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Establishing Warm-Season Grasses and Forbs Using Herbicides and Mowing

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ESTABLISHING WARM-SEASON GRASSES AND FORBS USING HERBICIDES AND MOWING

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Abstract. The objective of this study was to provide a preliminary assessment of the use of selected herbicides in establishing a diverse stand of prairie grasses and forbs. An upland and a lowland site in eastern Nebraska, consisting of well-drained, fine-silty clay, loess-derived soils, were seeded with 23 native prairie grass and forb species and subsequently mowed or treated at rates of 0.6, 1.1, 1.7, and 2.2 kg/ha with atrazine [6-chloro-N-ethyl-N'-(1-methylethyl)-1,3,5-triazine-2,4-diamine] or 2,4-D (2,4-dichlorophenoxyacetic acid). Treatments were applied at one and two-year intervals. Canopy cover in unreplicated treatment areas (12 x 30 m) was evaluated in ten randomly located plots (0.5 x 1.0 m). In the lowland, four species of seeded forbs were established only in mulch-mowed plots. In the upland, the number of successfully established, seeded forb species was greatest in the control plot (9 species). While forb establishment was not maximized with herbicide use, such use did contribute to the rapid establishment of some warm-season grasses such as switchgrass (*Panicum virgatum* L.), 77% cover, and eastern gammagrass [*Tripsacum dactyloides* (L.) L.], 21% cover, in the lowland and blue grama [*Bouteloua gracilis* (H.B.K.) Lag. *ex* Griffiths], 11% cover with 2,4-D, and little bluestem (*Andropogon scoparius* Michx.), 60% cover with atrazine. Comparisons of fall total standing crop biomass (1.11 kg/m^2 for lowlands and 0.47 kg/m^2 for uplands) and seedling establishment suggested that high standing crop biomass, regardless of species composition, was likely to affect the establishment of a diverse stand of grasses and forbs. Where stand diversity is the primary objective, methods that prevent high biomass accumulations, particularly the first year or two, will be most successful.

Key Words. grassland reestablishment, forbs, grasses, atrazine, 2,4-D, herbicides, Nebraska

INTRODUCTION

Native prairie species have been seeded for a multitude of purposes including stabilization of disturbed areas, such as abandoned fields, roadsides, and flood-control dams (Landers 1972, MacLauchlan 1973, Brakeman 1975), as well as to reestablish grasslands for preservation efforts (Bland 1970, Bragg 1978). Depending on specific climatic and site conditions, however, these species may require several years to become well established, at least in part because of competition with undesirable (e.g. weedy) species (Cornelius and Atkins 1946, Martin *et al*. 1982). Herbicide application is one of the more common methods used to counter the effect of such undesirable species and thus to speed the rate of establishment. Atrazine [6-chloro-N-ethyl-N'-(1-methylethyl)-1,3,5-triazine-2,4-diamine] and 2,4-D (2,4-dichlorophenoxyacetic acid) are among herbicides often used. Both herbicides are sold under various trade names.

Atrazine

Atrazine is a preplanting, pre- and post-emergence herbicide for the control of undesirable broadleaf plants and certain grasses. In grassland reestablishment efforts, atrazine at rates varying from 1.1 to 4.5 kg/ha, resulted in well established stands of warm-season grasses such as switchgrass (*Panicum virgatum* L.) and big bluestem (*Andropogon gerardii* Vitman), particularly at higher rates (McCarty 1976, Martin *et al*. 1982, Vogel 1987). Switchgrass was particularly favored, thriving even under high concentrations of atrazine (Morrow and McCarty 1976). On the other hand, substantial reductions were reported for cool-season species (Plumb 1988), and poor establishment was reported for indiangrass [*Sorghastrum nutans* (L.) Nash], sideoats grama [*Bouteloua curtipendula* (Michx.) Torr.], and sand lovegrass [*Eragrostis trichodes* (Nutt.) Wood] even at rates as low as 1.1 kg/ha (Vogel *et al*. 1981, Bahler, *et al*. 1984, Weimer *et al*. 1988). Atrazine carryover in reestablishment studies has been shown to last for 6 to 12 months (Martin *et al*. 1977) and thus may also have some effect on late-germinating seeds.

In range improvement studies, atrazine also increased warm-season grasses, often at the expense of cool-season species (Houston 1977, Morrow *et al*. 1977, Baker and Powell 1978, Samson and Moser 1982, Waller and Schmidt 1983, Rehm 1984, Gillen *et al*. 1987). For example, atrazine, at a rate of 3.3 kg/ha, was effective in recovering warm-season species on previously seeded but overgrazed pastures that had been invaded by cool-season species (Dill *et al*. 1986); lower application rates, however, were not as effective.

2,4-D

2,4-D is a growth regulating phenoxy herbicide for broadleaf weed control in grass crops (McCarty *et al*. 1974, Furrer *et al*. 1981). It also is used to control woody plants (Morrow and McCarty 1975, Wilson *et al*. 1984, Sturges 1986), which often occur during reestablishment efforts. In reestablishment studies, 2,4-D applied at rates from 0.6 to 1.1 kg/ha did not significantly increase switchgrass, indiangrass, or 'Champ' bluestem [a cross between big bluestem and sand bluestem (*Andropogon hallii* Hack.)] (McCarty 1976) although it has been shown to effectively control some undesirable forbs (Quimby *et al*. 1978) and to increase warm-season grass establishment in some areas (Cox and McCarty 1958).

Different responses, however, were obtained from range improvement studies using 2,4-D. For example, a single application of 2,4-D at rates of 0.6 and 1.1 kg/ha significantly increased overall warm-season grass yields in Oklahoma (Elwell and McMurphy 1973). One community-level effect of using auxin-type herbicides, such as 2,4-D, is that the increased number of grasses and the reduced number of broadleaf herbs results in a persistent simplification of community type (Tomkins and Grant 1977) which is counter to the goals of some reestablishment studies.

Of the various studies on native plant reestablishment, most have focused primarily on warm-season grasses with little research on the concurrent establishment of perennial forbs. Forbs, however, are an integral part of the diversity of natural ecosystems and, since many reestablishment efforts are designed to recreate such diversity, it is particularly important to include them when developing such grassland reestablishment procedures. The successful establishment of forbs in an already established grassland is particularly difficult, thus it is desirable to seed both grasses and forbs at the same time. The use of herbicides in such grassland reestablishment efforts has been considered to be important to improve the successful establishment of seeded species. However, herbicides are also designed to deter broadleaf plant (i.e. forb) establishment, and, thus is likely to be counter productive.

This study was designed to assess problems associated with the establishment of both native prairie forbs and grasses. In particular, the focus was on forb establishment in areas likely initially to have a substantial cover of undesirable (e.g. weedy) species that, therefore, may need to be controlled with herbicides. The focus of the study was to assess the net effect of treatment on grass and forb establishment. While essential to a full understanding of the effect of herbicides on native plant establishment, the proximal causes of any observed effects were not part of the design. The study, therefore, implies, but does not attempt to determine, whether the results are a consequence of direct effects of the herbicide on seeds or seedlings, of excessive biomass resulting in reduced solar radiation reaching the prairie seedlings, of effects of allelochemicals that are known to be produced by several of the species identified in this study (Rice 1984), or of any other possible causes.

METHODS AND MATERIALS

Study Site

The study was conducted from 1975 through 1978 on two, previously cultivated fields located at a recently developed flood-control dam site situated about 20 km northwest of Omaha, Nebraska. This area is locally designated Dam Site 11 or Cunningham Reservoir. Soils of the site are mostly of the Mollisol soil order. One field, the Lowland Site (SE1/4 of SE1/4, Section 22, T16N, R12E), was located on a Colo/Kennebec Series (Ck) soil complex (Cumulic Haplaquolls and Hapludolls). These soils are deep, nearly level, somewhat poorly drained to well-drained fine-silty clay loam soils that typify the occasionally-flooded bottomlands along major streams of this portion of eastern Nebraska. The second field, the Upland Site (SW1/4 of SW1/4, Section 22, T16N, R12E), was situated on a Monona/Ida Series (MoD and MsE2) soil complex (Typic Hapludolls and Typic Udorthents the latter of the Entisol Soil Order). These are deep, well-drained, sloping fine-silty and silty loam soils (7-11% slopes) formed over 9-15 m of loess. Climate of the region varies from average high temperatures of 31 C in July to -11 C in January; annual precipitation averages 71 cm with 75% falling from April to September. The growing season averages 167 days. Soil and climatic data are from Bartlett (1975).

Treatments

At each of the two sites, a 0.82 ha study plot was permanently marked and divided into 22 treatment plots (12 x 30 m). The study plots were disked and harrowed just prior to seeding to provide a weed-free seed bed (Cox and McCarty 1958). From 21 to 23 May 1975, 16 species of native prairie forbs and 7 of native prairie grasses were seeded in each study site at rates averaging 19 pure live seed (PLS) per m^2 for grasses and 28 seeds per m^2 for forbs (Table 1). Seeds were obtained from the Soil Conservation Service's Plant Materials Center in Manhattan, Kansas. Seeding was accomplished using a Nesbit drill and planting at a depth of 0.6 cm. Forb seeds were mixed with bran to prevent size-sorting during drilling. The bran-forb seed mixture was uniformly drilled across both upland and lowland sites on 21 May 1975 at a rate of 26 kg/ha.

Grasses were drilled evenly across each study site on 22 and 23 May 1975, but the species seeded varied for each topographic location (Table 1). Eastern gammagrass [*Tripsacum dactyloides* (L.) L.] was an exception. It was broadcast, followed by harrowing, because of the large size of the seed.

Atrazine and 2,4-D treatments were applied at rates of 0.6, 1.1, 1.7, and 2.2 kg/ha. All treatment plots evaluated, including untreated controls, were separated by buffer plots of equal size to reduce the effects of pesticide drift or edge effect. In 1975, atrazine was applied in the 80% wettable powder form on 23 May, the time of grass seeding, while 2,4-D was applied as a liquid spray on 10 July 1975. Mowed plots were mulch-mowed to a height of approximately 5-10 cm on 17 July and 8 August 1975 for the lowland site, and 24 July and 8 August 1975 on the upland site. Untreated control plots were not treated in any way. One half of each treatment plot was retreated in 1976 at the same rate applied the previous year. Atrazine was applied in the wettable powder

Table 1. Seeded species coding and application rates. Species indicated with an asterix (*) were seeded but not found in any treatment plot.

Code	*Scientific and Common/Varietal Name*	*Quantity*
Forbs - upland/lowland seeding:		% trt[1]
AscTub	*Asclepias tuberosa* L. (butterfly milkweed)	0.7*
CeaHer	*Ceanothus herbaceous* Raf. var. *pubescens* T. & G. (inland ceanothus; New Jersey Tea)	5.7
DalCan	*Dalea candida* Michx. ex Willd. (white prairie clover)	11.4
DalPur	*Dalea purpurea* Vent. (purple prairie clover)	12.1*
DesIll	*Desmanthus illinoensis* (Michx.) MacM. (Illinois bundleflower)	1.8*
EchAng	*Echinacea angustifolia* DC. (purple coneflower)	2.9
HelMax	*Helianthus maximilianii* Schrad. (Maximilian sunflower)	3.8
HelHel	*Heliopsis helianthoides* (L.) Sweet var. *scabra* (Dun.) Fern. (false sunflower)	3.1
LesCap	*Lespedeza capitata* Michx. (round-head lespedeza)	8.0
LiaAsp	*Liatris aspera* Michx. (rough gay-feather)	7.2
LiaPun	*Liatris punctata* Hook. (dotted gay-feather)	4.8*
LiaPyc	*Liatris pycnostachya* Michx. (thickspike gay-feather)	7.7*
PenGra	*Penstemon grandiflorus* Nutt. (shell-leaf penstemon)	12.0
RatPin	*Ratibida pinnata* (Vent.) Barnh. (grayhead prairie coneflower)	21.9
SalAzu	*Salvia azurea* Lam. (Pitcher sage)	2.7
SchNut	*Schrankia nuttallii* (DC.) Stand. (catclaw sensitive brier)	0.7
Grasses upland seeding:		kg PLS/ha
AndSco	*Andropogon scoparius* Michx. ('Aldous' little bluestem)	1.74
BouCur	*Bouteloua curtipendula* (Michx.) ('El Reno' sideoats grama)	2.56
BouGra	*Bouteloua gracilis* (H.B.K.) Lag. *ex* Griffiths ('Nature' blue grama)	1.27
Grasses lowland seeding:		
AndGer	*Andropogon gerardii* Vitman ('Kaw' big bluestem)	1.39
AndSco	*Andropogon scoparius* Michx. ('Aldous' little bluestem)	2.16
PanVir	*Panicum virgatum* L. ('Blackwell' switchgrass)	1.68
SorNut	*Sorghastrum nutans* (L.) Nash ('Oto' indiangrass)	2.73
TriDac	*Tripsacum dactyloides* (L.) L. (eastern gammagrass)	2.12

[1]Based on estimates of counts of disseminules of each species; total estimate = 442,500 disseminules.

form on 12 March 1976, and 2,4-D was sprayed on 25 May 1976. In 1976, mowing was completed on 30 March. Information on effects of mowing was limited due to inadvertent mowing of the lowland site just prior to the scheduled sampling date in 1978 and early mowing of some treatment plots in 1977.

Evaluations

Evaluations were conducted 30 August to 10 September 1976, 21 September to 6 October 1977, and, for upland only, on 15 September 1978. Evaluations in 1976 were conducted using 10 microplots (0.5 x 1.0 m) randomly located within each treatment plot. For 1977 and 1978, five circular microplots (1 m^2) were used; this increase in size and reduction in number was needed to accommodate the reduced size of the treatment plots resulting from herbicide retreatment of half of each of the original plots. Within each microplot, canopy cover by species was estimated using seven canopy cover categories: 0%, < 5%, 5-25%, 25-50%, 50-75%, 75-95%, and > 95% (Daubenmire 1959). In addition, from 1 to 20 September 1976, biomass was clipped from 3 microplots (0.5 x 1.0 m) from within each treatment plot and separated into grasses, forbs, and woody plants.

RESULTS AND DISCUSSION

Responses to herbicide application rates were adequately reflected in 1.1 and 2.2 kg/ha treatments thus, for the sake of clarity, only these two rates are addressed in this study. The effects of all four herbicide application rates, however, are available from the authors.

Effects on Overall Diversity

In the lowland site, where standing crop biomass was highest (1.11 kg/ha), mowing resulted in the establishment of the most diverse stand of seeded grasses and forbs. No seeded forbs were found in any plot treated with either atrazine or 2,4-D (Figure 1, Table 2) due to either the effect of the herbicide or the strong favoring of a seeded species, such as switchgrass, which resulted in high standing crop biomass. In the upland, however (standing crop biomass = 0.47 kg/m^2), seeded grass and forb diversity was highest in the untreated plots (Table 3). In combination, these results suggest that herbicides are is not necessary when the objective is to establish a diverse stand of perennial forbs. However, while herbicides did adversely affect overall forb establishment, some forbs were able to become established in treated plots. In those instances, a single application of 2,4-D at any concentration was more successful than was any atrazine treatment or any retreatment.

While 2,4-D and atrazine adversely affected forb establishment, a result that was consistent with the normal use of these herbicides, they were beneficial when the need for rapid grass establishment was the principal objective. Overall results of this study show that, at certain rates, atrazine or 2,4-D were useful in encouraging the rapid establishment of big bluestem, little bluestem, switchgrass, eastern gammagrass, sideoats grama, and blue grama (Figure 2, Tables 2 and 3). Results for individual species were consistent with the findings of others (McCarty 1976, Morrow and McCarty 1976, Martin *et al.* 1982, Bahler *et al.* 1984, Vogel 1987). While forbs may be absent following application of atrazine or 2,4-D, grass diversity can be high even though one species may dominate. For example, first-year, lowland grass stands with atrazine were dominated by switchgrass (ave. cover = 60%) but also contained eastern gammagrass (ave. cover = 19%), big bluestem (ave. cover = 18%), and little bluestem (ave. cover = 10%). However, retreatment, particularly with high concentrations of atrazine, tended to reduce diversity by strongly favoring switchgrass over other species (Table 2). Switchgrass was the only lowland seeded grass to show a consistent increase as atrazine application rates increased from 0.6 to 2.2 kg/ha.

Differences between conditions for the successful establishment of prairie species (mowing in the lowland, control in the upland) and between average standing crop biomass (0.47 kg/m^2 in the upland, 1.11 kg/m^2 in the lowland) (Figure 2), suggest that the amount of standing crop biomass, regardless of the species from which derived (i.e. whether ruderal or seeded), may be at least one factor that adversely affects the establishment and success of seeded forbs. This effect is in addition to any direct effect of herbicides. The relationship between biomass and the number of established species was supported by a weak correlation between total standing biomass and the number of established, seeded species ($R = 0.40$; $P < 0.05$).

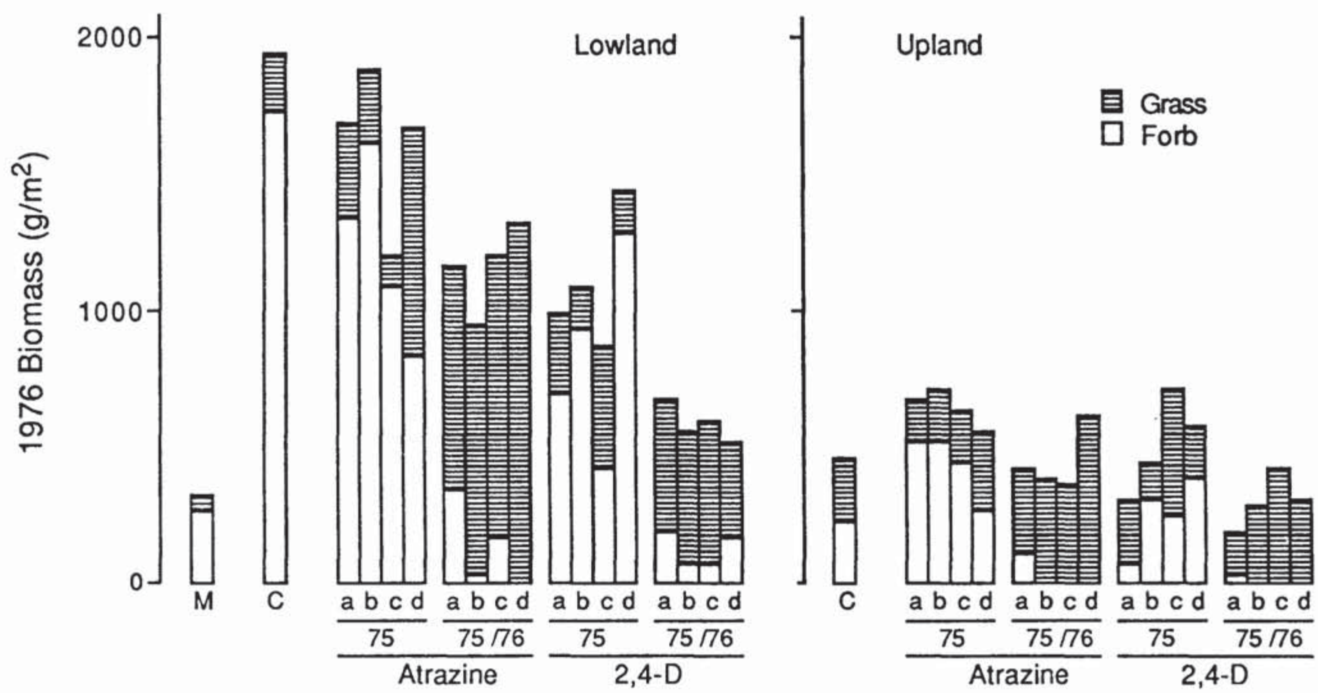

FIG. 1. Biomass for 1976 for upland and lowland sites. M = mowed, C = control, 75 = treated in 1975, 75/76 = treated in both 1975 and 1976, a-c are rates of herbicide application: a = 0.6, b = 1.1, c = 1.7, and d = 2.2 kg/ha.

Table 2. Canopy cover (% ± S.E.) of selected Lowland Site species for 1976 and 1977, two and three growing seasons following seeding and treatment with 2,4-D and atrazine. Selected species are those specifically seeded or those with either at least one average cover value > 25% or a frequency > 70%. See Table 1 or below for species coding. OPEN = bare soil, "tr" = <0.5% cover; "-" = not evaluated.

				Treatment (Rate and Number of Years Applied)							
				2,4-D				*Atrazine*			
				1.1 kg/ha		*2.2 kg/ha*		*1.1 kg/ha*		*2.2 kg/ha*	
Species	*Year*	*Control*	*Mow*	*1 yr*	*2 yr*	*1 yr*	*2 yr*	*1 yr*	*2 yr*	*1 yr*	*2 yr*
		%									
AmbTri[1]	1976	44 ± 13.2	0	0	0	4 ± 3.7	0	64 ± 13.3	6 ± 6.2	31 ± 12.1	0
	1977	56 ± 23.2	0	0	0	0	0	0	12 ± 12.4	6 ± 3.7	0
AndGer	1976	1 ± 0.3	0	2 ± 1.5	11 ± 3.6	2 ± 1.5	8 ± 3.7	3 ± 1.4	24 ± 3.6	12 ± 4.6	31 ± 4.1
	1977	0	25 ± 16.6	11 ± 7.1	48 ± 9.5	50 ± 14.1	38 ± 7.4	19 ± 7.9	33 ± 8.7	26 ± 7.3	1 ± 0.5
AndSco	1976	1 ± 0.3	0	2 ± 1.5	15 ± 3.0	8 ± 4.8	15 ± 4.0	1 ± 0.3	14 ± 3.1	9 ± 2.3	17 ± 3.8
	1977	1 ± 0.5	19 ± 4.4	4 ± 2.7	26 ± 14.8	12 ± 3.0	4 ± 2.7	19 ± 4.4	3 ± 2.9	0	0
AscSpe[1]	1976	2 ± 1.5	0	10 ± 4.8	15 ± 8.7	2 ± 1.5	0	4 ± 2.3	2 ± 1.5	tr	2 ± 1.5
	1977	tr	1 ± 0.5	3 ± 3.0	9 ± 3.7	3 ± 3.0	0	4 ± 2.8	3 ± 2.9	tr	1 ± 0.5
CheAlb[1]	1976	tr	0	2 ± 1.5	0	2 ± 1.5	0	0	0	0	0
	1977	4 ± 2.8	tr	0	0	0	0	0	0	0	0
HelAnn[1]	1976	30 ± 9.9	0	59 ± 6.7	0	54 ± 8.6	2 ± 1.5	40 ± 13.4	tr	21 ± 7.8	0
	1977	40 ± 18.5	31 ± 13.0	76 ± 5.6	21 ± 7.2	68 ± 13.0	57 ± 13.7	58 ± 17.3	35 ± 9.9	71 ± 9.5	0
HelMax	1976	0	4 ± 3.7	0	0	0	0	0	0	0	0
	1977	0	20 ± 12.7	0	0	0	0	0	0	0	0
HelHel	1976	0	0	0	0	0	0	0	0	0	0
	1977	0	tr	0	0	0	0	0	0	0	0
LacSpp[1]	1976	3 ± 2.0	3 ± 2.0	3 ± 2.0	0	7 ± 3.9	0	0	0	0	0
	1977	0	18 ± 8.3	10 ± 7.2	0	10 ± 7.2	0	0	0	0	0
PanVir	1976	0	0	tr	3 ± 2.0	2 ± 1.5	6 ± 3.8	8 ± 4.9	66 ± 8.5	70 ± 12.5	97 ± 1.3
	1977	0	3 ± 3.0	tr	0	6 ± 3.7	3 ± 2.9	3 ± 3.0	59 ± 15.6	59 ± 15.2	95 ± 2.6
Polpen[1]	1976	3 ± 2.0	48 ± 7.4	87 ± 4.6	27 ± 5.6	87 ± 5.9	45 ± 7.1	5 ± 2.3	0	56 ± 11.6	0
	1977	6 ± 3.7	33 ± 8.7	9 ± 3.7	10 ± 7.2	9 ± 3.7	16 ± 5.9	10 ± 3.4	3 ± 3.0	6 ± 3.7	0
RatPin	1976	0	tr	0	0	0	0	0	0	0	0
	1977	0	3 ± 3.0	0	0	0	0	0	0	0	0
SalAzu	1976	0	2 ± 1.5	0	0	0	0	0	0	0	0
	1977	0	0	0	0	0	0	0	0	0	0
SetFab[1]	1976	88 ± 8.3	52 ± 9.4	81 ± 8.2	98 ± 0.0	69 ± 7.9	94 ± 3.6	82 ± 8.3	80 ± 5.8	16 ± 5.8	44 ± 9.2
	1977	7 ± 3.4	4 ± 2.7	69 ± 14.7	79 ± 12.5	47 ± 12.0	98 ± 0.0	19 ± 4.4	16 ± 5.9	31 ± 5.9	21 ± 6.9
SorNut	1976	tr	7 ± 2.2	1 ± 0.3	2 ± 1.5	2 ± 1.5	5 ± 2.2	tr	tr	tr	0
	1977	0	23 ± 18.9	0	13 ± 6.8	18 ± 8.3	7 ± 3.4	4 ± 2.8	6 ± 3.5	0	0
TriDac	1976	2 ± 1.5	2 ± 1.5	2 ± 1.5	2 ± 1.5	0	9 ± 4.9	15 ± 6.3	22 ± 4.1	24 ± 7.5	16 ± 5.0
	1977	tr	0	0	0	0	tr	11 ± 7.1	21 ± 2.7	14 ± 6.6	13 ± 6.8
GRASS	1976	94 ± 2.0	63 ± 11.8	83 ± 11.1	98 ± 0.0	78 ± 10.9	98 ± 0.0	88 ± 9.5	98 ± 0.0	94 ± 3.6	98 ± 0.0
	1977	7 ± 3.2	2 ± 0.0	78 ± 10.5	98 ± 0.0	88 ± 2.6	98 ± 0.0	47 ± 15.8	98 ± 0.0	93 ± 3.2	98 ± 0.0
FORB	1976	80 ± 9.3	75 ± 6.3	95 ± 2.4	27 ± 7.9	98 ± 1.8	44 ± 11.0	95 ± 1.7	20 ± 9.7	75 ± 10.7	tr
	1977	95 ± 2.6	93 ± 3.2	90 ± 3.2	28 ± 5.4	78 ± 10.5	57 ± 13.7	73 ± 10.5	48 ± 9.5	71 ± 9.5	1 ± 0.5
WOODY	1976	3 ± 1.4	0	tr	0	0	0	tr	0	0	0
	1977	4 ± 2.7	10 ± 3.2	0	0	tr	0	tr	0	0	0
OPEN	1976	0	5 ± 2.4	0	tr	tr	tr	0	0	0	0
	1977	1 ± 0.5	1 ± 0.5	tr	0	0	0	13 ± 12.2	0	0	0

[1]AmbTri = giant ragwweed (*Ambrosia trifida* L.) AscSpe = showy milkweed (*Asclepias speciosa* Torr.), CheAlb = lamb's quarters (*Chenopodium album* L.), HelAnn = common sunflower (*Helianthus annuus* L.), LacSpp = (wild lettuce), PolPen = Pennsylvania smartweed (*Polygonum pensylvanicum* L.), SetFab = Chinese foxtail (*Setaria faberi* Herrm.) (Great Plains Flora Association 1986).

Table 3. Canopy cover (% ± S.E.) of selected Upland Site species for 1976, 1977, and 1978, two, three, and four growing seasons following seeding and treatment with 2,4-D and Atrazine. Selected species are those specifically seeded or those with either at least one average cover value > 25% or a frequency > 70%. See Table 1 or below for species coding. OPEN = bare soil, "tr" = < 0.5% cover; "-" = not evaluated.

				Treatment (Rate and Number of Years Applied)							
				2,4-D				*Atrazine*			
				1.1 kg/ha		*2.2 kg/ha*		*1.1 kg/ha*		*2/2 kg/ha*	
Species	*Year*	*Control*	*Mow*	*1 yr*	*2 yr*	*1 yr*	*2 yr*	*1 yr*	*2 yr*	*1 yr*	*2 yr*
		%									
AndGer	1976	0	—	0	0	0	0	tr	2 ± 1.5	tr	0
	1977	0	0	0	0	0	0	0	0	0	0
	1978	0	—	0	0	0	0	0	0	3 ± 2.7	0
AndSco	1976	1 ± 0.3	—	1 ± 0.3	1 ± 0.3	2 ± 1.4	6 ± 2.1	7 ± 2.1	6 ± 2.1	17 ± 3.8	13 ± 3.4
	1977	16 ± 5.9	9 ± 3.7	tr	9 ± 3.7	12 ± 3.0	9 ± 3.4	17 ± 5.6	12 ± 2.6	33 ± 4.4	28 ± 5.4
	1978	28 ± 4.9	—	9 ± 3.3	20 ± 4.0	12 ± 2.7	24 ± 8.5	30 ± 9.6	43 ± 8.0	71 ± 8.4	48 ± 8.5
BouCur	1976	14 ± 3.2	—	8 ± 2.3	4 ± 1.8	3 ± 1.4	15 ± 3.0	15 ± 5.1	14 ± 5.7	16 ± 4.8	10 ± 3.7
	1977	16 ± 5.9	19 ± 4.4	19 ± 4.4	43 ± 13.6	19 ± 4.4	19 ± 4.4	15 ± 0.0	15 ± 0.0	29 ± 9.3	9 ± 3.7
	1978	38 ± 11.4	—	38 ± 0.0	43 ± 8.0	34 ± 7.9	34 ± 10.4	21 ± 6.5	34 ± 7.9	21 ± 6.5	21 ± 6.5
BouGra	1976	3 ± 1.4	—	1 ± 0.2	4 ± 1.8	4 ± 1.8	13 ± 4.4	4 ± 1.9	4 ± 1.9	2 ± 1.4	tr
	1977	6 ± 3.7	4 ± 2.7	12 ± 2.6	12 ± 3.0	15 ± 0.0	12 ± 2.6	3 ± 3.0	0	3 ± 2.9	3 ± 3.0
	1978	2 ± 0.4	—	4 ± 2.5	4 ± 2.6	12 ± 2.7	10 ± 3.0	0	1 ± 0.4	0	0
CeaAme	1976	tr	—	0	tr	tr	0	0	0	0	0
	1977	tr	0	tr	0	0	0	0	0	0	0
	1978	1 ± 0.4	—	3 ± 2.7	0	0	0	0	0	0	0
CheAlb[1]	1976	31 ± 8.3	—	68 ± 9.5	0	72 ± 8.4	0	70 ± 6.7	0	14 ± 6.6	0
	1977	0	tr	0	0	0	0	0	0	0	9 ± 3.4
	1978	0	—	0	0	1 ± 0.5	1 ± 0.5	4 ± 2.4	4 ± 2.4	4 ± 2.5	10 ± 3.0
ConCan[1]	1976	5 ± 2.3	0	5 ± 2.3	tr	4 ± 3.6	0	13 ± 3.4	0	5 ± 3.8	0
	1977	83 ± 5.8	6 ± 3.5	88 ± 2.6	88 ± 2.6	74 ± 7.5	85 ± 0.0	88 ± 2.6	90 ± 3.2	54 ± 14.2	76 ± 5.6
	1978	24 ± 4.9	—	53 ± 10.7	76 ± 4.9	38 ± 9.5	34 ± 10.4	7 ± 3.0	20 ± 4.0	6 ± 3.3	29 ± 8.4
DalCan	1976	tr	—	0	2 ± 1.5	tr	tr	0	0	0	0
	1977	0	0	0	3 ± 2.9	0	3 ± 2.9	0	0	0	0
	1978	0	—	0	1 ± 0.4	0	4 ± 2.6	0	0	0	0
DalPur	1976	tr	—	0	tr	tr	1 ± 0.3	0	0	tr	0
	1977	0	tr	0	0	0	0	0	0	0	0
	1978	1 ± 0.4	—	1 ± 0.4	0	1 ± 0.4	1 ± 0.4	0	0	0	0
EchAng	1976	0	—	tr	0	0	0	0	0	0	0
	1977	tr	0	0	0	0	0	0	0	0	0
	1978	0	—	0	1 ± 0.4	0	0	1 ± 0.4	0	0	0
HelMax	1976	4 ± 3.7	—	2 ± 1.5	0	3 ± 2.0	0	0	0	0	0
	1977	6 ± 3.7	tr	3 ± 2.9	0	6 ± 3.7	0	3 ± 3.0	0	0	0
	1978	4 ± 2.5	—	15 ± 0.0	4 ± 2.5	3 ± 2.7	0	6 ± 3.3	3 ± 2.7	0	0
HelHel	1976	5 ± 2.3	0	tr	0	tr	0	tr	0	tr	0
	1977	1 ± 0.5	0	1 ± 0.5	0	7 ± 7.4	0	0	0	0	0
	1978	10 ± 3.0	—	14 ± 5.7	1 ± 0.5	16 ± 5.4	1 ± 0.4	1 ± 0.4	0	1 ± 0.4	0
LiaAsp	1976	tr	—	0	0	0	0	0	0	0	0
	1977	0	0	0	0	0	0	0	0	0	0
	1978	1 ± 0.5	—	0	0	0	0	0	0	0	0
PanVir	1976	0	—	0	0	0	0	0	0	4 ± 3.7	2 ± 1.5
	1977	0	0	0	0	0	0	0	0	0	0
	1978	0	—	0	0	0	1 ± 0.4	0	0	1 ± 0.4	0
PenGra	1976	1 ± 0.5	—	tr	tr	2 ± 1.5	0	tr	0	tr	0
	1977	tr	tr	1 ± 0.5	0	6 ± 3.7	0	3 ± 2.9	0	tr	0
	1978	4 ± 2.5	—	4 ± 2.6	0	1 ± 0.5	0	4 ± 2.6	0	6 ± 3.3	0
PolPen[1]	1976	1 ± 0.3	—	11 ± 4.7	9 ± 2.4	tr	tr	0	0	0	0
	1977	0	9 ± 3.4	0	0	0	0	0	0	0	0
	1978	0	—	6 ± 3.1	4 ± 7.5	6 ± 3.1	1 ± 0.4	0	1 ± 0.4	0	3 ± 2.7

Table 3. Continued

				Treatment (Rate and Number of Years Applied)							
				2,4-D				*Atrazine*			
				1.1 kg/ha		*2.2 kg/ha*		*1.1 kg/ha*		*2/2 kg/ha*	
Species	*Year*	*Control*	*Mow*	*1 yr*	*2 yr*	*1 yr*	*2 yr*	*1 yr*	*2 yr*	*1 yr*	*2 yr*
		%									
RatPin	1976	5±2.2	—	2±1.5	0	2±1.5	0	1±0.3	0	1±0.3	0
	1977	3±2.9	4±2.8	1±0.5	0	6±3.5	0	9±3.4	0	tr	0
	1978	1±0.4	—	4±2.6	1±0.5	10±3.0	1±0.4	9±3.3	0	0	0
SalAzu	1976	2±1.5	—	tr	0	0	0	0	0	0	0
	1977	0	0	1±0.5	0	0	0	0	0	4±2.8	0
	1978	1±0.5	—	0	0	0	0	0	0	1±0.4	0
SetFab[1]	1976	0	0	79±5.4	92±2.2	78±9.3	89±3.6	89±2.0	98±0.0	73±7.2	95±1.7
	1977	0	88±7.0	0	tr	0	0	0	0	0	0
	1978	1±0.4	—	7±0.3	10±3.0	7±3.0	10±3.0	4±2.5	20±4.0	8±2.7	14±5.9
SchNut	1976	0	—	0	0	0	0	0	0	0	0
	1977	0	0	0	0	0	0	0	0	0	0
	1978	0	—	0	0	0	0	0	0	1±0.4	0
GRASS	1976	95±5.3	—	79±7.7	94±2.8	92±3.1	92±3.1	92±3.1	98±0.0	90±5.2	97±1.8
	1977	19±4.4	98±0.0	24±5.4	57±13.4	33±8.7	24±5.4	19±4.4	19±4.4	52±6.1	28±5.4
	1978	80±4.5	—	42±5.0	48±12.0	48±15.8	71±13.8	64±16.4	76±9.5	90±3.1	74±10.6
FORB	1976	52±7.5	—	72±10.6	12±2.6	77±8.0	9±5.3	75±6.3	4±5.2	23±13.0	0
	1977	90±3.2	15±0.0	93±3.2	88±2.6	83±5.8	85±0.0	93±3.2	90±3.2	62±7.6	76±5.6
	1978	43±8.3	—	85±0.0	76±5.5	62±10.6	38±14.8	30±7.5	24±5.5	20±11.1	48±12.0
WOODY	1976	tr	—	0	0	tr	0	0	0	0	0
	1977	1±0.5	0	tr	0	0	0	0	0	0	0
	1978	1±0.5	—	3±3.0	0	0	0	0	0	0	0
OPEN	1976	2±0.3	—	4±2.7	3±1.9	1±0.5	5±2.4	1±0.5	2±0.4	6±3.0	6±2.9
	1977	0	0	1±0.5	tr	1±0.5	1±0.5	tr	0	2±0.0	tr
	1978	0	—	1±0.6	2±0.5	2±0.6	2±0.6	2±0.6	2±0.0	1±0.5	2±0.6

[1]CheAlb = lamb's quarters (*Chenopodium album* L.), ConCan = horse-weed [*Conyza canadensis* (L.) Cronq.], PolPen = Pennsylvania smartweed (*Polygonum pensylvanicum* L.), SetFab = Chinese foxtail (*Setaria faberi* Herrm.) (Great Plains Flora Association 1986).

Effects on Individual Species

While neither 2,4-D nor atrazine were the most successful method in forb diversity establishment, various species-specific results were observed that may be useful in those instances where herbicide application is deemed necessary. Such a need is likely to be determined for locations, such as the lowland of the present study, where the potential exists for substantial accumulations of undesirable plant biomass.

Effects on seeded species: upland (low biomass) site.

Data for 1978 were collected only from the upland site due to the inadvertent mowing of the lowland site prior to evaluation. These data, however, reflect the net effect of reestablishment efforts and thus are particularly relevant to the principal objective of this study. It was also only on the upland that forbs were successfully seeded in any other than the mowed plot (Figure 1, Tables 2 and 3).

While individual forb species differed, 1978 data generally indicate that 2,4-D applied once and at concentrations varying from 1.1-2.2 kg/ha significantly increased the canopy cover of Maximilian sunflower (*Helianthus maximilianii* Schrad.) and false sunflower [*Heliopsis helianthoides* (L.) Sweet var. *scabra* (Dun.) Fern.]. These species declined either with atrazine or with any retreatment. Grayhead prairie coneflower [*Ratibida pinnata* (Vent.) Barnh.] was increased by single treatments of both 2,4-D and atrazine although it, too, declined with retreatment. For grass establishment, high concentrations of atrazine for little bluestem and 2,4-D for blue grama were more successful than the control (Table 3). As with switchgrass in the lowland, little bluestem was one of three grass species to show a consistent increase following treatment with atrazine.

Of the seeded forbs, only white prairie clover (*Dalea candida* Michx. *ex* Willd.) increased with retreatment. Little bluestem responded similarly. By 1978, blue grama cover was higher with a single treatment of 2,4-D than in the control, although its cover was substantially lower with atrazine. Other seeded species were too infrequent to provide reliable information on the effect of treatments. The upland mowed site could not be evaluated in 1978, but data from previous years indicate that mowing enhanced the establishment of many seeded species.

These results suggest that, where standing crop biomass is low, perhaps around 0.5 kg/m^2, a diverse forb and grass stand can be obtained without applying herbicides. Should herbicides be deemed necessary, however, a single application of 2,4-D is more likely to result in the desired diversity than is the use of atrazine or the use of any second-year retreatment.

Effects on undesirable species: lowland (high biomass) site.

Giant ragweed (*Ambrosia trifida* L.), annual sunflower (*Helianthus annuus* L.), Pennsylvania smartweed (*Polygonum pensylvanicum* L.), and Chinese foxtail (*Setaria faberi* Herrm.) were the dominant undesirable species of the lowland site, although a total of 22 such species was recorded during the study. The effect

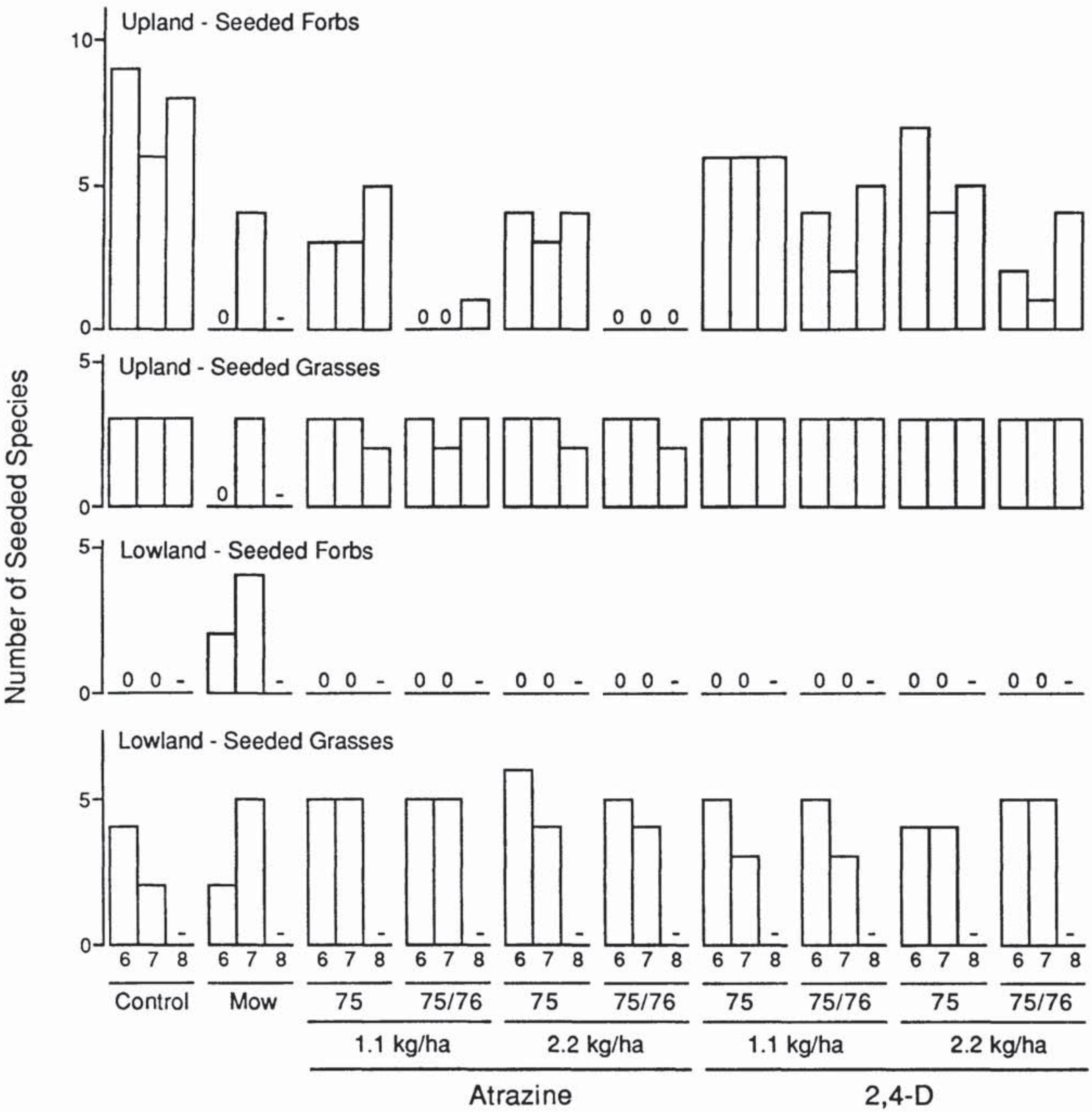

FIG. 2. Number of seeded species located within 1.1 and 2.2 kg/ha herbicide treatment plots for 1976-78. 75 = treated in 1975, 75/76 = treated in both 1975 and 1976, 6 = 1976 data, 7 = 1977 data, 8 = 1989 date, 0 = none, - = not evaluated.

of a single application of 2,4-D or atrazine was assessed by comparing means and standard errors from the control plot with each treated plot using data from 1977, two growing seasons following herbicide retreatment. This date was selected since it was the last year during which both upland and lowland sites were evaluated. For both 2,4-D and atrazine, declines were noted for giant ragweed at all concentrations and Chinese foxtail at high concentrations (Table 2). Chinese foxtail, as well as annual sunflower, were two of only a few species that showed a consistent decline as application of atrazine increased from 0.6 to 2.2 kg/ha. Areas treated with low concentrations of 2,4-D, however, contained high annual sunflower cover. Similarly, low concentrations of atrazine did not adversely affect Pennsylvania smartweed, although all concentrations of 2,4-D and high concentrations of atrazine resulted in significant increases in this species.

Retreatment with 2,4-D or atrazine was assessed by comparing mean and standard errors from single-year treatment plots to those from two-year treatment plots for 1977 data. For lowland 2,4-D retreatments, annual sunflower declined at low concentrations, and giant ragweed declined at high concentrations (Table 2). Chinese foxtail, however, increased following retreatment at 2.2 kg/ha 2,4-D. With atrazine, however, giant ragweed, annual sunflower, and Pennsylvania smartweed all declined at all concentrations in plots treated the previous year. At least in part, these responses are likely to reflect the effect of an increasingly greater canopy cover of switchgrass occasioned by atrazine treatments. Perennial grasses, such as switchgrass, with established root systems would be expected to have a long-term competitive advantage over annuals.

Mowing in the lowland resulted in significant declines in giant ragweed but an increase in Pennsylvania smartweed (Table 2). Woody species of any consequence were located only in the control plots or in plots receiving the lowest herbicide rate.

Effects on undesirable species: upland (low biomass) site.

Of the 18 undesirable species recorded on the upland during the study, the dominants were Chinese foxtail, horse-weed [*Conyza canadensis* (L.) Cronq], and lamb's quarters (*Chenopodium* spp.). Upland data for 1977 indicate no significant difference between the control and herbicide treatment plots for horse-weed or lamb's quarters although canopy cover of Chinese foxtail was higher for all concentrations of 2,4-D and atrazine (Table 3). Horse-weed, however, increased again in 1978 indicating the short-term effect on the control of this species. Retreatment resulted in no significant decline in undesirable species. Horse-weed and Chinese foxtail, however, significantly increased with atrazine despite retreatment. Horse-weed was the only undesirable species of the upland that was significantly reduced by mowing. As in the lowland, woody species of any consequence were located only in the control plots or in plots receiving the lowest herbicide rate.

CONCLUSIONS

The results of this study need to be considered in light of the absence of replication and, thus, should be taken as preliminary in nature. The study, however, presents information that should be useful in making decisions until more studies are conducted. Based on this preliminary study, one of the most important factors in reestablishing a diverse native perennial forb and grass stand, at least in eastern Nebraska and in the soil types and topographic settings evaluated, appears be the prevention of a dense vegetative canopy of any one species, whether that species be one of those seeded or a ruderal species. For sites with a standing crop biomass potential averaging greater than 0.5 kg/m^2, such as the lowland site of this study, some form of control of ruderal species is likely to be necessary and, where forb establishment is a principal goal, mechanical rather than chemical means are most likely to best achieve the desired result. However, if rapid establishment is of more importance than maximum diversity, a single application of 2,4-D may result in an adequate grass stand with a greater diversity of forbs than will atrazine. If, however, grass establishment is the objective and a forb component is not necessary, the use of atrazine or a second-year treatment with either 2,4-D or atrazine may be the most successful, particularly if used in conjunction with herbicide-tolerant species such as switchgrass and big bluestem.

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