Optimizing graminoid composition in cost-effective seed mixes for prairie strips

Preliminary Technical Report

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Introduction

In order to reduce nutrient loss and increase other ecological benefits, there is growing interest in integrating reconstructed tallgrass prairie stands within and around crop fields. The most recent Farm Bill creates a new conservation practice (CP-43, Prairie Strips) to encourage prairie vegetation in and around farmed fields for the Conservation Reserve Program (CRP). Because this practice is flexible and easy to integrate into conventionally farmed fields, Prairie Strips have proven very popular, and nearly 15,000 acres have been enrolled in less than 2 years (Farm Service Agency 2021).

To optimize the potential value of this popular nutrient reduction practice, we need to ensure they maximize multifunctionality (i.e., they simultaneously provide multiple ecological benefits) in a cost-effective way. Multi-functional, high quality prairie habitat consists of grassland with high abundance of forbs, but attempts to restore diverse stands of mixed grasses and forbs often result in poor establishment or poor long-term persistence of forb species. Several authors have shown that the overabundance of grasses in the establishing stands of native grassland vegetation can lead to poor forb establishment or loss of forb abundance and diversity over time (Dickson and Busby 2009; Grman et al. 2021). These and similar studies such as Meissen et al. (2020) and Peters and Schottler (2010) show that seed mix design, especially the use of balanced grass to forb seeding rates (by seed density), plays a leading role in increasing forb establishment and limiting grass dominance.

Balanced grass-forb seed mix designs may not necessarily ensure successful forb establishment or long-term persistence. There is a tendency for many commercial seed mixes used in CRP practices (including those that encourage balanced grass forb seeding such as CP-43 Prairie Strips) to prioritize simple, low cost seed mix designs that meet minimum specifications. This type of seed mix design typically leads to mixes with high seeding rates of a few readily available, low-cost warm-season grass species but few other species of grass-like plants (graminoids). Despite some degree of commercial availability and feasibility of use, most non-C4 graminoids, especially sedges, are underrepresented in prairie reconstructions (Kindscher and Tieszen 1998; Sivicek and Taft 2011). Seed mixes with low graminoid diversity and high abundance of common warm-season grasses may result in poor forb establishment and persistence, even when seed mixes have a well-developed forb component. In contrast, addition of sedges and cool-season grasses may increase the ecosystem services supported. For example, some sedges and cool season grasses host pollinators that other grasses do not (Narem and Meyer 2017). Phenological diversity in prairie species restoration increases weed resistance (Losure et al. 2007). Increasing the potential graminoid species making up the established stand could thus improve the long-term habitat quality and ecosystem functioning of prairie strips.

Timing of seeding may also play an important role in determining how well prairie strips can be established in the context of differing seed mix designs. Even in seed mixes with low graminoid diversity and high abundance of common warm-season grasses, seeding in the dormant season may prevent overabundance of warm-season grasses by lowering initial establishment rates of dominant warm-season grasses while increasing forb establishment (Larson et al. 2011). In seed mixes that include diverse graminoids such as sedges and C3 grasses, seeding in the dormant season may increase establishment of non-C4 graminoids as well as forbs (Glidden et al. 2021), resulting in denser stands more resistant to invasive C3 grasses.

In this report, our objective was to investigate whether graminoid diversity in seed mixes influences performance of prairie strips by evaluating the effects of graminoid composition in seed mixes (diverse vs. simple) and timing of seeding (dormant vs. spring) on native plant establishment and cost-effectiveness.

Methods

Study site and design

The study site is located at the Roadman Farm Demonstration Area near Dike, IA in Grundy County (Fig. 1). The soils underlying the study site are primarily moderately well drained Kenyon loams, though significant areas are composed of somewhat poorly drained Clyde silty clay loams and Floyd loams (Natural Resources Conservation Service 2021). Topographically, the study site is located on generally level ground where slopes do not exceed 5% grade. Land use prior to this study was agricultural, with corn and soybeans consistently grown in rotation at the site.

This study is part of a larger prairie strips project developed and installed in partnership with Iowa State University's STRIPS program and Hertz Farm Management. The fields where this project was established were enrolled in the 2019 initial sign-up of the USDA's CP-43 Prairie Strips practice. The ISU STRIPS team determined strip placement in the field, while UNI researchers determined the makeup and location of study treatments on the placed strips.

We prepared the study site using tillage after crop production. In the summer of 2020, the farm operator grew corn throughout the site. The farm operator used a combine with a chopping corn head to harvest in October 2020. To break up the remaining residue, we used one pass of disc cultivation after harvest. The prepared seedbed was firm but generally covered by 50-75% corn residue.

To assess native plant establishment and cost-effectiveness of seed mix designs with varied graminoid composition, we installed an experiment with a split plot design in November 2020 (Fig. 2). We established a study area consisting of eight prairie strips, each approximately 1 ha. Individual strips were either 12.2 m wide and 750 m long or 24.4 m wide and 390 m long. One strip was 12.2 m wide and 610 m long since a residential lot interrupted the strip. Another strip was slightly irregularly shaped to border a grain bin site. We randomly assigned a seed mix, diverse grass composition or simple grass composition, to each strip (whole plot). Within each strip, we randomly applied a seeding time treatment to each half of the strip at two levels: 1) dormant seeded and 2) spring seeded (split plot) (n=8).

In order to explore whether graminoid diversity influences performance in prairie reconstruction we tested two seed mixes with contrasting composition of graminoids. We varied the rates and number of graminoid species included, but we held the forb composition constant (Appendix 1). We designed two seed mixes: 1) a 5 Grass Mix that included 4 common warm season grasses and 1 common cool season grass (all planted at high rates), and 2) a 16 Grass Mix that included 8 warm-season grasses, 2 cool-season grasses, 5 sedges, and one rush (all planted at low to moderate rates). In 2020, the 16 Grass Mix was $751/ ha, while the 5 Grass Mix was $720/ ha. The diverse forb component matches those of seed mixes from similar studies (Meissen et al. 2020; Glidden et al. 2021). To ensure accuracy in seeding rates and seed purity, we calculated seeding rates for each species using pure live seed (PLS). We standardized the overall seeding rate among mixes at approximately 430 PLS seeds per square meter. We purchased seed from native seed nurseries in Iowa and adjacent states in January 2020 and stored the seed in a temperature and humidity controlled (4°C, 45% RH) cooler until planting. We weighed, bagged, and mixed the seed for each plot separately. To ensure soils were stabilized as prairie seedlings established, we included a nurse crop of oats in spring seeded treatments at a rate of 16.8 kg/ha and winter wheat in fall seeded treatments at a rate of 16.8 kg/ha.

We seeded the study site in the dormant and spring seasons of 2020-2021. We used a Truax FLX-86U no-till drill with a John Deere JD-5325 tractor to seed each treatment area. To minimize seed contamination between treatments, we cleaned out the drill after seeding different mixes. Dormant seeded treatments were planted November 20-21, 2020 while spring seeded treatments were planted May 24-26, 2021. We chose mid-November as a dormant seeding date since NRCS generally restricts planting earlier than November 15 in Iowa, and seeding later when ground temperatures were below freezing would have prevented the seed drill from operating properly. We chose a late-May spring seeding date primarily to reflect the timing preference of farmers establishing similar types of habitat in related CRP practices (CP-42) (Jackson and Meissen 2019).

The farm operator conducted establishment mowing over the first growing season to control weed growth. We mowed vegetation throughout the 2021 growing season to ~ 10 cm when most vegetation reached approximately 1 m in height. Due to drought conditions throughout the 2021 growing season, weed regrowth was slower than normal and we reduced mowing frequency. The farm operator mowed once in mid-summer, and left the resulting thatch on site.

Data collection and analysis

We measured plant density and frequency in August 2021, and used density estimates to calculate establishment and cost-effectiveness metrics. We sampled later in the year to allow seedlings to grow to a size that allowed for confidence in seedling identification. We used QGIS (QGIS Development Team 2022) to generate 10 random sampling points within polygons mapped to each treatment area. In one case, part of one strip was farmed during the year and we generated sampling polygons to avoid sampling in the farmed area. We applied a negative buffer of 2 m to the polygons to avoid sampling edges. In some areas, the prairie strips seeded did not exactly match the planting plan, resulting in sampling points outside the strip. In these cases, we re-positioned the sampling point 2 m inside and perpendicular to the true strip edge from the initially mapped sampling point. To sample plant composition at each random point, we used a modified nested quadrat sampling method described in the National Protocol Framework for Monitoring Vegetation in Prairie Reconstructions (McColpin et al. 2019). In this method, observers record plant identity and presence in a series of nested quadrats (0.0625, 0.125, 0.25, 0.5, and 1 m^2). We additionally measured density of sown species in the 0.125 m^2 quadrats, where we counted and identified all individuals (ramets) of seeded species >10 cm tall. We calculated frequency and species richness metrics using the 1 m^2 quadrat measurements. We assessed responses of general vegetation types based on typical land management objectives of prairie strips (i.e. prioritizing native perennial plants of high conservation value). We defined the following classifications within this group: 1) sown forbs, 2) sown graminoids, 3) ruderal weeds (annual or biennial species of any origin with a coefficient of conservatism (CoC) < 1), 4) ruderal native perennials (unsown perennial native species with CoC < 1), 5) perennial weeds (introduced perennial species), 6) woody plants (tree and shrub species of any origin), and 7) other native species (unsown native species with CoC > 1). We found that ruderal native perennials, woody plants, and other unsown native species were generally absent from the vegetation, and do not present data from these categories in our results.

To assess cost-effectiveness, we divided the sum of observed ramets of each sown species in each plot by the total cost of inputs per plot to estimate the amount of prairie plants produced per each dollar spent (ramets/$1). We considered all relevant inputs required to prepare, plant, and manage each treatment. Inputs included costs ($ per acre) of disking, seed, drill seeding, and mowing. We used quote prices from our seed purchase for this project as the seed input cost. For other inputs, we used Plastina (2020) and Plastina (2021) to estimate CRP management costs directly relevant to prairie reconstruction in agricultural landscapes.

To evaluate the effect of seed mix graminoid composition on prairie strip establishment we used linear mixed effects (LME) models. We analyzed LME models in R using ANOVA (R Core Team 2020) to test for main effects and interactions. We modeled seed mix, timing of seeding, and interactions as fixed effects and whole-plot (strip) as a random effect. To meet the assumptions of normality and homoscedasticity of residual variance, we used a log(y+0.01) transformation for total ramets, milkweed ramets and ramets/$. We present raw data in all figures, while we report and discuss results of analyses using transformed data.

Results

Sown Species Density

Based on preliminary first year data, initial native plant establishment in our study was low. We found sown native species at densities of approximately 16 individuals (ramets)/m^2 (Fig. 3). Seed mix graminoid diversity did not predict overall native plant density, but we found it was generally higher with dormant seeding ($F = 13.73$, $df = {}_{1,6}$, $p < 0.05$).

Frequency of Plant Types

Emerging stands generally comprised a mix of sown forbs, sown graminoids and ruderal/ perennial weeds. We found sown forbs at 76.9% frequency (SE, 5.1%) overall (Fig. 4). Sown forbs were more abundant in dormant seeded treatments (87.5% frequency (SE, 3.7%) than in spring seeded ones (66.3% frequency (SE, 8.0%) ($F = 5.01$, $df = {}_{1,6}$, $p < 0.05$), but graminoid diversity of the seed mix did not influence forb frequency. Sown graminoids were especially common in all treatments, and were found at 84.4% frequency (SE, 3.2%) (Fig. 4). Neither timing of seeding nor graminoid diversity of the seed mix predicted frequency of sown graminoids. We found ruderal weeds to be the most abundant vegetation type in our study, with 100% frequency (SE, 0 %) (Fig. 5). Perennial weeds were also relatively common, and were found at 60.6% frequency (SE, 7.7%) (Fig. 5). No treatments predicted frequency of either ruderal or perennial weeds.

Species Richness

On average and across treatments, we found prairie strips in our study to have approximately 14 species in total. Among graminoids and forbs, species richness of grasses was higher in the 16 Grass Mix (7.0 species (SE, 0.3 species)) than in the 5 Grass Mix (4.6 species (SE, 0.2 species)) ($F = 40.11$, $df = {}_{1,6}$, $p < 0.001$), but seed mix did not predict forb richness (Fig. 6). Forb species richness was considerably higher with dormant seeding (11.3 species (SE, 0.6 species)) than with spring seeding (5.6 species (SE, 0.6 species)) ($F = 49.39$, $df = {}_{1,6}$, $p < 0.001$) (Fig. 6). Timing of seeding did not predict species richness in grasses.

Cost-effectiveness

Timing of seeding affects cost-effectiveness. We found that dormant seeding is more cost-effective than spring seeding, where we found dormant seeded strips produced 244 ramets/ dollar (SE, 46 ramets/ dollar) and spring seeded strips produced 103 ramets/ dollar (SE, 37 ramets/ dollar) ($F = 13.73$, $df = {}_{1,6}$, $p < 0.05$) (Fig. 7). While there was no statistically significant effect of seed mix on cost-effectiveness, we found that the 16 Grass Mix produced 196 ramets/ dollar (SE, 58 ramets/ dollar) while the 5 Grass Mix produced 151 ramets/ dollar (SE, 37 ramets/ dollar).

Discussion

Graminoid diversity of the seed mix has mixed effects on initial prairie strip establishment. We found that grass species richness in emerging plantings was the establishment measure most affected by graminoid diversity in the seed mix. Unsurprisingly, the 16 Grass Mix produced more graminoid species than the 5 Grass Mix. Other measures, such as graminoid abundance were not initially affected by the composition of graminoids in the seed mix. We were surprised to find no decrease in establishment with the warm-season grass dominated 5 Grass Mix when dormant planting. Other studies show substatially lower establishment in similar seed mixes when comparing dormant and spring seeding (Glidden et al. 2021). Our study coincided with an historic drought during summer 2021, which may have masked the effect of seeding time on grass establishment by creating generally poor conditions for emerging seedlings seeded in late May when drought conditions were particularly severe. Dormant-seeded grass seedlings may have had more time to establish during the cooler, slightly wetter times during late April and early May.

Timing of seeding has a substantial positive initial impact on prairie strip establishment regardless of the graminoid composition of the seed mix. Forb establishment increased dramatically with dormant seeding and drove an overall improvement in stand establishment. Dormant seeding increased forb abundance, doubled forb species richness, and increased overall sown species density by nearly twofold. These results accord generally with other studies that have assessed timing of seeding, which typically show higher forb abundance in dormant compared to growing season plantings (Larson et al. 2011; Glidden et al. 2021); though see Peters and Schottler (2010) who found no overall impact of seeding time.

By seeding prairie strips in the dormant season, higher quality habitat can be established at no additional cost. Initial cost-effectiveness was roughly twice as high in prairie strips seeded in the dormant season compared to those seeded in spring. The increase was likely due to the high performance of forbs which strongly benefitted from dormant seeding, though high cool season grass stem establishment may have contributed to the cost-effectiveness differences. Further data analysis on functional group stem density may help pinpoint the plants driving differences. Because our study was implemented during a significant drought year, it is unknown whether such large differences in cost effectiveness from seeding time could be expected when establishing prairie strips in more typical year. Other studies suggest differences would be more modest (Glidden et al. 2021).

More time is needed to assess the full effects of seed mix graminoid composition. Our study assesses only first year seedling establishment, but other studies show the effects of grass overdominance do not become apparent until years 5-10 (Dickson and Busby 2009; Grman et al. 2021). At least 3 to 4 more years of data is required before drawing well founded conclusions about the effects of graminoid diversity of the seed mix on prairie strip performance.

Acknowledgements

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Figure 1. Location of study site within Iowa.

Figure 2. Experimental layout at Roadman Farm Demonstration Area.

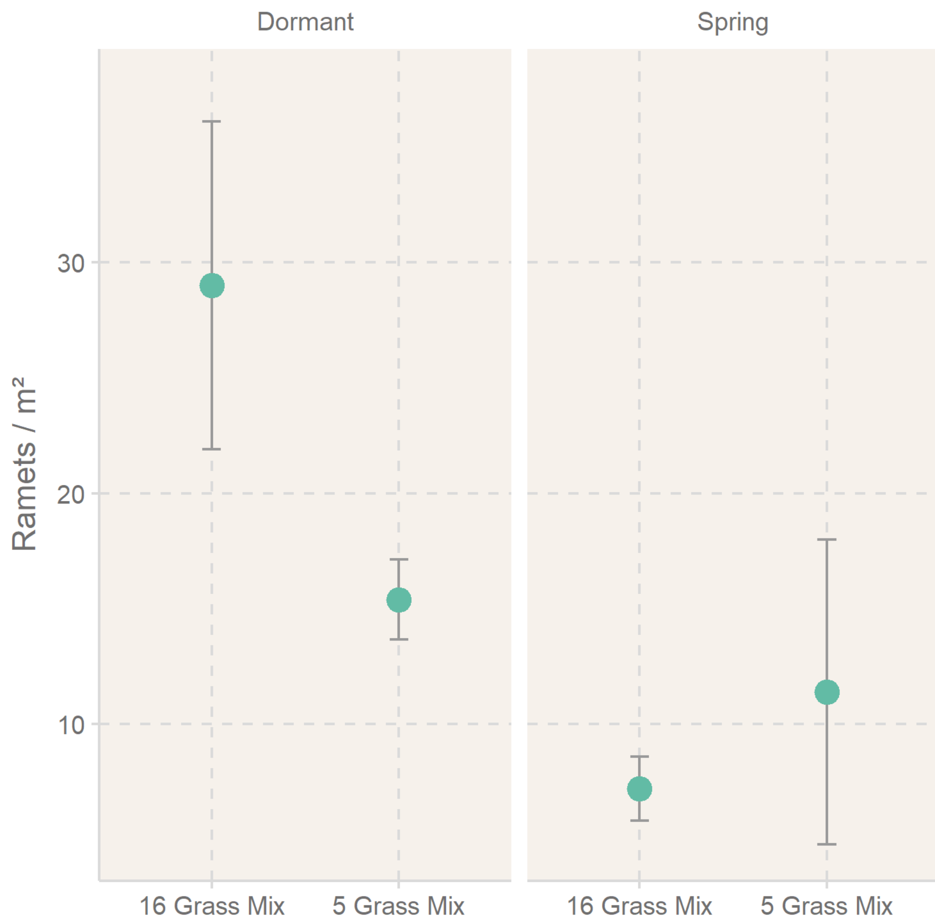

Figure 3. Overall stem density of seeded species in seed mixes with a diverse (16 species) or simple (5 species) graminoid component seeded in the dormant or spring season.

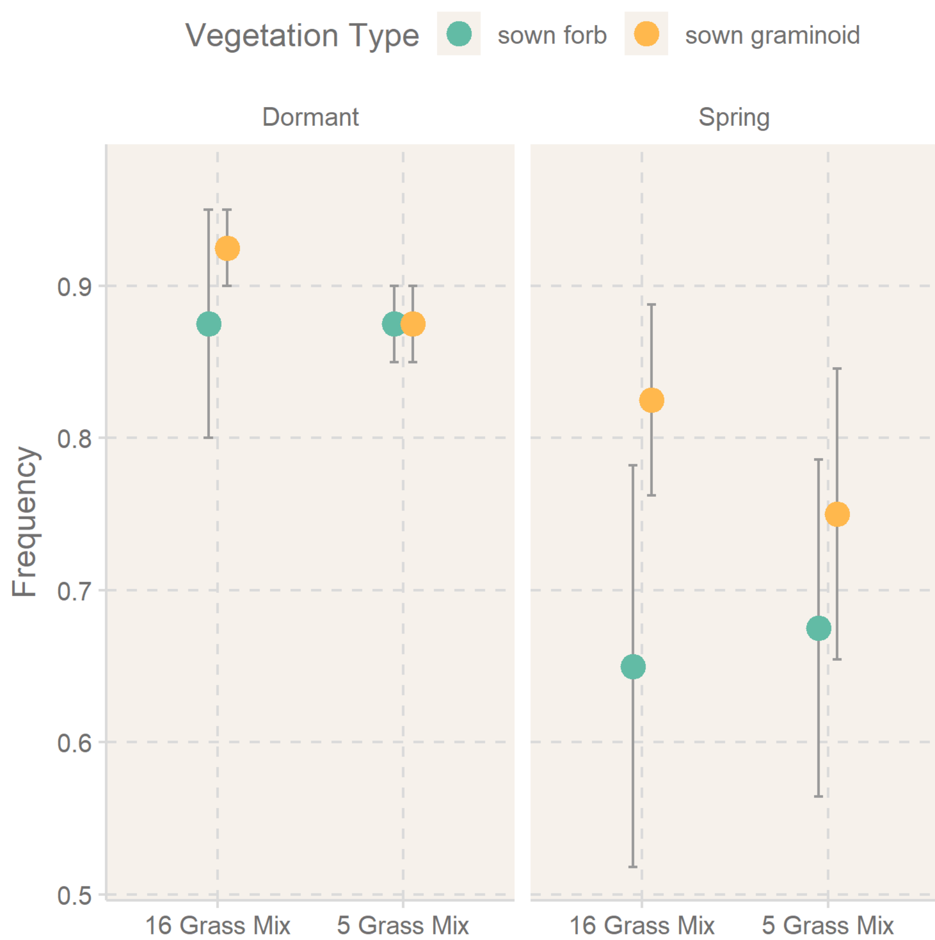

Figure 4. Frequency of sown forbs and graminoids in seed mixes with a diverse (16 species) or simple (5 species) graminoid component seeded in the dormant or spring season.

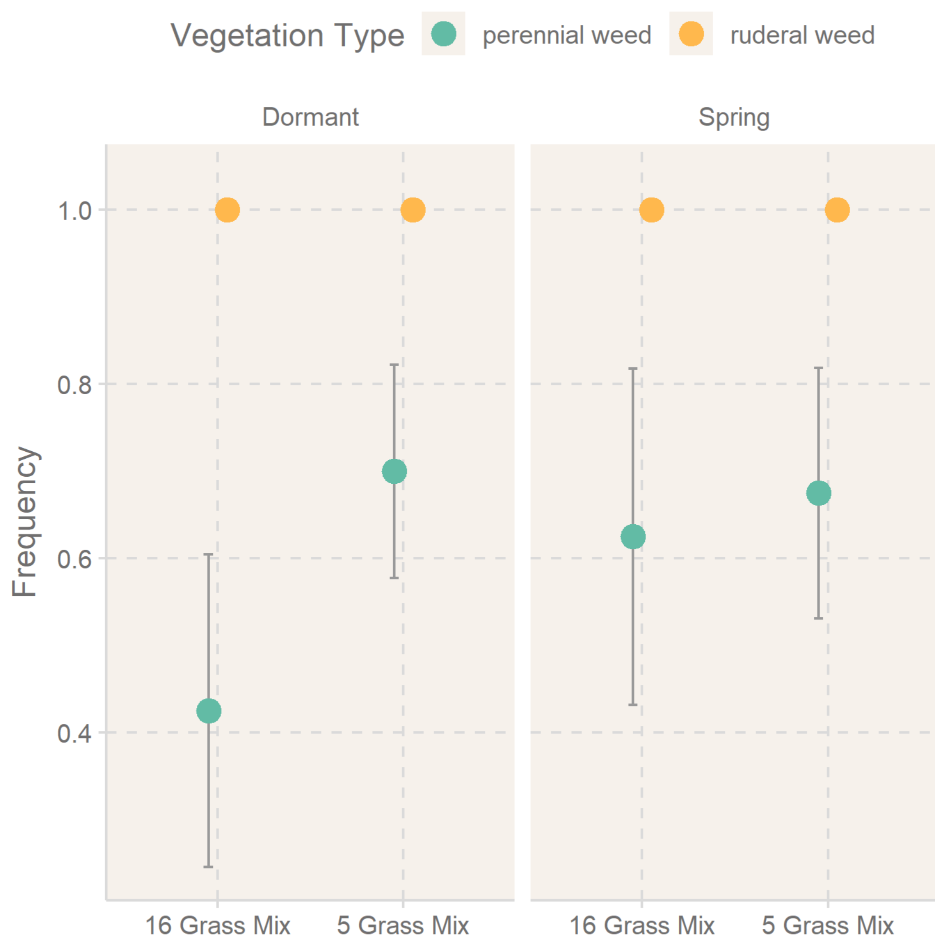

Figure 5. Frequency of ruderal and perennial weeds in seed mixes with a diverse (16 species) or simple (5 species) graminoid component seeded in the dormant or spring season.

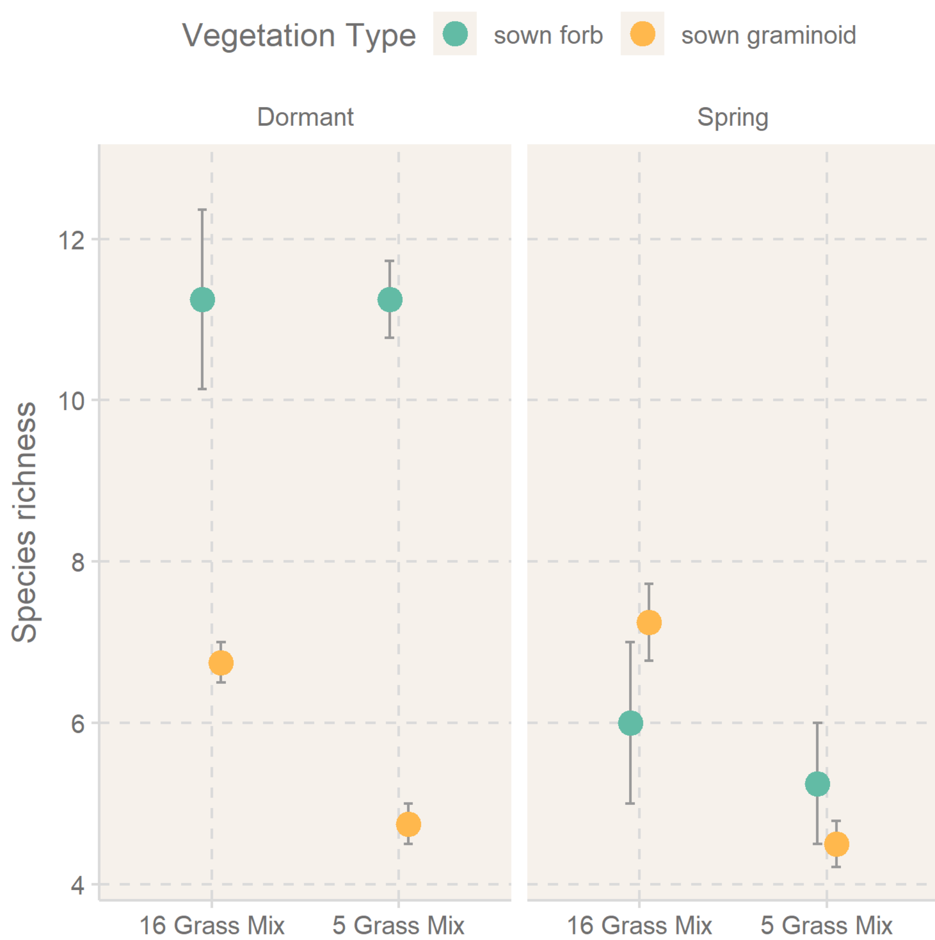

Figure 6. Species richness of sown forbs and graminoids in seed mixes with a diverse (16 species) or simple (5 species) graminoid component seeded in the dormant or spring season.

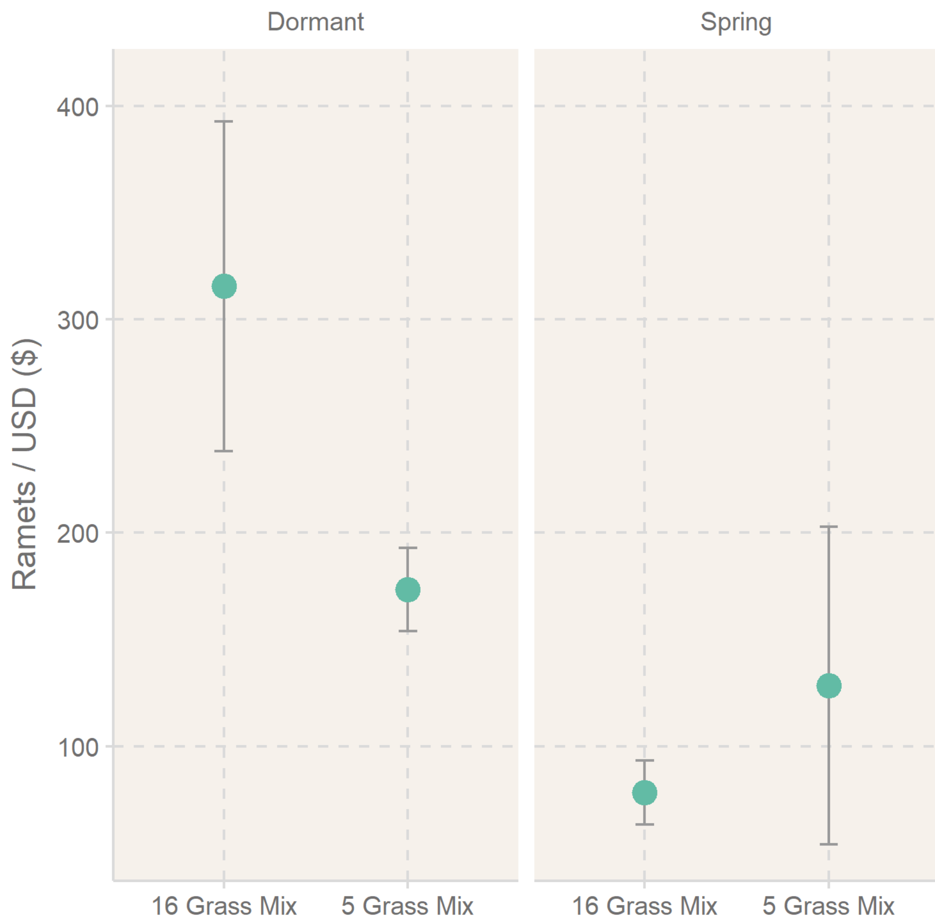

Figure 7. Number of ramets produced per $1 of input (seed, planting and establishment management) in seed mixes with a diverse (16 species) or simple (5 species) graminoid component seeded in the dormant or spring season.

Appendix 1. Seed mixes planted as treatments at the Roadman Farm Demonstration Area

Diverse Graminoid Mix (16 graminoid species)

Common Name	*Scientific Name*	*Functional group*	*Seeds/m2*
big bluestem	*Andropogon gerardii*	warm-season graminoid	10.76
sideoats grama	*Bouteloua curtipendula*	warm-season graminoid	37.67
marsh muhly	*Muhlenbergia racemosa*	warm-season graminoid	2.69
switchgrass	*Panicum virgatum*	warm-season graminoid	10.76
little bluestem	*Schizachyrium scoparium*	warm-season graminoid	37.67
Indiangrass	*Sorghastrum nutans*	warm-season graminoid	13.99
composite dropseed	*Sporobolus compositus*	warm-season graminoid	48.44
prairie dropseed	*Sporobolus heterolepis*	warm-season graminoid	0.54
yellowfruit sedge	*Carex annectens*	cool-season graminoid	10.76
Bicknell's sedge	*Carex bicknellii*	cool-season graminoid	2.15
shortbeak sedge	*Carex brevior*	cool-season graminoid	8.61
heavy sedge	*Carex gravida*	cool-season graminoid	0.22
troublesome sedge	*Carex molesta*	cool-season graminoid	4.31
Canada wildrye	*Elymus canadensis*	cool-season graminoid	8.61
Virginia wildrye	*Elymus virginicus*	cool-season graminoid	7.53
poverty rush	*Juncus tenuis*	cool-season graminoid	10.76
Canadian anemone	*Anemone canadensis*	spring forb	0.22
candle anemone	*Anemone cylindrica*	spring forb	0.54
New Jersey tea	*Ceanothus americanus*	spring forb	0.54
foxglove beardtongue	*Penstemon digitalis*	spring forb	10.76
downy phlox	*Phlox pilosa*	spring forb	0.22
longbract spiderwort	*Tradescantia bracteata*	spring forb	0.54
bluejacket	*Tradescantia ohiensis*	spring forb	1.08
golden zizia	*Zizia aurea*	spring forb	2.69
swamp milkweed	*Asclepias incarnata*	summer forb	1.08
common milkweed	*Asclepias syriaca*	summer forb	2.15
butterfly milkweed	*Asclepias tuberosa*	summer forb	0.32
whorled milkweed	*Asclepias verticillata*	summer forb	0.54
Canadian milkvetch	*Astragalus canadensis*	summer forb	10.76
largeleaf wild indigo	*Baptisia lactea*	summer forb	0.22
partridge pea	*Chamaecrista fasciculata*	summer forb	3.23
stiff tickseed	*Coreopsis palmata*	summer forb	0.43
purple prairie clover	*Dalea purpurea*	summer forb	10.76
showy ticktrefoil	*Desmodium canadense*	summer forb	1.61
Illinois ticktrefoil	*Desmodium illinoense*	summer forb	0.54
tall cinquefoil	*Drymocallis arguta*	summer forb	10.76
pale purple coneflower	*Echinacea pallida*	summer forb	2.15
button eryngo	*Eryngium yuccifolium*	summer forb	2.15

flowering spurge	*Euphorbia corollata*	summer forb	0.32
northern bedstraw	*Galium boreale*	summer forb	1.08
smooth oxeye	*Heliopsis helianthoides*	summer forb	5.38
roundhead lespedeza	*Lespedeza capitata*	summer forb	0.54
wild bergamot	*Monarda fistulosa*	summer forb	8.07
wild quinine	*Parthenium integrifolium*	summer forb	1.08
whorled mountainmint	*Pycnanthemum pilosum*	summer forb	8.07
narrowleaf mountainmint	*Pycnanthemum tenuifolium*	summer forb	10.76
Virginia mountainmint	*Pycnanthemum virginianum*	summer forb	10.76
pinnate prairie coneflower	*Ratibida pinnata*	summer forb	10.76
blackeyed Susan	*Rudbeckia hirta*	summer forb	8.07
wholeleaf rosinweed	*Silphium integrifolium*	summer forb	0.22
compassplant	*Silphium laciniatum*	summer forb	0.11
purple meadow-rue	*Thalictrum dasycarpum*	summer forb	0.54
Culver's root	*Veronicastrum virginicum*	summer forb	5.38
white sagebrush	*Artemisia ludoviciana*	fall forb	10.76
tall thoroughwort	*Eupatorium altissimum*	fall forb	2.69
flat-top goldentop	*Euthamia graminifolia*	fall forb	10.76
closed bottle gentian	*Gentiana andrewsii*	fall forb	5.38
sawtooth sunflower	*Helianthus grosseserratus*	fall forb	1.08
stiff sunflower	*Helianthus pauciflorus ssp.*	fall forb	0.22
prairie blazing star	*Liatris pycnostachya*	fall forb	1.08
great blue lobelia	*Lobelia siphilitica*	fall forb	10.76
sweet coneflower	*Rudbeckia subtomentosa*	fall forb	8.07
stiff goldenrod	*Solidago rigida*	fall forb	8.07
showy goldenrod	*Solidago speciosa*	fall forb	8.07
smooth blue aster	*Symphyotrichum laeve*	fall forb	5.38
New England aster	*Symphyotrichum novae-angliae*	fall forb	5.38
skyblue aster	*Symphyotrichum oolentangiense*	fall forb	2.69
prairie ironweed	*Vernonia fasciculata*	fall forb	2.69
	Overall total:		433.04

Simple Graminoid Mix (5 graminoid species)

Common Name	*Scientific Name*	*Functional group*	*Seeds/m^2*
big bluestem	*Andropogon gerardii*	warm-season graminoid	53.82
switchgrass	*Panicum virgatum*	warm-season graminoid	43.06
little bluestem	*Schizachyrium scoparium*	warm-season graminoid	32.29
Indiangrass	*Sorghastrum nutans*	warm-season graminoid	53.82
Canada wildrye	*Elymus canadensis*	cool-season graminoid	32.29
Canadian anemone	*Anemone canadensis*	spring forb	0.22
candle anemone	*Anemone cylindrica*	spring forb	0.54
New Jersey tea	*Ceanothus americanus*	spring forb	0.54
foxglove beardtongue	*Penstemon digitalis*	spring forb	10.76
downy phlox	*Phlox pilosa*	spring forb	0.22
longbract spiderwort	*Tradescantia bracteata*	spring forb	0.54
bluejacket	*Tradescantia ohiensis*	spring forb	1.08
golden zizia	*Zizia aurea*	spring forb	2.69
swamp milkweed	*Asclepias incarnata*	summer forb	1.08
common milkweed	*Asclepias syriaca*	summer forb	2.15
butterfly milkweed	*Asclepias tuberosa*	summer forb	0.32
whorled milkweed	*Asclepias verticillata*	summer forb	0.54
Canadian milkvetch	*Astragalus canadensis*	summer forb	10.76
largeleaf wild indigo	*Baptisia lactea*	summer forb	0.22
partridge pea	*Chamaecrista fasciculata*	summer forb	3.23
stiff tickseed	*Coreopsis palmata*	summer forb	0.43
purple prairie clover	*Dalea purpurea*	summer forb	10.76
showy ticktrefoil	*Desmodium canadense*	summer forb	1.61
Illinois ticktrefoil	*Desmodium illinoense*	summer forb	0.54
tall cinquefoil	*Drymocallis arguta*	summer forb	10.76
pale purple coneflower	*Echinacea pallida*	summer forb	2.15
button eryngo	*Eryngium yuccifolium*	summer forb	2.15
flowering spurge	*Euphorbia corollata*	summer forb	0.32
northern bedstraw	*Galium boreale*	summer forb	1.08
smooth oxeye	*Heliopsis helianthoides*	summer forb	5.38
roundhead lespedeza	*Lespedeza capitata*	summer forb	0.54
wild bergamot	*Monarda fistulosa*	summer forb	8.07
wild quinine	*Parthenium integrifolium*	summer forb	1.08
whorled mountainmint	*Pycnanthemum pilosum*	summer forb	8.07
narrowleaf mountainmint	*Pycnanthemum tenuifolium*	summer forb	10.76
Virginia mountainmint	*Pycnanthemum virginianum*	summer forb	10.76
pinnate prairie coneflower	*Ratibida pinnata*	summer forb	10.76
blackeyed Susan	*Rudbeckia hirta*	summer forb	8.07
wholeleaf rosinweed	*Silphium integrifolium*	summer forb	0.22
compassplant	*Silphium laciniatum*	summer forb	0.11
purple meadow-rue	*Thalictrum dasycarpum*	summer forb	0.54
Culver's root	*Veronicastrum virginicum*	summer forb	5.38

white sagebrush	*Artemisia ludoviciana*	fall forb	10.76
tall thoroughwort	*Eupatorium altissimum*	fall forb	2.69
flat-top goldentop	*Euthamia graminifolia*	fall forb	10.76
closed bottle gentian	*Gentiana andrewsii*	fall forb	5.38
sawtooth sunflower	*Helianthus grosseserratus*	fall forb	1.08
stiff sunflower	*Helianthus pauciflorus ssp.*	fall forb	0.22
prairie blazing star	*Liatris pycnostachya*	fall forb	1.08
great blue lobelia	*Lobelia siphilitica*	fall forb	10.76
sweet coneflower	*Rudbeckia subtomentosa*	fall forb	8.07
stiff goldenrod	*Solidago rigida*	fall forb	8.07
showy goldenrod	*Solidago speciosa*	fall forb	8.07
smooth blue aster	*Symphyotrichum laeve*	fall forb	5.38
New England aster	*Symphyotrichum novae-angliae*	fall forb	5.38
skyblue aster	*Symphyotrichum oolentangiense*	fall forb	2.69
prairie ironweed	*Vernonia fasciculata*	fall forb	2.69
	Overall total:		433.90