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Assessing outcome predictability in prairie strip establishment

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Assessing outcome predictability in prairie strip establishment

Technical Report

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Introduction

In order to secure long-term practice buy-in and increase new adoption of highly beneficial conservation initiatives like the USDA's Prairie Strips practice, it is important to ensure farmers can successfully employ native plant revegetation methods on their first try. Many farmers and landowners are new to establishing native vegetation, and must rely on second-hand forms of information such as practice implementation guidelines. Guidelines that are currently available are often not based on applicable scientific research. A strong scientific understanding of the methods that can achieve success in a cost-effective way are required to inform useful prairie reconstruction guidelines. In particular, three methods and design choices are especially important when implementing a prairie reconstruction: seed mix design, timing of seeding, and first year mowing management.

Seed mix design is one of the largest determinants of project cost and ecological outcomes for prairie reconstructions. Native seeds are typically the largest expense for high diversity prairie reconstruction projects (Phillips-Mao et al. 2015), with the quantity of forbs affecting cost the most since forb seed is typically much more expensive relative to grass species (Jackson and Meissen 2019). Seeding rates of different plant functional groups also affect ecological outcomes. Grass seeding rates that are especially high produce overly competitive stands which exclude forbs (McCain et al. 2010), potentially resulting in low quality pollinator habitat (Hopwood 2008). Low grass seeding rates promote bare ground, leading to perennial weed invasion in establishing stands (Meissen 2020).

Timing of seeding is an important determinant of early grassland reconstruction performance. Most prairie reconstructions are seeded either during the early growing season (Apr-Jun) or in the dormant season (Nov-Mar). For many tallgrass prairie species, particularly forbs, cold moist stratification lasting up to 60-90 days is required before seed dormancy can be broken and germination can occur (Baskin and Baskin 2014).While most conditions for dormancy breaking may be met in dormant seedings, it would be rare in growing season plantings, especially those seeded later in the summer. Larson and others (2011) showed that dormant season seeding often resulted in greater cover of native forbs. For prairie strips with wildlife habitat goals, and particularly pollinator habitat goals, increasing the abundance of diverse plant functional groups at a site by optimizing seeding time may increase ecosystem service provision at no additional cost. Surveys of private conservation landowners in Iowa indicated that the vast majority of those who planted stands of pollinator habitat seeded during the growing season rather than the dormant season (Jackson and Meissen 2019). This is in stark contrast to professional land managers from non-profit and government sectors, who nearly all prefer to seed in the dormant season (Rowe 2010). Given the objectives of prairie strips, this mismatch in actual vs. optimal seeding time may show an area where significant gains in cost effectiveness may be realized.

First-year management, particularly frequent mowing, also affects outcomes in prairie reconstruction. By the time sown prairie seeds begin germinating, post-agricultural reconstuction sites are typically thoroughly colonized by annual weeds (Smith et al. 2010). For slow-growing prairie seedlings, the highly competitive environment created by vigorous annual weed growth may result in poor seedling survival and poor prairie establishment. Williams and others (2007) showed that sown prairie seedlings survived in the high light conditions of frequently mowed warm-season grasses, while those in unmowed areas generally did not. Considering the high cost of seed (which can be over 15 times higher than the cost of mowing (Phillips-Mao et al. 2015)), cost-effectiveness could be increased through mowing by improving the establishment of seedlings.

Meissen and others (2020) found that prairie reconstruction methods, specifically using a grass-forb balanced seed mix design and conducting frequent first-year mowing, can improve ecological outcomes and cost effectiveness in prairie strips. However, this experiment was performed at a single location and single planting year, and ecosystem processes can vary dramatically across space and time. To improve our understanding of implementation methods, we conducted a field experiment to validate Meissen et al.'s (2020) conclusions about seed mix design and first year mowing, and integrated an additional treatment to test the influence of seeding time on native plant establishment and cost-effectiveness. In this report, our objectives were to (1) evaluate the effects of seed mix design (grass dominated, forb dominated, or grass-forb balanced), timing of seeding (dormant vs. spring), and first-year mowing (frequently mowed vs. unmowed) on native plant establishment and cost-effectiveness, and (2) verify the consistency of results across two equivalent field experiments at different sites and planting years.

Methods

Study sites

The study sites are located in northern Iowa at the Prairie on Farms Research and Demonstration Site in Cedar Falls, IA (42° 51′ N, 92° 48′ W) in Black Hawk County (Cedar Falls Site) and at the Iowa State University Northeast Research and Demonstration Farm (42° 56′ N, 92° 34′ W) near Nashua, IA in Floyd County (Nashua Site) (Fig. 1). The soils underlying both study sites are primarily poorly drained Clyde clay loams (NRCS 2021). Topographically, both sites are located on a low rolling hill, and slopes do not exceed 5% grade. Land use prior to this experiment was agricultural, with corn and soybeans consistently grown in rotation at the site.

We prepared the study site at Cedar Falls using tillage after crop production. In the summer of 2018, the farm operator grew corn throughout the site. Herbicide management during the 2018 growing season is unknown, but given the relative lack of weeds we observed in the area during the growing season, likely consisted of post-emergence herbicide application. The farm operator used a combine without a chopping header to harvest in October 2018, leaving heavy residue throughout the site. To create a suitable seedbed for seeding, we used four passes of disc cultivation, followed by one pass with a harrow in November 2018.

At the Nashua Site, the farm manager grew soybeans the year prior to reconstruction (2014). The farm manager applied pre-emergent herbicide (Zidua) in May, and a post-emergent herbicide (Roundup Weathermax) in mid-July. To create a suitable seedbed before planting in the spring of 2015, the farm manager chisel plowed the site in March and field cultivated twice in April. At both sites, the prepared seedbed was firm, with clods less than 0.25 in diameter.

Study design

To assess cost effective seed mix design and establishment management, we carried out two randomized complete block experiments at two different sites. At the Nashua Site, we installed a randomized complete block experiment with three replicates in May 2015 (Fig. 2). We established two 40 x 253 ft strips as blocks, each consisting of eighteen 20 x 28 ft plots. In each plot, we randomly assigned a combination of mowing and seed mix treatments (*n*=36). We manipulated mowing at two levels: 1) unmowed and 2) mowed, and seed mix treatments at three levels: 1) economy grass mix, 2) diversity mix, and 3) pollinator mix. At the Cedar Falls Site, we installed a randomized complete block experiment with three replicates in November 2018 (Fig. 2). We established two 84 x 240 ft strips as blocks, each consisting of thirty-six 20 x 28 ft plots. In each plot, we randomly assigned a combination of mowing, seed mix treatments, and seeding time (*n*=72). Mowing and seed mix design treatments were identical to those at the Nashua site, and we manipulated seeding time at two levels: dormant seeding and 2) growing season seeding.

We varied seed mix treatments primarily based on grass to forb ratio and used the same seed mixes in both studies. We designed three seed mixes to mimic typical NRCS approved mixes commonly planted in Iowa: 1) an economy grass mix which included 21 species at a 3:1 grass to forb seeding rate ratio, 2) a diversity mix which included 71 species at a 1:1 grass to forb seeding rate ratio, and 3) a pollinator mix which included 38 species at a 1:3 grass to forb ratio (Appendix 1). We selected species to meet the objectives for common USDA Conservation Reserve Program (CRP) conservation practices. The economy mix modeled the CP-25 Rare and Declining Habitat Practice, the diversity mix modeled the CP-43 Prairie Strips Practice, and the pollinator mix modeled the CP-42 Pollinator Habitat Practice. 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 40 PLS seeds per square foot. We purchased seed from native seed nurseries in Iowa and adjacent states in early 2015 (Nashua Site) and early 2018 (Cedar Falls Site) and stored the seed in a temperature and humidity controlled (4°C, 45% RH) cooler until planting. Because the seed was purchased in different years, the cost of seed differed between sites. At the Cedar Falls site, the Pollinator mix cost $819/ acre, the Diversity mix cost $545/acre, and the Economy mix cost $213/acre. At the Nashua site, the Pollinator mix cost $368/ acre, the Diversity mix cost $291/acre, and the Economy mix cost $130/acre. 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 at a rate of 32 lb/acre for growing season seeded treatments (Nashua Site, growing season seeded portions of Cedar Falls site) and a nurse crop of winter wheat at a rate of 30 lb/acre in dormant seeded portions of the Cedar Falls site.

We varied seeding time to match common practice and options for land managers working in agricultural landscapes. At the Cedar Falls site, dormant seeding occurred on November 15, which in Iowa reflects the earliest time NRCS allows participants implementing CRP plantings to begin dormant seedings. We chose the growing season planting date of April 30 to match the planting date at the Nashua site (April 28), and to reflect common practice in prairie reconstruction methods (Smith et al. 2010). At both sites we used a John Deere JD-5325 tractor to seed each plot independently. To minimize seed contamination between treatments, we cleaned out the drill after seeding each plot. Because plot size was small, we used tube modifications connected to the seed cups to accommodate the small amounts of seed. The drill operator started at the west end of each strip and seeded each consecutive plot in the strip. Since there were no buffers between plots, drilling was unidirectional to eliminate seed contamination in adjacent plots.

For the mowing treatment, we mowed vegetation frequently throughout the first growing season at both sites. We mowed plots to 4.5 in. when vegetation height reached approximately 20 in. (4 total mowings and left the resulting thatch on site. At the Nashua site, we mowed June 16, July 23, August 13, and November 4. At the Cedar Falls site we mowed June 12, July 11, August 8, and October 28. To reduce seed contamination at the Cedar Falls site between plots via overhang of extremely tall weeds (e.g. *Ambrosia trifida*) we clipped the edges of unmowed plot vegetation to a height of 40 in. and width of 20 in. in November. No clipping occurred at the Nashua site because weed height was not tall and posed little risk from seed contamination between plots.

Data collection and analysis

At both sites, we measured plant density and canopy cover in August or September, and used density estimates to calculate establishment and cost-effectiveness metrics. We sampled later in the growing season to allow seedlings to grow to a size that allowed for confidence in seedling identification. To sample plant density and canopy cover, we used five 1.35 ft.^{2} quadrats spaced every 3.3 ft. along a 18 ft. west to east transect placed randomly in each plot. To reduce edge effects, we did not lay quadrats within 3.3 ft. of plot borders. In each quadrat, we counted and identified all individuals (ramets) of seeded species >4 in. tall.

To assess cost-effectiveness at the Cedar Falls site, we divided the sum of observed ramets of each sown species in each plot among all years 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, harrowing, 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 (2018) and Plastina (2019) to estimate CRP management costs directly relevant to prairie reconstruction in agricultural landscapes.

To evaluate the effect of prairie reconstruction methods on native plant establishment and cost-effectiveness, we analyzed species richness, stem density (both overall and within functional groups), cost-effectiveness of the Cedar Falls sites using repeated measures ANOVA. We treated seed mix, mowing, and plant time as fixed factors, year as the repeated measure, and plot nested within block as a random factor. To meet the assumptions of normality and homoscedasticity of residual variance, we cube-root transformed grass and forb stems. We used a log(y+0.001) transformation for stems/$1. We present raw data in all figures, while we report and discuss results of analyses using transformed data. To compare effects of prairie reconstruction methods between experiments at the Cedar Falls and Nashua Sites, we analyzed species richness and stem density using repeated measures ANOVA. We compared only the spring planted portion of the experiment at Cedar Falls with the spring planted Nashua experiment. We treated seed mix and mowing as fixed factors, planting age as the repeated measure, and plot nested within block as a random factor. To meet the assumptions of normality and homoscedasticity, we cube-root transformed grass and forb stems. We used post-hoc Tukey HSD tests to compare significant treatment effects within years. All data were analyzed in R (RStudio Team 2020).

Results

Species Richness

At the Cedar Falls site, sown species richness did not initially differ between seed mixes, but by 2020 the Diversity mix had a significantly higher richness than the Economy and Pollinator mixes (Fig. 3A). First year mowing increased sown species richness initially, but differences were no longer detectable by 2020 ($F = 8.19$, $df = _{1,60}$, $p < 0.01$) (Fig. 3D). In 2019, native species richness was greater in plots where seeding occurred in the dormant season, but this difference was no longer noticeable by 2020 (Fig. 3G).

When comparing the Cedar Falls site to the Nashua site, sown species richness trends were similar and did not differ between sites. At both sites, seed mix effected species richness ($F = 12.22$, $df = _{1,58}$, $p < 0.0001$) where 1) the Diversity mix had more sown species than the Pollinator mix, and 2) the Economy mix resulted in comparable richness to both in the first and second year (Fig. 4A). First-year mowing increased native forb richness at both sites ($F = 35.26$, $df = _{1,58}$, $p < 0.0001$), particularly in the first growing season (Fig. 4B).

Stem Density

At the Cedar Falls site, native grass ($F = 41.53$, $df = _{2,29}$, $p < 0.0001$) and forb ($F = 9.72$, $df = _{2,29}$, $p < 0.001$) stem density differed across seed mixes. The Economy mix produced the most grass stems while the Pollinator mix produced the fewest grass stems across both years (Fig. 3B). The Pollinator mix had significantly more forb stems than the Economy mix, while the Diversity mix was comparable to both (Fig. 3C). First year mowing generally increased grass (F= 28.49, $df = {}_{1,60}$, $p < 0.0001$) and forb (F= 12.10, $df = {}_{1,60}$, $p < 0.001$) stem density. Mowing increased grass stem density in the first year (Fig. 3E), but by the second year, it increased both grass and forb stems (Fig. 3F). While we found more forbs in dormant plantings (F= 4.70, $df = {}_{1,29}$, $p < 0.05$), further testing (Tukey post hoc) showed this difference was not statistically significant (Fig. 3H,I).

The effect of management methods on native stem density was similar at both the Cedar Falls and Nashua sites. Grass stem density varied by seed mix at both sites (F= 84.86, $df = {}_{2,28}$, $p < 0.0001$) and was greatest in the Economy and Diversity mix compared to the Pollinator mix (Fig. 4C). The abundance of grass stems differed between the sites and Nashua had on average more grass stems than Cedar Falls, resulting in a significant site × mix interaction (F= 3.77, $df = {}_{2,28}$, $p < 0.05$). Forb stem density also varied by seed mix at both sites (F= 10.81, $df = {}_{2,28}$, $p < 0.0001$) and was highest in the Pollinator and Diversity mixes (Fig. 4E). First-year mowing increased native grass (F= 99.68, $df = {}_{1,58}$, $p < 0.0001$) and forb (F= 18.72, $df = {}_{1,58}$, $p < 0.0001$) stem density at both sites (Fig. 4D,E).

Functional Group Stem Density

In mowed plots, warm-season grass stem density was significantly higher than unmowed plots across both years, and the effects were more pronounced by 2020 (F= 62.82, $df = {}_{1,60}$, $p < 0.0001$). (Fig. 5A). Mowing did not affect cool-season grass abundance. Both warm and cool-season grasses varied across seeding times. More specifically, growing season seeding increased warm-season grasses (F= 9.47, $df = {}_{1,29}$, $p < 0.01$), but the effects were only significant in 2020 (Fig. 5C). In contrast, dormant plantings increased cool-season grasses significantly across both years (F= 20.48, $df = {}_{1,29}$, $p < 0.0001$) (Fig. 5D).

In general, mowing and dormant seeding increased the abundance of most types of forbs. Summer forb stem density was significantly higher in mowed compared to unmowed plots with effects more pronounced by 2020 ((F= 9.85, $df = {}_{1,60}$, $p < 0.005$); Fig. 6B). Mowing also increased fall forb stem density (F= 8.13, $df = {}_{1,60}$, $p < 0.01$), though there was a significant three-way interaction that obscures interpretation (Fig. 6C). Spring forbs were unaffected by mowing. Planting time increased spring and fall forb stem density, but not summer forb stems. Both spring (F= 21.83, $df = {}_{1,29}$, $p < 0.0001$) and fall forbs (F= 21.43, $df = {}_{1,29}$, $p < 0.0001$) were more abundant in dormant seeded plots compared to those seeded in the growing season. (Fig. 6D,F).

Cost-effectiveness

Most prairie reconstruction methods affected cost-effectiveness of stands. Seed mix strongly influenced cost effectiveness (F= 54.36, $df = {}_{2,29}$, $p < 0.0001$) (Fig. 7A). By a wide margin, the

Economy mix produced the most stems per dollar. Cost effectiveness was moderate in the Diversity mix, and the Pollinator mix was least cost effective. Mowing predicted cost effectiveness (F= 8.89, $df = _{1,30}$, $p < 0.01$), where mowed plots produced more stems per dollar (Fig. 7B). Seeding time did not influence how many stems were produced per dollar.

Discussion

Seed mix design has a very strong, consistent effect on native plant establishment and resulting composition of prairie strips. Even among different sites and planting years, we found consistent results: planting a diverse, grass-forb balanced seed mix results in a stand that outperforms a grass dominated seed mix on forb plant density and native species richness while also outperforming a forb dominated pollinator seed mix on overall native stem density and native species richness. Ultimately the overall design of the mixes tends to predict the resulting stand, with grass dominated or forb dominated mixes leading to a plant community dominated by grasses and forbs respectively. Conversely, balanced seed mixes lead to balanced stands. The finding that seed mix strongly determines ecological outcomes is encouraging, since it is one of the easiest and richest ways to shape implementation of prairie reconstructions. Other studies (Grman et al. 2013; Meissen et al. 2020) have also found that seed mix design is one of the most important predictors of prairie reconstruction establishment. Our study significantly strengthens this past work by validating the result among multiple experiments.

While effects are sometimes short-term, native species establishment of prairie strips is consistently improved with frequent establishment mowing. We found that mowing increased native species richness and the establishment of both grasses and forbs at different planting sites and planting years, suggesting establishment mowing is likely a useful tool to increase successful outcomes when planting prairie strips throughout the Cornbelt. Species richness gains from mowing faded by the second year in one experiment, but this acceleration of establishment still represents an important improvement for CRP contracts that may only last 10 years. Mowing is already a well adopted practice among most farmers who plant CRP ((Jackson and Meissen 2019), and our study can help provide the evidence needed to ensure the practice is fully adopted and codified in best management practices.

Dormant seeding produces stands with higher value for pollinators. Compared to spring seeded plantings, dormant seeding produced stands that had more spring and fall forbs (though summer forbs were equally abundant in both seeding times). By providing abundant forbs in all seasons, it is also more likely that more flowers will be available to pollinators throughout the growing season in dormant seeded prairies. For many pollinator species, the expanded timeframe of floral provision would significantly increase habitat quality (Dolezal et al. 2019). We also found that the abundance of warm-season grass was lower in dormant season plantings. Because overabundance of warm-season grass can lead to low quality pollinator habitat (Dickson and Busby 2009; McCain et al. 2010), dormant seeding may represent a strategy to prevent warm-season grasses that are essential to all tallgrass prairie reconstructions from outcompeting forb species.

Prairie strips can be made more cost effective with frequent establishment mowing and by using sufficient grass in seed mixes. Even when accounting for the increased input cost of mowing, we found that mowing still produced a better value than not mowing at all. Based on results from other studies (Meissen et al. 2020)it is possible this effect from mowing will fade over time, but the added value from an aesthetic or cultural standpoint of non-weedy prairies is important as well. We also found that in general, the more grass used in the seed mix, the more cost-effective it was when considering only stems produced per input cost. It is important to point out that depending on the objectives of the stand, other cost-effectiveness metrics should be considered such as flowers produced per input cost. Indeed, Meissen and others (2020) found that even if a prairie was most cost-effective on the basis of stem density, it tended to be least cost-effective on the basis of floral density. Further study is warranted on determining the most relevant cost-effective metrics. While dormant seeding produced high quality prairie reconstructions, we did not find evidence that it increased cost-effectiveness. This null result may be due to the contrasting performance of warm-season and cool-season grasses that produce high abundance of stems. The concurrent increase of warm-season grass stems with spring seeding and cool-season grass stems with dormant seeding likely masked the contributions of high forb performance in spring and fall species.

Conclusions

Our findings show that the effects of many prairie reconstruction implementation methods are predictable. We were able to verify the consistency of results across two field experiments at different sites and planting years. By using a diverse, grass-forb balanced seed mix and conducting frequent first year mowing in prairie strips, first time farmer adopters and policymakers can be more confident that they can relaibly produce multifunctional stands of perennial vegetation that can help improve issues of water quality and pollinator decline. Preliminary findings that dormant seeding results in further gains in ecological quality are encouraging. Continued monitoring of this study for at least two more years is needed so that we can understand what post-establishment conclusions can be drawn about season of planting at the Prairie on Farms Research and Demonstration Site.

Acknowledgements

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expressed in this material are those of the author and do not necessarily reflect the views of the Iowa Nutrient Research Center.

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Figure 1. Location of study sites within Iowa: 1) Prairie on Farms Research and Demonstration Area (Cedar Falls Site) and 2) ISU Northeast Research and Demonstration Farm (Nashua Site).

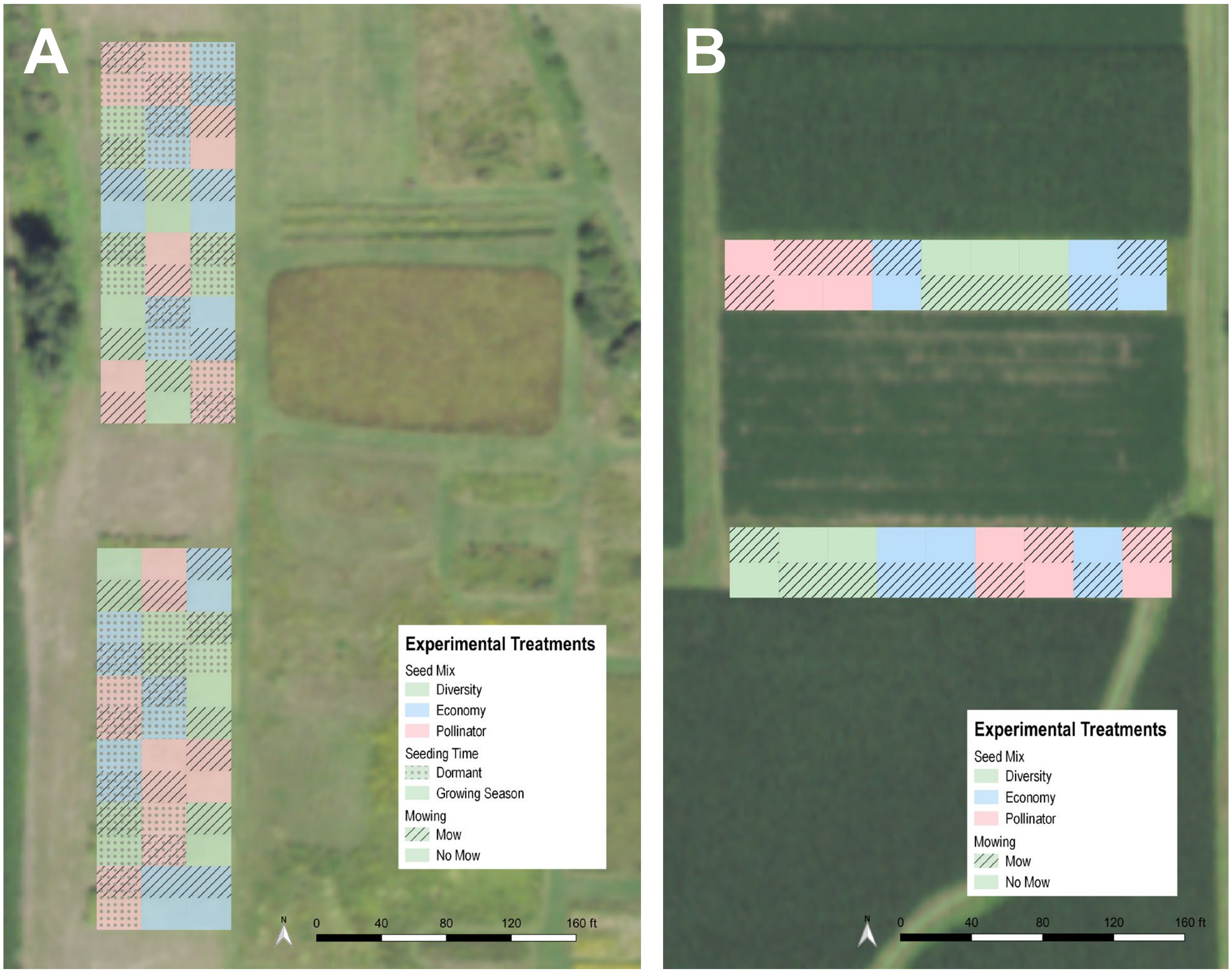

Figure 2. Experimental layout at A) the Prairie on Farms Research and Demonstration Area (Cedar Falls Site) and B) the ISU Northeast Research and Demonstration Farm (Nashua Site).

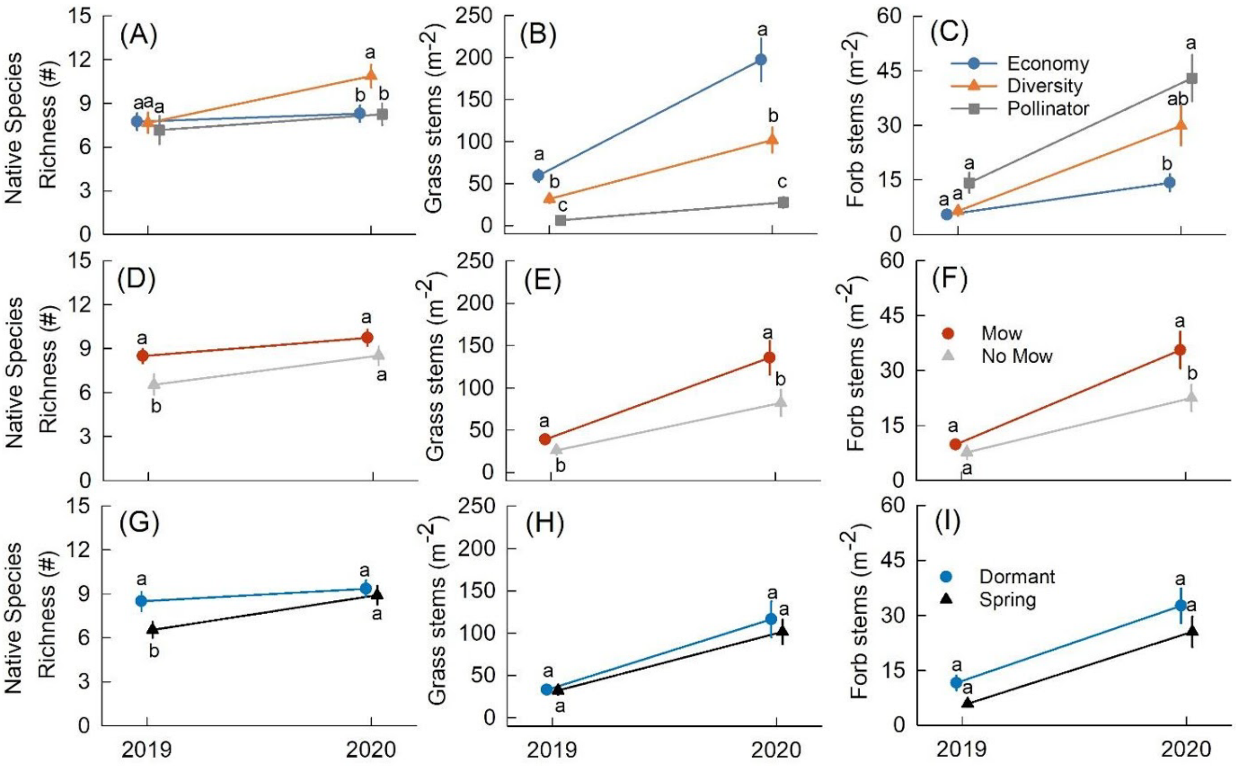

Figure 3. Effects of seed mix (A-C), first-year mowing management (D-F), and planting time (G-I) on native species richness (left column), grass stem density (center column), and forb stem density (right column). Error bars represent ± 1 SE. Lowercase letters denote significant differences within year via different letters. Graphic by Alec Glidden.

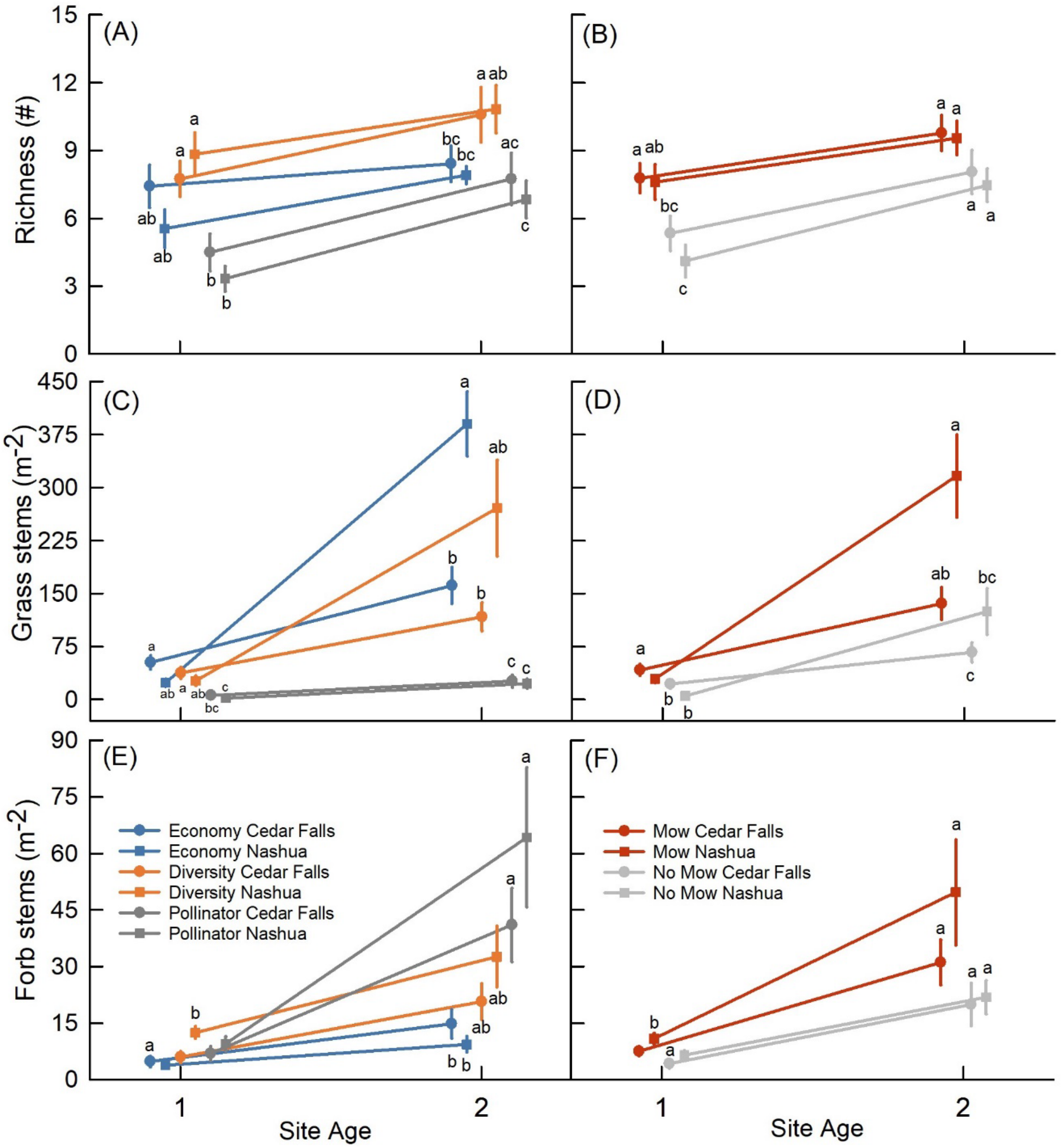

Figure 4. Effects of seed mix (A,C,E), first-year mowing (B,D,F), on native species richness (top row), grass stem density (center row), and forb stem density (bottom row) for the first two growing seasons at Cedar Falls and Nashua. Error bars represent ± 1 SE. Lowercase letters denote significant differences within year via different letters. Graphic by Alec Glidden.

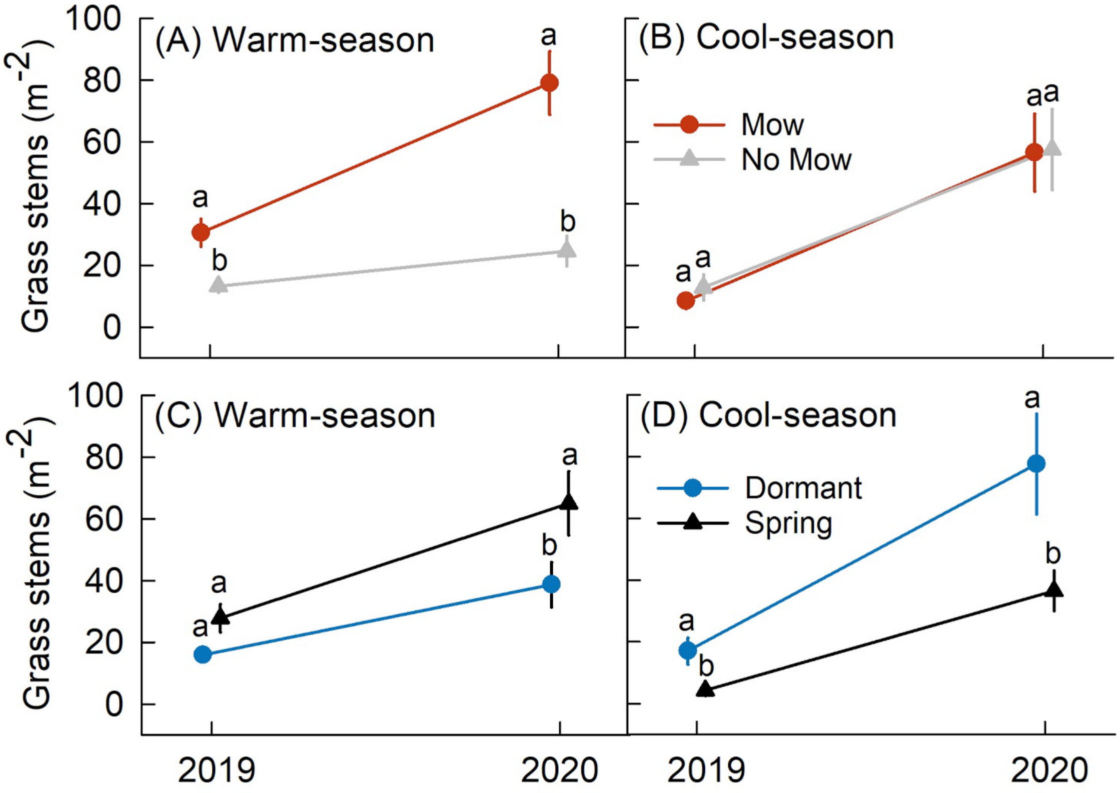

Figure 5. Stem density of warm-season (left column) and cool-season grasses (right column) based on first-year mowing (A-B) and planting time (C-D). Error bars represent ± 1 SE. Lowercase letters denote significant differences within year via different letters. Graphic by Alec Glidden.

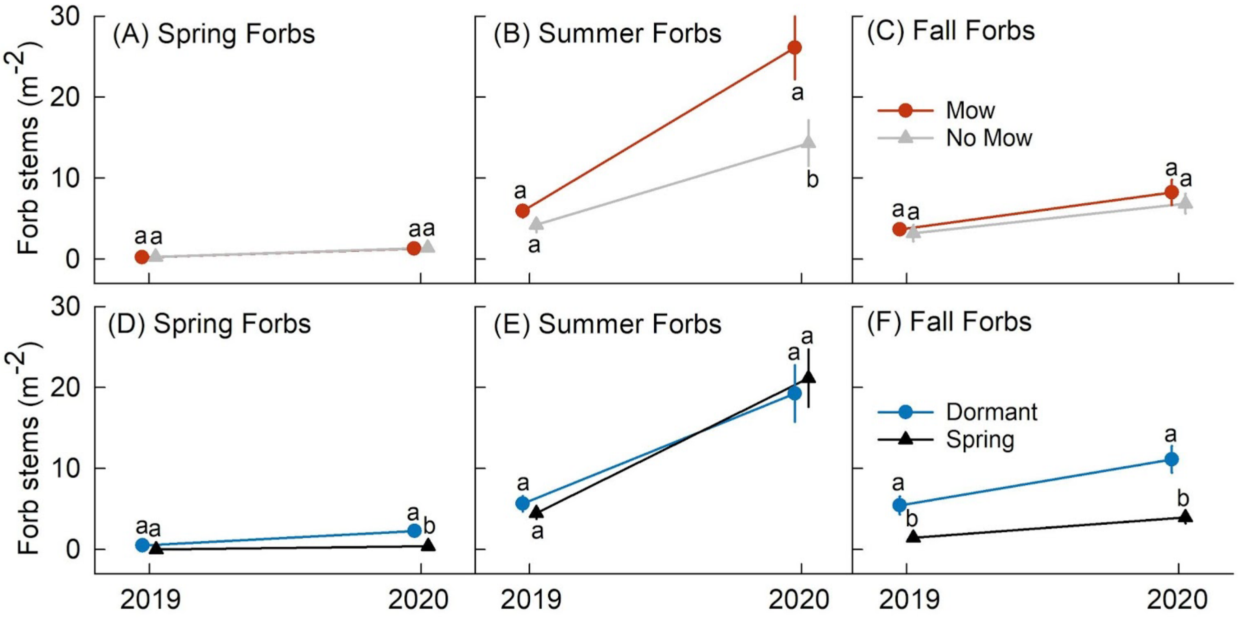

Figure 6. Forb stem density of spring (left column), summer (center column), and fall (right column) forbs based on first-year mowing (A-C) and planting time (D-F). Error bars represent ± 1 SE. Lowercase letters denote significant differences within year via different letters. Graphic by Alec Glidden.

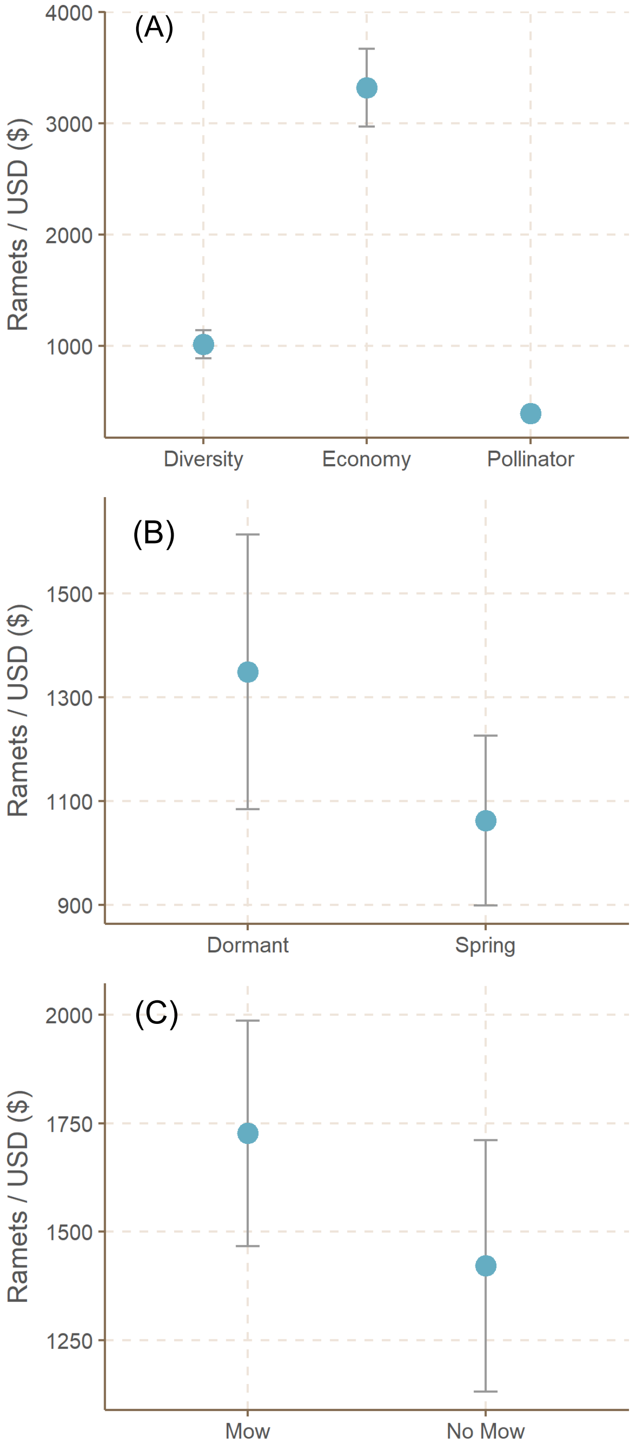

Figure 7. Cost effectiveness (ramets produced from 1$ of input cost) of seed mixes (A), time of seeding (B), and mowing (C). Data shown is untransformed; error bars represent ± 1 SE.

Appendix A. Seed mixes planted as treatments at both the Nashua and Cedar Falls Sites

Pollinator Mix (1:3 grass-to-forb seeding rate ratio)

Common Name	*Scientific Name*	*Functional group*	*Seeds/m^2*	*% mix*
Junegrass	*Koeleria macrantha*	grass (cool season)	31.6	7.32%
big bluestem	*Andropogon gerardii*	grass (warm season)	3.6	0.82%
side-oats grama	*Bouteloua curtipendula*	grass (warm season)	3.4	0.80%
little bluestem	*Schizachyrium scoparius*	grass (warm season)	29.1	6.72%
tall dropseed	*Sporobolus compositus*	grass (warm season)	17.8	4.11%
prairie dropseed	*Sporobolus heterolepis*	grass (warm season)	3	0.70%
yellow fox sedge	*Carex vulpinoidea*	sedge	19.8	4.58%
Canada milkvetch	*Astragalus canadensis*	forb (legume)	3.3	0.77%
white wild indigo	*Baptisia alba*	forb (legume)	0.6	0.15%
white prairie clover	*Dalea candida*	forb (legume)	22.5	5.20%
purple prairie clover	*Dalea purpurea*	forb (legume)	25.2	5.82%
common milkweed	*Asclepias syriaca*	forb	1.6	0.37%
butterfly milkweed	*Asclepias tuberosa*	forb	3.4	0.80%
pale purple coneflower	*Echinacea pallida*	forb	6.2	1.44%
rattlesnake master	*Erynigium yuccifolium*	forb	8.9	2.07%
Sneezeweed	*Helenium autumnale*	forb	20.6	4.75%
Alumroot	*Heuchera richardsonii*	forb	27.7	6.39%
prairie blazingstar	*Liatris pycnostachya*	forb	8.7	2.02%
wild bergamot	*Monarda fistulosa*	forb	19.7	4.55%
stiff goldenrod	*Oligoneuron rigidum*	forb	8.1	1.87%
foxglove beardtongue	*Penstemon digitalis*	forb	10.3	2.39%
prairie phlox	*Phlox pilosa*	forb	0.3	0.07%
prairie cinquefoil	*Potentilla arguta*	forb	9.0	2.09%
common mountain mint	*Pycnanthemum virginianum*	forb	8.7	2.02%
yellow coneflower	*Ratibida pinnata*	forb	11.8	2.74%
black-eyed susan	*Rudbeckia hirta*	forb	25.5	5.90%
Rosinweed	*Silphium integrifolium*	forb	0.4	0.10%
compass plant	*Silphium laciniatum*	forb	0.8	0.17%
showy goldenrod	*Solidago speciosa*	forb	3.8	0.87%
heath aster	*Symphyotrichum ericoides*	forb	7.9	1.82%
smooth blue aster	*Symphyotrichum laeve*	forb	4.3	1.00%
New England aster	*Symphyotrichum novae-angliae*	forb	15.9	3.68%
sky-blue aster	*Symphyotrichum*	forb	3.1	0.72%
Ohio spiderwort	*Tradescantia ohiensis*	forb	4.7	1.09%
Ironweed	*Vernonia fasciculata*	forb	14.2	3.28%
Culver's root	*Veronicastrum virginicum*	forb	31.6	7.32%
prairie violet	*Viola pedatifida*	forb	1.1	0.25%
golden alexander	*Zizia aurea*	forb	14.1	3.26%
	Overall Total:		432.4	

Diversity Mix (1:1 grass-to-forb seeding rate ratio)

Common Name	*Scientific Name*	*Functional group*	*Seeds/ft^2*	*% mix*
prairie brome	*Bromus kalmii*	grass (cool season)	2.7	0.63%
Canada wildrye	*Elymus canadensis*	grass (cool season)	10.8	2.54%
fowl mannagrass	*Glyceria striata*	grass (cool season)	10.8	2.54%
big bluestem	*Andropogon gerardii*	grass (warm	21.5	5.07%
side-oats grama	*Bouteloua curtipendula*	grass (warm	32.3	7.61%
Switchgrass	*Panicum virgatum*	grass (warm	21.5	5.07%
little bluestem	*Schizachyrium scoparius*	grass (warm	21.5	5.07%
Indiangrass	*Sorghastrum nutans*	grass (warm	21.5	5.07%
tall dropseed	*Sporobolus compositus*	grass (warm	53.8	12.68%
prairie dropseed	*Sporobolus heterolepis*	grass (warm	2.7	0.63%
yellow fox sedge	*Carex annectens*	sedge	10.8	2.54%
Bicknell's sedge	*Carex bicknellii*	sedge	1.1	0.25%
plains oval sedge	*Carex brevior*	sedge	2.7	0.63%
heavy sedge	*Carex gravida*	sedge	0.2	0.05%
field oval sedge	*Carex molesta*	sedge	2.7	0.63%
Leadplant	*Amorpha canescens*	forb (legume)	2.2	0.51%
Canada milkvetch	*Astragalus canadensis*	forb (legume)	10.8	2.54%
white wild indigo	*Baptisia alba*	forb (legume)	0.2	0.05%
partridge pea	*Chamaecrista fasiculata*	forb (legume)	3.2	0.76%
purple prairie clover	*Dalea purpurea*	forb (legume)	10.8	2.54%
showy tick trefoil	*Desmodium canadense*	forb (legume)	1.6	0.38%
Illinois tick trefoil	*Desmodium illinoense*	forb (legume)	2.7	0.63%
round-headed	*Lespedeza capitata*	forb (legume)	0.5	0.13%
wild garlic	*Allium canadense*	forb	1.1	0.25%
Canada anemone	*Anemone canadensis*	forb	0.2	0.05%
Thimbleweed	*Anemone cylindrica*	forb	0.5	0.13%
prairie sage	*Artemisia ludoviciana*	forb	10.8	2.54%
swamp milkweed	*Asclepias incarnata*	forb	1.1	0.25%
common milkweed	*Asclepias syriaca*	forb	2.2	0.51%
butterfly milkweed	*Asclepias tuberosa*	forb	0.3	0.08%
whorled milkweed	*Asclepias verticillata*	forb	0.5	0.13%
New Jersey tea	*Ceanothus americanus*	forb	0.5	0.13%
prairie coreopsis	*Coreopsis palmata*	forb	0.4	0.10%
shootingstar	*Dodecatheon media*	forb	1.1	0.25%
pale purple coneflower	*Echinacea pallida*	forb	2.2	0.51%
rattlesnake master	*Erynigium yuccifolium*	forb	2.2	0.51%
tall boneset	*Eupatorium altissimum*	forb	2.7	0.63%
flowering spurge	*Euphorbia corollata*	forb	1.1	0.25%
grass-leaved goldenrod	*Euthamia graminifolia*	forb	10.8	2.54%
northern bedstraw	*Galium boreale*	forb	1.1	0.25%
bottle gentian	*Gentiana andrewsii*	forb	5.4	1.27%
bigtooth sunflower	*Helianthus grosseserratus*	forb	1.6	0.38%

prairie sunflower	*Helianthus laetiflorus*	forb	0.2	0.05%
ox-eye sunflower	*Heliopsis helianthoides*	forb	5.4	1.27%
prairie blazingstar	*Liatris pycnostachya*	forb	1.1	0.25%
Michigan lily	*Lilium michiganense*	forb	0.1	0.03%
great blue lobelia	*Lobelia siphilitica*	forb	10.8	2.54%
wild bergamot	*Monarda fistulosa*	forb	8.1	1.90%
stiff goldenrod	*Oligoneuron rigidum*	forb	8.1	1.90%
wild quinine	*Parthenium integrifolium*	forb	1.1	0.25%
foxglove beardtongue	*Penstemon digitalis*	forb	10.8	2.54%
prairie phlox	*Phlox pilosa*	forb	0.2	0.05%
prairie cinquefoil	*Potentilla arguta*	forb	10.8	2.54%
hairy mountain mint	*Pycnanthemum pilosum*	forb	8.1	1.90%
slender mountain mint	*Pycnanthemum tenuifolium*	forb	10.8	2.54%
common mountain mint	*Pycnanthemum virginianum*	forb	10.8	2.54%
yellow coneflower	*Ratibida pinnata*	forb	10.8	2.54%
black-eyed susan	*Rudbeckia hirta*	forb	8.1	1.90%
sweet coneflower	*Rudbeckia subtomentosa*	forb	8.1	1.90%
rosinweed	*Silphium integrifolium*	forb	0.2	0.05%
compass plant	*Silphium laciniatum*	forb	0.1	0.03%
showy goldenrod	*Solidago speciosa*	forb	8.1	1.90%
smooth blue aster	*Symphyotrichum laeve*	forb	5.4	1.27%
New England aster	*Symphyotrichum novae-angliae*	forb	5.4	1.27%
sky-blue aster	*Symphyotrichum*	forb	2.7	0.63%
purple meadow rue	*Thalictrum dasycarpum*	forb	0.5	0.13%
prairie spiderwort	*Tradescantia bracteata*	forb	0.5	0.13%
Ohio spiderwort	*Tradescantia ohiensis*	forb	1.1	0.25%
ironweed	*Vernonia fasciculata*	forb	2.7	0.63%
Culver's root	*Veronicastrum virginicum*	forb	5.4	1.27%
golden alexander	*Zizia aurea*	forb	2.7	0.63%
	Overall Total:		441.8	

Economy Mix (3:1 grass-to-forb seeding rate ratio)

Common Name	*Scientific Name*	*Functional group*	*Seeds/m^2*	*% mix*
Canada wildrye	*Elymus canadensis*	grass (cool season)	46.3	10.75%
big bluestem	*Andropogon gerardii*	grass (warm season)	46.3	10.75%
side-oats grama	*Bouteloua curtipendula*	grass (warm season)	46.3	10.75%
switchgrass	*Panicum virgatum*	grass (warm season)	32.3	7.50%
little bluestem	*Schizachyrium scoparius*	grass (warm season)	46.3	10.75%
Indiangrass	*Sorghastrum nutans*	grass (warm season)	46.3	10.75%
tall dropseed	*Sporobolus compositus*	grass (warm season)	59.2	13.75%
Canada milkvetch	*Astragalus canadensis*	forb (legume)	10.8	2.50%
purple prairie clover	*Dalea purpurea*	forb (legume)	10.8	2.50%
prairie sage	*Artemisia ludoviciana*	forb	10.8	2.50%
tall boneset	*Eupatorium altissimum*	forb	5.4	1.25%
ox-eye sunflower	*Heliopsis helianthoides*	forb	5.4	1.25%
wild bergamot	*Monarda fistulosa*	forb	10.8	2.50%
stiff goldenrod	*Oligoneuron rigidum*	forb	5.4	1.25%
prairie cinquefoil	*Potentilla arguta*	forb	10.8	2.50%
yellow coneflower	*Ratibida pinnata*	forb	10.8	2.50%
black-eyed susan	*Rudbeckia hirta*	forb	5.4	1.25%
sweet coneflower	*Rudbeckia subtomentosa*	forb	8.1	1.88%
showy goldenrod	*Solidago speciosa*	forb	5.4	1.25%
New England aster	*Symphyotrichum novae-*	forb	5.4	1.25%
golden alexander	*Zizia aurea*	forb	2.7	0.63%
	Overall Total:		430.4	