUCTION

The Iowa Department of Transportation (DOT) is currently planting native prairie grasses and forbs into interstate and highway rights-of-ways (ROW). Some of these plantings are 're-vegetation' projects. Re-vegetation plantings involve converting established non-native grass stands in the rights-of-ways to prairie plantings consisting of native grasses and forbs. The goal of this program is to create diverse native prairie plant communities resistant to soil erosion and weedy invasion, to improve water quality, to 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 non-selective herbicide (glyphosate) and the prairie seed is planted into the killed sod with a no-till drill and the site is periodically mowed in the first two growing seasons to reduce weeds and stimulate the natives (IADOT 2004). Iowa DOT utilizes this re-vegetation technique because the potential for soil erosion is low during the establishment phase of the prairie.

Prairie plant establishment in the first few growing seasons has always been a challenge when reconstructing a prairie. During this critical time, fast growing weeds can significantly reduce establishment of the slower growing prairie perennials (Williams et al 2007). Management techniques such as frequent mowing in the first and second growing seasons after seeding can significantly improve establishment of the natives (Williams et al. 2007). However, the weeds that persist after mowing and can still reduce native plant establishment (Brown and Bugg 2001).

Iowa DOT currently uses frequent mowing to reduce weeds in re-vegetation projects. However, effectiveness of this technique in weed suppression has varied (Carpenter 2004). In an attempt to control weeds in new prairie re-vegetation projects, Iowa DOT has added annual rye (*Lolium multiflorum*) with the prairie seed mix as a nurse crop. It is believed that a fast growing annual species, such as annual rye, will occupy (above and below ground) space that would otherwise be occupied by fast growing weeds before the slower growing perennial prairie plants are established. Iowa DOT seeding specifications for re-vegetation projects require annual rye to be seeded with the prairie seed at a rate of 5.6 kg/ha (5.0 lbs/ac). In addition, the specifications also require a no-till seed drill be used for seeding re-vegetation projects (Iowa DOT 2004).

Seeding annual rye at a rate of 5.6 kg/ha of annual rye equates to 259 live seeds per square meter (Henderson and Kern 1999). We hypothesized that annual rye seeds planted at this seeding rate into narrow furrows with a no-till grass drill would result in excessive competition for the natives and severely reduce their establishment.

The objectives of this study were to 1) assess and compare native plant emergence, richness, and biomass among three annual rye seeding treatments, and 2) assess and compare weed biomass and richness among three annual rye seeding rate treatments. The treatments were: No Rye, Rye (5.6 kg/ha - 5.0 lbs./ac) and 2x Rye (11.2 kg/ha - 10.0 lbs/ac). The seeding rate of prairie seed was the same in all treatments.

This research project was designed to provide information on the advisability of using annual rye as a nurse crop seed to a native seed mix in re-vegetation plantings. This information can be used to revise or develop nurse crop recommendations for re-vegetation projects.

MATERIALS AND METHODS

Site Description

Research plots were established in 2004 in the north and south right-of-way (ROW) of U.S. 20 between east Grundy County line and the north exit of U.S. 63 exit in Black Hawk County, Cedar Falls Iowa. The experiment used a randomized block design for treatments. Three blocks were located in the north and three in the south ROW. Each block consisted of three 0.07 ha plots. There were three rye treatments in the experiment: No Rye, Rye (5.6 kg/ha - 5.0 lbs/ac), and 2x Rye (11.2 kg/ha - 10 lbs/ac). 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 1). 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 added to each bag and mixed thoroughly with the seed to improve the flow of seed through the no-till drill.

The plots were seeded in early June of 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 2004 and 2005. 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). The vegetation was sampled at one meter intervals using a 0.10 m^2 quadrat frame. Within the quadrat, 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. Native grasses, forbs, and weeds were clipped at ground level and bagged by plant group. Bags were oven dried (60^{o}C) for three days and weighed.

Data Analysis

The data were analyzed using an analysis of variance (ANOVA) with two factors: block and seeding rate. The model included six blocks, and three seeding rate factors (No Rye, Rye, 2x Rye). 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 were log transformed to run the ANOVA and the reported results were back-transformed. A Tukey's protected test for pairwise comparisons was used to compare means among the seeding rate treatments.

<u>RESULTS and DISCUSSION</u>

Effects on Native Plant Emergence

Annual rye reduced prairie plant emergence. ANOVA results revealed significant differences among seeding rate treatments (Figure 1). Rye and 2x Rye plots had 22% and 36% fewer native seedlings than plots without annual rye (Figure 1). The addition of annual rye had a greater suppression effect on the native grasses than on the forbs. There was a 2-fold decrease of native grass seedlings in plots seeded with annual rye (Figure 2). It appears that the reduction in establishment of the native grasses affects certain species more than others. Big bluestem

(*Andropogon gerardii*) and Canada wild rye (*Elymus canadensis*) fared the worst. In annual rye plots, there were up to 60% fewer Canada wild rye plants and 52% fewer big bluestem plants than in plots not seeded with annual rye (Table 1). Both species are important components of reconstructed prairies in Iowa. Canada wild rye is an early colonizer and can provide weed and erosion control in the first few years of the planting. By contrast, big bluestem is a long-lived dominant species providing long-term erosion and weed control. As the planting matures, big bluestem comprises a significant portion of plant growth. In a re-vegetation planting, fewer Canada wild rye and big bluestem plants may permit establishment of undesirable species.

Similar phenologies of the nurse crop (annual rye) and the prairie grasses may account for the differential effects in establishment measured in the experiment. Annual rye and native grasses and have similar leaf and root structures. They may be competing for the same resources above and below ground. The rapid growing annual rye may simply garner those resources faster than the slower growing perennial prairie grasses. No-till drilling the seed of the two species in close proximity may have increased the competition between the annual rye and the prairie grasses.

Allelopathy may also be responsible for the decline in native grasses. Previous research has shown that annual rye produces compounds that inhibit germination of green foxtail (*Setaria viridis*) and other weedy plants (Putnam and DeFrank 1983). The high density of annual rye plants planted in close proximity to the natives, may have concentrated allelopathic compounds which inhibited native grass germination but not forbs in this experiment.

Effects on Species Richness

In 2004, plots with annual rye had fewer native species than plots without annual rye, however, the trend was not significant (Table 2). This trend was not observed in 2005 (Table 2). Very few representatives of many of the species were detected in quadrat samples. Therefore, there was no clear pattern of a single or a group of species favored by one treatment over another (Table 1).

Plant Biomass

Annual rye reduced weed biomass up to 41% in 2004 (Table 3). Less foxtail (*Setaria spp*.) was observed in plots seeded with annual rye. Quick establishment and rapid growth appears to give annual rye a competitive edge over many weeds. However, in year two (2005), there were no differences in weed biomass among rye treatments (Table 3). It appears that the benefit of using annual rye to suppress weeds in the first year did not extend into the second growing season.

Native plant biomass was similar among treatments in year one (Table 3). Most of the prairie seedlings that were sampled in the first year were very tiny plants. There was up to 9 times more biomass of weeds than the prairie plants (Table 3). This is the typical pattern for the first year of a prairie reconstruction.

In year two, there was up to 3.6 times more prairie grass biomass in no-rye plots although forb biomass was similar among all treatments (Table 3). This may be a function of two things. First, there were more individuals of native grass plants in no-rye plots than in the rye plots. Second, the prairie grasses in no-rye plots, while being similar in size to the plants in the rye plots in the first year, may have developed a more extensive root system because there was no annual rye competition. The vigorous growth of the native grasses in the no-rye plots in year-two may be reflective of the stunting of the native grasses by annual rye in year-one.

CONCLUSION

Seeding annual rye as a nurse crop with perennial prairie seed reduced weed growth in the first year. This may be acceptable if the planting site is prone to erosion and quick establishment of vegetative cover is needed to protect the soil. However, in a re-vegetation planting, retaining the killed sod virtually eliminates the potential for soil erosion and a nurse crop is not needed. This study shows that drill seeding an annual species, such as annual rye, with perennial prairie seed can negatively affect native plant emergence and growth in early establishment of a reconstructed prairie. The use of annual rye will result in fewer numbers of prairie plants and also stunt the growth of the prairie grasses. As a consequence, the prairie planting is more prone to weedy invasion. This may require additional maintenance for weed control or re-seeding, adding cost to the planting.

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Table 1. Native species and their seeding rates planted in 2004 and total plants that were sampled in 2005.

	SEEDING RATE	TOTAL SEEDLINGS SAMPLED in 2005 (in 54 sq. meters)		
GRASSES	Pure Live Seeds/sq. meter	NO RYE	RYE	2X RYE
Andropogon gerardii	11	21	10	10
Bouteloua curtipendula	11	13	12	7
Calamagrostis canadensis	11	0	0	0
Elymus canadensis	11	58	24	23
Koeleria macrantha	11	0	0	0
Panicum virgatum	5	5	4	7
Schizachyrium scoparius	11	2	1	2
Sorghastrum nutans	11	2	6	0
Spartina pectinata	11	0	0	0
Sporobolus asper	5	4	6	2
Sporobolus heterolepis	8	0	0	0
Stipa spartea	3	0	1	0
FORBS				
Allium canadense	5	0	0	0
Amorpha canescens	11	0	0	0
Anemone cylindrica	11	0	0	0
Artemisia ludoviciana	11	0	0	0
Asclepias incarnata	11	8	13	8
Asclepias tuberosa	3	4	8	2
Aster ericoides	11	8	19	6
Aster laevis	11	0	0	1
Aster novae-angliae	11	0	2	0
Aster sericeus	11	0	0	0
Astragalus canadensis	11	1	1	1
Baptisia leucantha	1	0	0	0
Cassia fasiculata	11	23	14	11
Coreopsis palmata	1	0	0	0
Dalea candida	11	4	2	0
Dalea purpurea	11	4	4	4
Desmodium canadense	1	6	1	1
Echinacea pallida	11	3	2	2
Erynigium yuccifolium	11	0	0	0
Eupatorium altissimum	22	1	3	1
Helenium autumnale	43	0	1	0
Helianthus grosseserratus	1	1	5	1
Helianthus laetiflorus	3	0	2	0
Heliopsis helianthoides	11	21	14	11
Lespedeza capitata	11	1	1	0
Liatris aspera	11	0	0	0
Liatris ligulistylis	5	0	0	0
Liatris pycnostachya	11	1	0	0

Lobelia siphilitica	11	0	0	0
Monarda fistulosa	22	14	12	4
Parthenium integrifolium	5	0	1	0
Penstemon digitalis	11	0	0	0
Penstemon grandiflorus	11	1	0	0
Phlox pilosa	2	0	0	0
Pycnanthemum virginianum	54	1	2	1
Ratibida pinnata	11	5	4	3
Rosa spp.	0.5	0	0	0
Rudbeckia hirta	11	20	13	11
Rudbeckia subtomentosa	11	5	2	0
Silphium integrifolium	1	4	3	0
Silphium laciniatum	0.1	0	0	0
Solidago graminifolia	11	1	0	0
Solidago nemoralis	11	0	0	0
Solidago rigida	11	4	3	2
Solidago speciosa	11	0	0	0
Tradescantia ohiensis	11	0	0	0
Verbena hastata	32	0	0	1
Verbena stricta	11	4	3	7
Vernonia fasciculata	11	0	0	1
Veronicastrum virginicum	11	0	0	0
Zizia aurea	11	3	5	2
TOTAL	666	253	204	132

Table 2. Mean numbers of native and weed species and standard deviations of plants sampled in September 2004 and 2005. Means were log 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 back-transformed.

	Treatments			
Plant Group (Year)	No Rye (s.d.)	Rye (s.d.)	2x Rye (s.d.)	p-value
Native Species (2004)	8.8 (4.09)	7.9 (2.84)	7.1 (2.28)	0.22
Native Species (2005)	5.8 (3.42)	6.6 (3.45)	4.8 (2.11)	0.35
Weed Species (2004)	6.1 (1.00)	5.8 (0.97)	5.3 (2.23)	0.35
Weed Species (2005)	7.3 (1.40)	7.4 (1.48)	6.8 (1.37)	0.40

Table 3. Mean biomass (grams-dry weight) and standard deviations of plant groups sampled in September 2004 and 2005. Means were log 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 back-transformed.

	----------------------Treatments----------------------			
Plant Group (Year)	No Rye (s.d.)	Rye (s.d.)	2x Rye (s.d.)	p-value
Native Grass (2004)	0.25 (0.248)	0.16 (0.184)	0.22 (0.144)	0.72
Native Grass (2005)	9.1 (5.14)[a]	2.5 (3.60)[b]	3.7 (3.47)[b]	0.001
Native Forbs (2004)	0.67 (0.619)	0.38 (0.292)	0.70 (0.501)	0.45
Native Forbs (2005)	4.9 (0.515)	6.5 (5.54)	4.0 (4.39)	0.47
Total Weeds (2004)	8.1 (2.95)	4.8 (2.70)	5.0 (2.57)	0.09
Total Weeds (2005)	14.3 (3.72)	16.5 (2.20)	17.0 (3.41)	0.11

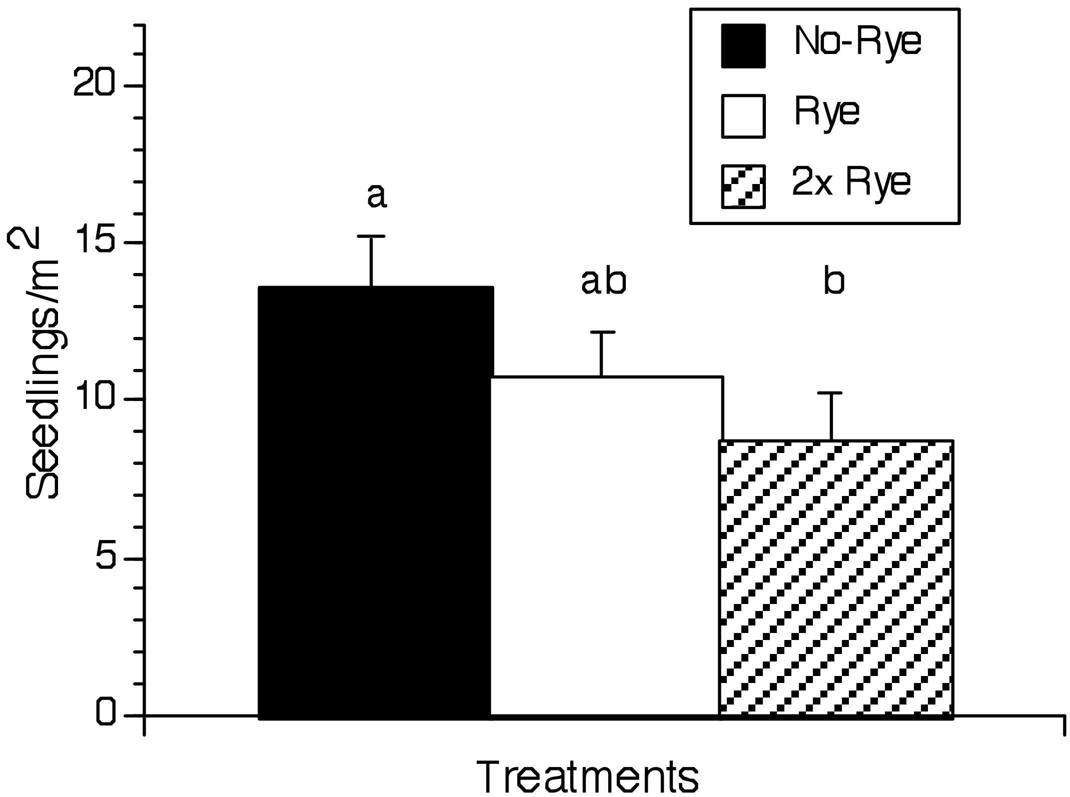

Figure 1. Mean number of native seedlings by rye treatment sampled in 2004. Native seedlings were significantly ($p<0.05$) lower in plots seeded with 2x rye (11.2 kg annual rye/ha) over no rye controls. Treatment means were log transformed and analyzed with a one-way ANOVA. Different letters are significantly ($p<0.05$) different based on a Tukey HSD test for each group. Reported means were back-transformed.

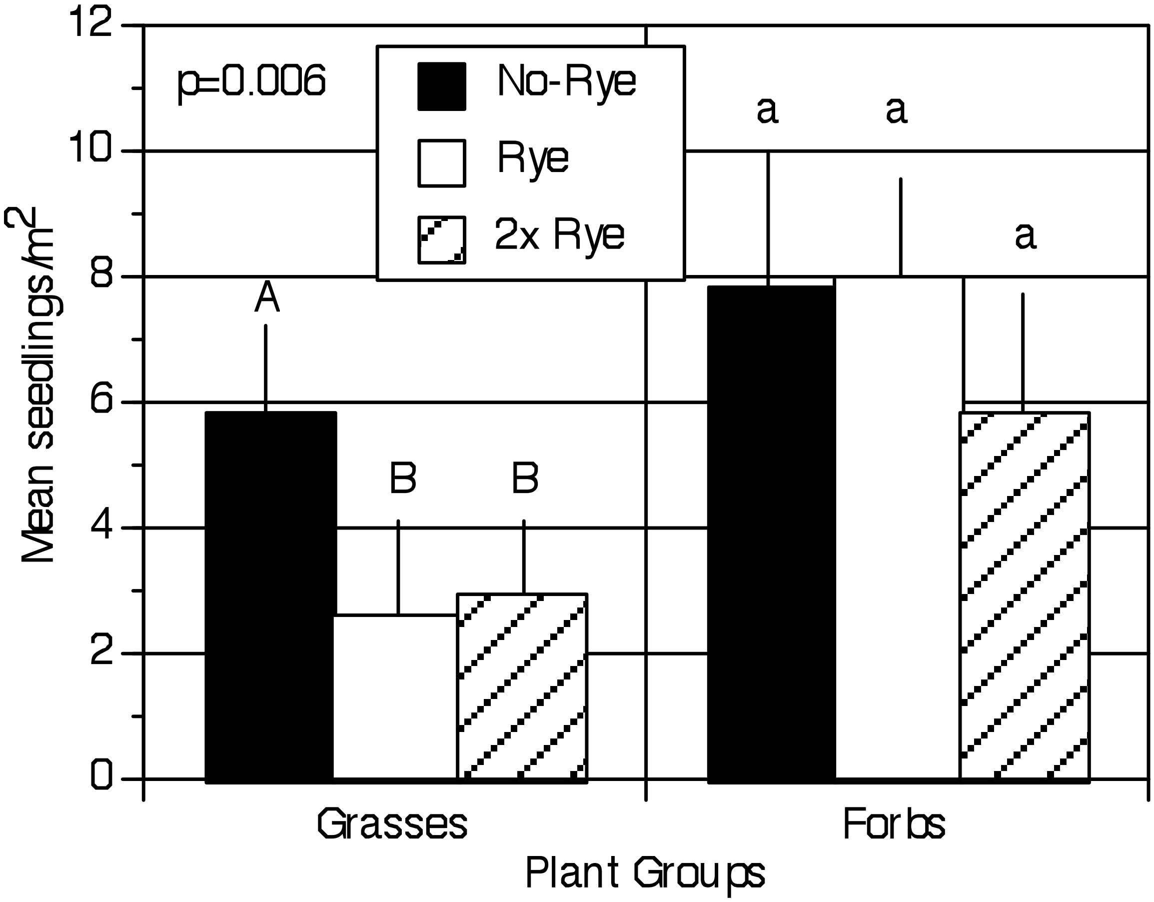

Figure 2. Mean number of native grass and forb seedlings by rye treatment sampled in 2004. Native grass seedlings were significantly ($p=0.006$) lower in plots seeded with rye and 2x rye over no rye controls. Forb emergence was not significantly different in plots seeded with annual rye. Treatment means were log transformed and 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 back-transformed.

Color or B&W Photo

Appendix Figure 1. A 2x-rye plot in the east bound right-of-way along U.S. Hwy. 20 in Black Hawk County, Iowa July 2004. This photograph was taken 5 weeks after the plot was seeded with a no-till grass drill. Note: Most of the grass growth in the rows was annual rye.

Color or B&W Photo

Appendix Figure 2. A no-rye (control) plot in the east bound right-of-way along U.S. Hwy. 20 in Black Hawk County, Iowa. This plot has never been burned and has not been mowed since August 2005. The photograph was taken in August 2009, six years after the plot was seeded.

Color or B&W Photo

Appendix Figure 3. A 2x rye plot in the east bound right-of-way along U.S. Hwy. 20 in Black Hawk County, Iowa. This plot has never been burned and has not been mowed since August 2005. The photograph was taken in August 2009, six years after the plot was seeded.