Effect *of* Seeding Date *on* Establishment *of* Native Grasses

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ABSTRACT

In this research, the best planting dates for warm-season grasses, little bluestem (*Schizachyrium scoparium* [Michx.] Nash [Poaceae]) and sideoats grama (*Bouteloua curtipendula* [Michx.] Torr. [Poaceae]), were 1 May through 20 July. For cool-season grasses, Canada wildrye (*Elymus canadensis* L. [Poaceae]) and Kalm's brome (*Bromus kalmii* A. Gray [Poaceae]), 1 May through 1 August were the best planting dates. Dormant seeding was successful only 1 y for the cool-season grasses. *Elymus canadensis* had significantly better second-season establishment than other species or mixes and may be useful as a cover crop in prairie restorations.

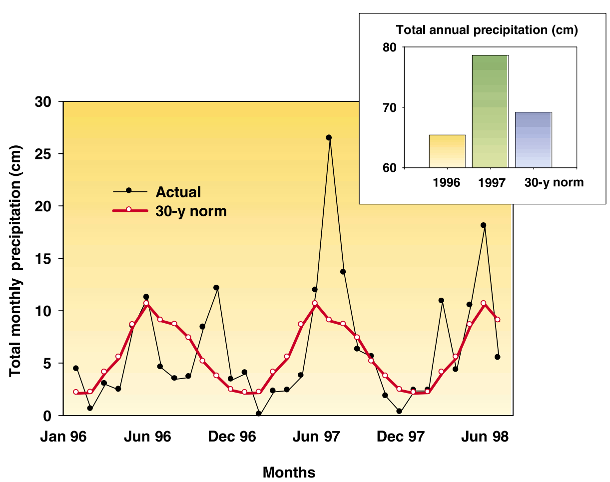

Figure 1 • *Total monthly precipitation for St Paul, Minnesota, January 1996 through June 1998 and 30-y norm. Yearly totals for 1996, 1997, and the 30-y norm are also shown.*

KEY WORDS: prairie restoration, *Schizachyrium scoparium*, little bluestem, *Bouteloua curtipendula*, sideoats grama, *Elymus canadensis*, Canada wildrye, *Bromus kalmii*, Kalm's brome

NOMENCLATURE: (plants) USDA NRCS (2000); (soil) Vinar (1980)

The tallgrass prairie that once covered much of the upper Midwest US is almost extinct. Until the 1980s, restoration methods were largely anecdotal (Howell and Jordan 1989). Documentation is limited on seed handling, site preparation, time of seeding, and management during early (< 5) years of establishment. Current recommendations, for example, limit seeding dates of warm-season grasses from late spring to early summer, approximately mid May through June (Diboll 1997). Many sites, such as highway roadsides, are under construction and require seeding throughout the growing season. Restricting seeding to just a few weeks slows or limits restoration efforts considerably.

Seeding date (Douglas and others 1960; Kilcher 1961; Fry and others 1993), year (McGinnies 1973), location (McGinnies 1973), and species (Douglas and others 1960) are important factors for early stand establishment in short and mixed-grass prairies. Ries and Hofmann (1996) reported significant seeding date X year interaction. White (1984) found a minimum amount of growth must occur before winter. Rodgers and Anderson (1989) found no significant difference in first-season grass seedlings from November and June plantings. *Schizachyrium scoparium* (Michx.) Nash (Poaceae) and switchgrass (*Panicum virgatum* L. [Poaceae]), however, produced significantly more second-season biomass when seeded in June rather than November, but Indian grass (*Sorghastrum nutans* [L.] Nash [Poaceae]) showed no biomass difference between spring and fall plantings (Rodgers and Anderson 1989). Frasier and others (1984) proposed a formula for selecting seeding date based on a species moisture requirements and the probability of receiving adequate rainfall.

Tallgrass prairies are dominated by warm-season grasses such as big bluestem (*Andropogon gerardii* Vitman [Poaceae]) and *S. scoparium*. Therefore, a planting with predominantly cool-season grasses, such as *E. canadensis* and *B. kalmii*, generally will not provide an acceptable outcome for a tallgrass prairie restoration. Cool-season grasses, however, may establish faster, germinate over a wider range of time, and provide a temporary cover crop for the first few years.

In this project we investigated the establishment of warm- and cool-season grass monocultures and 2 mixtures using 10 seeding dates throughout the growing season. Study objectives were to determine establishment differences between warm- and cool-season grasses and to document changes in species composition of the mixtures in the first 2 y.

TABLE 1

Quantities of native grasses and their percentage in mixes seeded over 10 dates in both 1996 and 1997 in St Paul, Minnesota

Mix or monoculture	Percentage by weight	Bulk seed rate (kg/ha) [a]	PLS %; kg/ha [b]
Monoculture			
Bouteloua curtipendula	100	24.4	7.3
Bromus kalmii	100	24.4	6.7
Elymus canadensis	100	24.4	11.0
Schizachyrium scoparium	100	24.4	7.2
Warm-season mix			
Bouteloua curtipendula	31.3	7.7	27.6; 17.3
Bromus kalmii	12.5	3.1	10.3; 3.3
Elymus canadensis	6.4	1.5	8.5; 2.7
Schizachyrium scoparium	50.0	12.2	53.6; 17.3
Cool-season mix			
Bouteloua curtipendula	25	6.2	20.6; 6.6
Bromus kalmii	25	6.2	22.4; 7.2
Elymus canadensis	25	6.2	31.5; 10.1
Schizachyrium scoparium	25	6.2	25.5; 8.2

[a] Conversion: 1 kg/ha = 0.9 lb/ac.

[b] PLS = pure live seed; (percentage purity • percentage germination)/100

MATERIALS AND METHODS

Field experiments were conducted at the University of Minnesota, St Paul (Lat 44° 59'N, Long 93° 11'W), where annual precipitation averages 72 cm (28 in) and the mean annual temperature is 7.2° C (45° F). Soil was Waukegan silt loam (well-drained, mesic Typic Hapludolls) with pH 6.6. Adjacent fields were planted in 1996 and 1997. The 1996 field had 4.6% organic matter and 1.4 ppm nitrate-nitrogen (NO3-N); the 1997 field had 6.3% organic matter and 8.0 ppm NO3-N; both fields had 100 and 300 ppm phosphorus and potassium, respectively (University of Minnesota Soil Testing Laboratory, St Paul, Minnesota). The University of Minnesota weather station, located approximately 90 m (295 ft) from the experimental plots, provided data on precipitation, air, and soil temperature.

Each planting year a split-plot design with 3 replications was used to investigate seeding date (main-plot effect) and mix (subplot effect). Subplots were 3.7 m X 4.0 m (12 ft X 13 ft). Beginning in May, 10 seeding dates were tested each year at 9- to 30-d intervals. The last 2 seedings, late September and October, were considered dormant seedings. Four species, each planted as a monoculture or as a portion of either a warm- or cool-season mix, were evaluated (Table 1).

Seeds were obtained from Prairie Restorations Inc (Princeton, Minnesota) and were stored at approximately 7 °C (45 °F) until planted. Seeding rates (Table 1), based on weight or an equivalent of pure live seed (PLS = (percentage purity • percentage germination)/100) were based on current recommendations (Diboll 1997). Seeds were broadcast into freshly tilled plots that were then raked and packed with a drum roller. No additional irrigation or fertilizer was applied. Plots were mowed to 10 to 15 cm (4 to 6 in) for weed control approximately 2 or 3 times per year.

Seedling population counts were conducted in September or October of the planting year (first-season establishment) and the following July (second-season establishment) by placing a 1-m^2 (3.3-ft^2) frame randomly in each plot and counting the num-

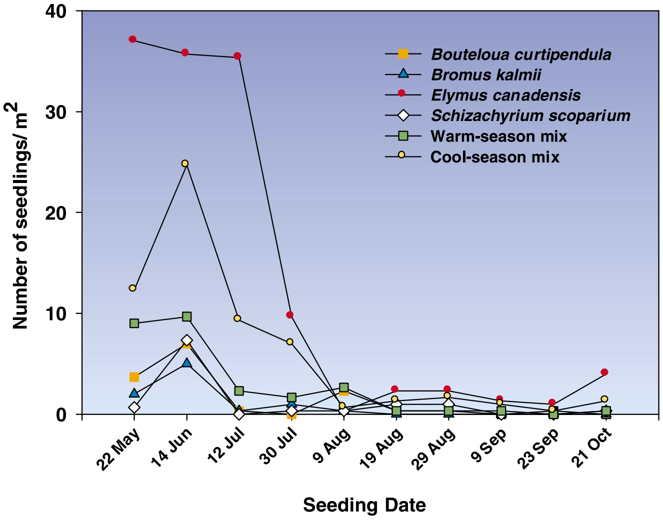

Figure 2 • *Second-season establishment for 1996 plantings of 4 species or 2 mixtures on 10 seeding dates.*

ber of target seedlings within the frame. Weed seedlings were not tallied due to large quantities and variation. Seedlings of the 4 target species were distinct from each other at the seedling stage, and a key was developed to distinguish between them and common weedy grasses (Meyer and Gaynor 2000).

Analysis of variance (ANOVA) for split-plot design was conducted using SAS software (SAS Institute 1996). To stabilize variances, data were transformed using the formula, square root [y] + square root [y+1]. Both planting years were analyzed separately resulting in first and second-season ANOVAs for each year. Each ANOVA tested seeding date, mix, and seeding date X mix interaction. The error term for seeding date was block X seeding date. Tukey's multiple comparison tests were conducted for seeding date and mix.

RESULTS AND DISCUSSION

In 1996, rainfall for July, August, and September totaled only 11.6 cm (4.6 in), compared with 46.2 cm (18.2 in) in 1997 (Figure 1). The normal amount for these 3 mo is 25 cm (9.8 in).

Seeding Date

Significant seeding date effects were evident for first- and second-season establishment (Table 2). In 1996, first-season establishment for May through August plantings did not differ significantly from each other, but June and early July seeding dates were significantly better than September and October. By the second-season, May and June 1996 seedings had significantly higher establishment than late July through October seedings, yielding an average of 11 seedlings/m^2 (1 seedling/ft^2) for May, and 15 seedlings/m^2 (1.4 seedlings/ft^2) for June (Figure 2). For 1997 plantings, late July through August dates had the best first-season establishment (Table 2). By the second-season, late July through early September 1997 planting dates averaged over 32 seedlings/m^2 (3.0 seedlings/ft^2) (Figure 3) and had significantly higher establishment than May, June, and late October plantings (Table 2). Seedlings that established early in the season (May and June 1996 plantings) were able to survive summer drought the first year, a phenomenon that was noted in early establishment studies (Cornelius 1944) and one that is commonly observed in dry western states. Plantings done during drought weeks, but receiving good subsequent rainfall, did not always result in good establishment. In 1997, for example, seedings done during the drought of May and June had poor

TABLE 2

Mean seedling counts per m² [a] of 4 monocultures and 2 mixes of native grasses by planting date

Year	Establishment season	Planting date 22 May	13 Jun	12 Jul	30 Jul	9 Aug	19 Aug	29 Aug	9 Sep	23 Sep	21 Oct
1996	First	8.8 ab [b]	10.4 a	11.0 a	10.1 ab	8.3 abc	9.3 ab	7.8 abc	6.8 bc	4.9 c	1.0 d
	Second	5.6 ab	7.2 a	4.2 bc	3.2 cd	2.0 d	1.9 d	1.9 d	1.5 d	1.4 d	2.0 d
1997	First	1.9 e	2.4 de	8.0 cd	16.3 a	20.1 a	15.7 ab	18.3 a	10.2 bc	1.0 e	1.0 e
	Second	2.0 b	2.1 b	6.5 ab	10.5 a	11.5 a	9.8 a	9.8 a	9.8 a	7.0 ab	4.6 b

[a] Conversion: plants per m^2 / 10.8 = plants per ft^2.

[b] Within a row, values with the same letter do not differ significantly ($P < 0.05$) as determined by Tukey multiple comparison tests.

establishment while seedings done a few weeks later, during weeks of substantial rainfall, had good establishment. Moisture requirements for establishment of native grasses are poorly documented, but it has been shown that 5 wet days are sufficient for good germination and emergence of *B. curtipendula* in the field (Frasier and others 1987).

Dormant seedings of *E. canadensis* and *B. kalmii* were successful in 1 of the 2 planting years. In 1996, *E. canadensis* germinated in late September and had extremely high winter mortality, suggesting that dormant seeding for this species should occur after late September. *Schizachyrium scoparium* and *B. curtipendula* did not establish well from dormant seedings. Rodgers and Anderson (1989) also reported poor or reduced establishment for dormant seeding of some warm-season grass species.

Species or Mixture

Establishment differed significantly for species or mixture, for both first- and second-season establishment for both years (Table 3). For the 1996 plantings, *E. canadensis* had significantly better first- and second-season establishment than all other species and mixes. The cool-season mix sown in 1996 had significantly more seedlings than *B. kalmii* and the warm-season materials. For the 1997 plantings, by the second season *E. canadensis* again had significantly higher establishment than other species or mixes. Though it was sown at a higher PLS rate, it had a disproportionately higher density, often over 10X as many seedlings as the warm-season species (Figures 2 and 3). Establishment counts in 1997 for *E. canadensis* and *B. kalmii* were similar, averaging 43 and 37 seedlings/m^2 (4.0 and 3.4 seedlings/ft^2) respectively, across the 10 seeding dates (Figure 3). By the second season of the 1997 planting, *B. kalmii* and the cool-season mix had significantly better establishment than the warm-season materials. *Schizachyrium scoparium* and *B. curtipendula* had significantly lower establishment than other species or mixes, averaging only 2.5 and 3.8 seedlings/m^2 (0.2 and 0.4 seedlings/ft^2) respectively, across the 10 seeding dates (Figure 3). For *S. scoparium* monocultures, by the end of the experiment only 2 of the 20 planting dates resulted in over 3 seedlings/m^2 (0.3 seedlings/ft^2) (Figures 2 and 3) confirming this species is difficult to establish (Howell and Kline 1992).

Seeding Date X Mixture

The seeding date X mix interaction was statistically significant (Figures 2 and 3). The trends followed those already described for seeding date, with best establishment from early 1996 and summer 1997 plantings. The latest planting date providing good second-season establishment (> 10 seedlings/m^2) (> 0.9 seedlings/ft^2) for *S. scoparium* and *B. curtipendula* was 8 August; the latest planting date providing good second-season establishment for *E. canadensis* and *B. kalmii* was 10 September. Also, *S. scoparium* and *B. curtipendula* averaged < 1 seedling/m^2 (< 0.1 seedlings/ft^2) from dormant seeding (Figures 2 and 3); in contrast, *E. canadensis* and *B. kalmii* established well from dormant seedings done late September 1997, averaging over 25 seedlings/m^2 (2.3 seedlings/ft^2) (Figure 3). *Elymus canadensis* also established well from the October 1997 planting, with over 40 seedlings/m^2 (3.7 seedlings/ft^2) (Figure 3).

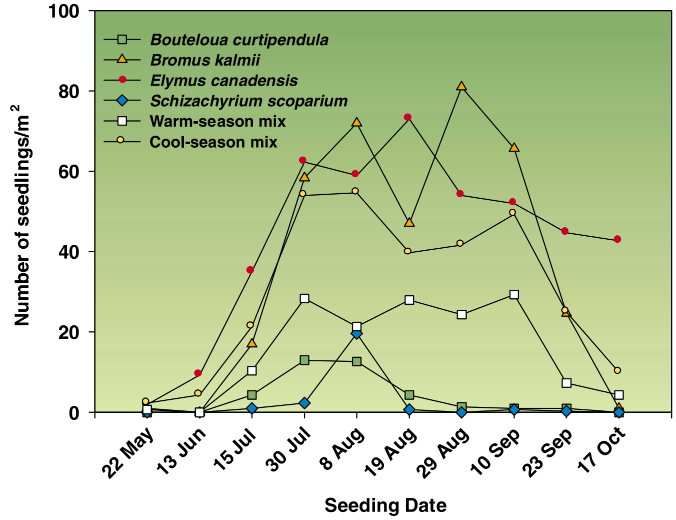

Figure 3 • *Second-season establishment for 1997 plantings of 4 species or 2 mixtures on 10 seeding dates.*

Winter Mortality and Change in Composition of Mixture

For the 1996 plantings, winter mortality, defined as seedling mortality between the end of the first season and the middle of the second season, was 72% for *B. kalmii* and 89% to 90% for the other 3 species (data not shown). For the 1997 plantings, *S. scoparium* had a winter mortality rate of 92%, and *B. curtipendula* 84%, but the cool-season grasses had relatively low mortality of 26% *B. kalmii* and 33% *E. canadensis.*

The mixtures experienced a shift in species composition from first to second season (Table 4). By the second season, cool-season grasses dominated both mixes. Our experiments confirm that species or mix are important factors in stand establishment, supporting other studies (Kilcher 1961; Ries and Hofmann 1996).

Several patterns differentiated cool- and warm-season grasses. The warm-season grasses tested had lower establishment counts, higher winter mortality, a shorter planting season, and poorer establishment from dormant seeding.

Our results support the commonly accepted generalization that cool-season native grasses are easier to establish than warm-season grasses. This may be due to higher root and shoot biomass (Robocker and others 1953) or higher root weights (Qi and Redmann 1993). Newman and Moser (1988) showed that seedlings of *Elymus* spp. had many adventitious roots, which may be required for drought survival (Hyder and others 1971; Briske and Wilson 1980), while *S. scoparium* had few adventitious roots.

Cool-season grasses such as *E. canadensis* are reported to decline after 5 to 8 y and are replaced by other native species (Morgan 1997). *Elymus canadensis* is sometimes used as a short-lived perennial cover crop (Liegel and Lyon 1984; Morgan 1997; Barry and Dana 1998). Restorationists in Wisconsin reported that *E. canadensis* peaked the third season and declined the fourth season (Liegel and Lyon 1984). Mixes with a high percentage of cool-season grasses establish rapidly, prevent erosion, compete well with weed seedlings, and quickly form aesthetically acceptable stands. However, additional reports are needed to document long-term shifts in species composition for mixes with a high percentage of cool-season grasses. Ideally, *E. canadensis* and other cool-season grasses decrease over time and warm-season species such as *S. scoparium* and *B. curtipendula* increase to adequate levels.

RECOMMENDATIONS AND CONCLUSIONS

In this study, the best planting dates for upper Midwest US for warm-season grasses *S. scoparium* and *B. curtipendula* were 1 May through 20 July. If moisture is adequate, these dates may be extended through early August (8 August in this experiment), resulting in a 14-wk planting season.

Best planting dates in the upper Midwest US for cool-season *E. canadensis* and *B. kalmii* were 1 May through 1 August. If moisture is adequate, these dates may be extended through early September (9 September in this experiment), resulting in a 19-wk planting season. Dormant seedings of *E. canadensis* and *B. kalmii* were successful when planted after mid October in 1997. Dormant seedings of *S. scoparium* and *B. curtipendula* did not establish well in this experiment.

Our study suggests that cool-season native grasses are more likely to be successful in improving stand establishment when sown later in the growing season and as dormant seedings than warm-season grasses. *Elymus canadensis* showed significantly better establishment than other warm-season grasses in this study and may be useful in extending seeding dates in tallgrass prairie restorations in the upper Midwest US.

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TABLE 3

Mean seedling counts per m² [a] of 4 monocultures and 2 mixes of native grasses

Year	Establishment season	Mix or monoculture					
		Bouteloua curtipendula	*Bromus kalmii*	*Elymus canadensis*	*Schizachyrium scoparium*	Warm-season mix	Cool-season mix
1996	First	4.7 d [b]	3.6 d	17.7 a	4.8 d	6.6 c	9.6 b
	Second	2.1 cd	1.8 d	5.9 a	1.9 d	2.8 c	4.0 b
1997	First	7.3 d	10.4 ab	11.8 a	7.8 cd	9.2 bc	10.5 ab
	Second	2.9 d	10.0 b	12.2 a	2.1 d	6.9 c	10.1 b

[a] Conversion: plants per m² / 10.8 = plants per ft².

[b] Within a row, values with the same letter do not differ significantly ($P < 0.05$) as determined by Tukey multiple comparison tests.

TABLE 4

Mean number of seedlings per m^2 (shown as a percentage of total seedlings) of native grasses in 2 mixtures from first to second season for all planting dates

Year planted	Species	Warm-season mix: First season	Warm-season mix: Second season	Cool-season mix: First season	Cool-season mix: Second season
		Percentage of mix			
1996	*Bouteloua curtipendula*	28	9	10	2
	Bromus kalmii	1	7	4	6
	Elymus canadensis	37	65	78	89
	Schizachyrium scoparium	34	18	8	2
1997	*Bouteloua curtipendula*	18	4	10	< 1
	Bromus kalmii	12	47	29	66
	Elymus canadensis	19	47	31	33
	Schizachyrium scoparium	52	2	19	< 1

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