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Influence of improvement practices on big bluestem and indiangrass seed production in tallgrass prairies

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Abstract

Tallgrass prairies provide a valuable source of diverse native plant germplasm. Seed harvested from native prairies can be used to revegetate highly erodible or marginal cropland and degraded rangeland if adequate quantities of seed can be produced. The effect of spring burning, fertilization, and atrazine [6-chloro-N-ethyl-N′-(1-methylethyl)-1,3,5-triazine-2,4-diamine] on big bluestem (*Andropogon gerardii* Vitman var. *gerardii* Vitman) and indiangrass [*Sorghastrum nutans* (L.) Nash] reproductive stem density and seed production was determined in 9 tallgrass prairie environments (each year by site was considered a unique environment). Studies were conducted at tallgrass prairies near Bloomfield, Lincoln, and Virginia, Nebr., from 1987 through 1990. Atrazine was applied at rates of 0 and 2.2 kg a.i. ha^{-1} in mid-spring. Fertilizer rates applied in late spring were 0 and 110-0 kg N-P ha^{-1} at Lincoln in 1987, 0 and 110-22 kg N-P ha^{-1} at Bloomfield in 1987 and all sites in 1988, and 0 and 67-22 N-P kg ha^{-1} at all sites in 1989 and 1990. Improvement practices increased stem density of big bluestem in 5 environments and indiangrass in 4 environments. Number of germinable seed produced by the grasses was influenced by treatment only in 1987 and 1990 when precipitation amounts were above or near the long-term average. In 1987, atrazine increased indiangrass germinable seed number from 202 to 481 seed m^{-2} at Bloomfield. At Lincoln in 1987, the combined effects of fire, fertilizer, and atrazine increased the number of germinable indiangrass seed to 2,517 seed m^{-2} as compared to 331 seed m^{-2} produced on areas that had not been treated. In 1990, burning in mid-May increased big bluestem seed number from 52 to 125 germinable seed m^{-2} at Virginia, and fertilizer increased big bluestem seed number from 333 to 724 seed m^{-2} at Lincoln. The tallgrasses did not produce germinable seed in 1988 and 1989, presumably because of drought conditions that persisted both years. Improvement practices evaluated in this study increased native grass seed production when precipitation was adequate. However, no single treatment or combination of treatments reliably or consistently increased the number of seed produced and the absolute amount of seed produced on native prairies was low.

Key Words: reproductive stem density, seed rain, fire, nitrogen fertilizer, phosphorus fertilizer, atrazine, *Andropogon gerardii* Vitman var. *gerardii* Vitman and *Sorghastrum nutans* (L.) Nash

There are over 4.3 million ha of remnant tallgrass prairies in Kansas, Nebraska, and South Dakota (Herbel et al. 1982). These prairies are a valuable forage resource and repository for native plant germplasm. The prairies provide a diverse assortment of plant species and ecotypes within species that are well adapted to local edaphic and climatic conditions. Seed from native prairie plants are a resource of considerable value to man-directed germplasm improvement programs (Vogel et al. 1989). Seed from native prairies can be used to reestablish prairies on severely depleted range sites and reclaim highly erodible cropland if adequate quantities of seed are available for harvest. Grass seed harvested from prairies was used to revegetate about 15% of the 500,000 ha enrolled in the Conservation Reserve Program in Nebraska from 1985 through 1990 (K. Hladek, USDA-SCS, 1991, personal communication).

Prairies are assumed to be unreliable sources of seed because of the negative influence plant competition and adverse climatic conditions, such as erratic precipitation and high temperature, have on seed production. Cornelius (1950) conducted a study in Kansas and compared grass seed yields from commercial seed production fields and native prairies. Seed yields from native prairies were much more variable than from commercial seed production fields. Big bluestem (*Andropogon gerardii* Vitman var. *gerardii* Vitman) in native prairies produced "harvestable quantities" of seed in only 3 out of 9 years from 1937 to 1945. The same species in cultivated stands produced adequate quantities of seed each year during the same time period.

Cornelius (1950) determined that burning and fertilization in late spring increased warm-season grass seed yields from cultivated stands. Influence of these treatments on seed yield of grasses in native prairies was not assessed. Spring burning, fertilization, and atrazine [6-chloro-N-ethyl-N′-(1-methylethyl)-1,3,5-triazine-2,4-diamine] have been used to manipulate botanical composition and improve herbage productivity of warm-season grasses in southern and central Great Plains tallgrass prairies (Gillen et al. 1987, Masters et al. 1992). Studies were conducted to evaluate the influence of these improvement practices on reproductive stem density and seed production of big bluestem and indiangrass [*Sorghastrum nutans* (L.) Nash] growing in tallgrass prairies. The purpose of the studies was to determine if these practices could be used to reliably increase seed production of big bluestem and indiangrass.

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Materials and Methods

Three studies were conducted from 1987 through 1990 in 9 tallgrass prairie environments located near Bloomfield, Lincoln, and Virginia, Nebr. In this research, each year by site was considered a unique environment. The influences of burning, fertilizer, and atrazine on big bluestem and indiangrass reproductive stem density and seed production were assessed the year of treatment application. These 2 grasses were selected for study because they are common in most tallgrass prairies and seed of these species mature at about the same time in the fall. Livestock were excluded from the study sites during the year of treatment.

Precipitation was below normal at 8 of 9 sites during the studies (Fig. 1). Precipitation amounts in 1987 were 18% above the long-term average at Lincoln and 6% below average at Bloomfield. Precipitation at Lincoln in 1988, 1989, and 1990 was 31, 9, and 1% below normal, respectively, and at Virginia was 38, 27, and 17% below normal in 1988, 1989, and 1990, respectively. The precipitation deficit at Lincoln and Virginia in 1988 and 1989 was below the long-term average throughout the growing season. Precipitation in 1990 closely followed the long-term average throughout the year at Lincoln and through July at Virginia.

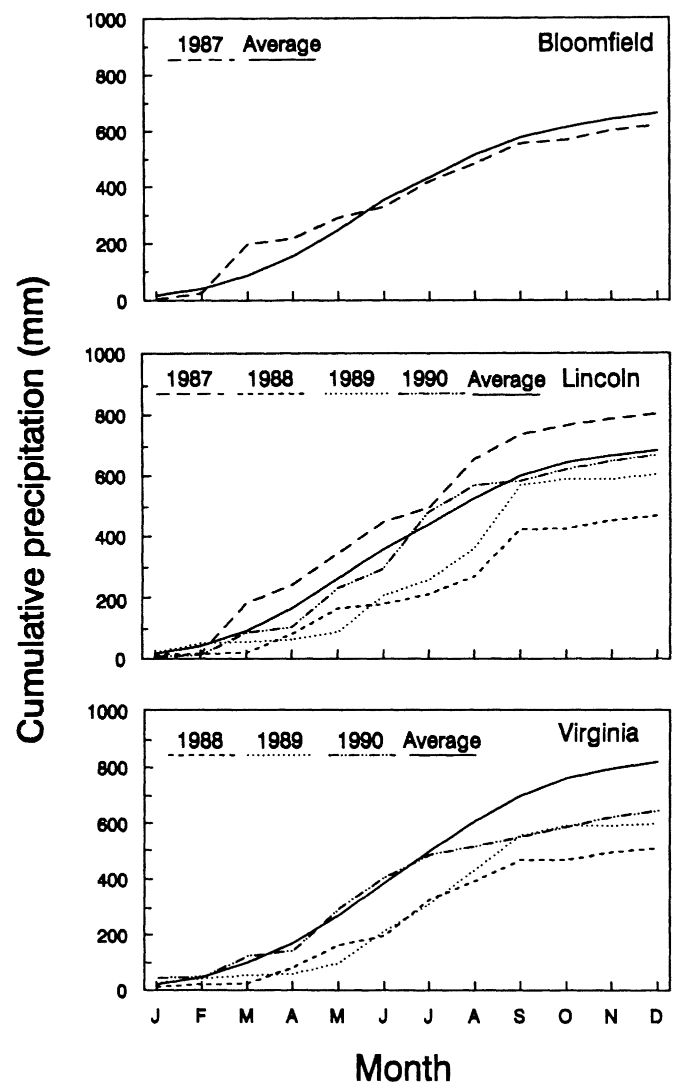

Fig. 1. Cumulative precipitation at 3 locations in eastern Nebraska during the time the studies were conducted.

Study 1

In 1987, sites were established on grasslands located 15 km northwest of Lincoln, Nebr. (Nine-Mile Prairie) and 10 km southwest of Bloomfield, Nebr. The soil at the Lincoln site was a Sharpsburg silty clay loam, fine, montmorillonitic, mesic, Typic Argiudoll and at the Bloomfield site was a Dickinson loamy sand, coarse-loamy, mixed, mesic, Typic Hapludoll. The Lincoln site was a tallgrass prairie that had not been grazed and had been burned at 3-year intervals since 1968. The Bloomfield site supported a grassland community that had been grazed annually since revegetation with tall- and mid-grasses in the 1950's.

One-half of an area, 148 × 54 m in size, was burned at the Lincoln and Bloomfield sites on 18 April and 23 April 1987, respectively. Three plots, each 74 × 18 m, were delineated within the burned and unburned areas at each site. In May 1987, one-half of each plot was fertilized with 110 kg N ha^{-1} at Lincoln and 110-22 kg N-P ha^{-1} at Bloomfield. Atrazine was applied at 2.2 kg a.i. ha^{-1} to half of each fertilized and unfertilized plot within the burned and unburned areas. Density of big bluestem and indiangrass stems with inflorescences was determined in early October 1987 by counting numbers of stems within two 0.5-m^2 quadrats randomly located in each subplot. Big bluestem and indiangrass inflorescences within 4 × 8-m areas located in the center of each subplot were harvested after stems were counted.

Study 2

In 1988, sites were established on tallgrass prairies near Lincoln (Nine-Mile Prairie) and Virginia (Dalbey-Halleck Farm), Nebr. The soil at the Lincoln site was a Sharpsburg silty clay loam and at the Virginia site was a Pawnee clay loam, fine, montmorillonitic, mesic, Aquic Argiudoll. The Lincoln site had a similar history to the tallgrass prairie in Study 1. Two sites located on a tallgrass prairie 5 km south of Virginia were used in this study. For a period of 25 years before initiation of this study, 1 site (Virginia-G) had been moderately grazed for 50 to 60 days during the summer and the other site (Virginia-H) had been hayed in late July or early August. The Virginia-G site was sprayed with atrazine at 4.4 kg a.i. ha^{-1} in 1986 and with 1.1 or 2.2 kg a.e. ha^{-1} of 2,4-D [(2,4-dichlorophenoxy)acetic acid] each year from 1982 to 1987. Both sites were burned in mid-April 1986 and 1987.

Eight plots, each 10 × 20 m, were established at each site in April 1988. Four of these plots were burned at each site on 6 May 1988. Four 5 × 10-m subplots were delineated within each main plot after burning. On 12 May 1988, 2 randomly selected subplots were fertilized at a rate of 110-22 kg N-P ha^{-1} and atrazine was applied at a rate of 2.2 kg a.i. ha^{-1} to 1 fertilized and unfertilized subplot within each plot. Density of big bluestem and indiangrass reproductive stems with inflorescences was determined by counting number of stems within four 0.5-m^2 quadrats randomly located in each subplot in early October 1988. Big bluestem and indiangrass inflorescences were harvested from within the quadrats after stems were counted.

Study 3

In 1989 and 1990, study sites were established on tallgrass prairies near Lincoln (Nine-Mile Prairie) and Virginia (Dalbey-Halleck Farm), Nebr. The soil at the Lincoln site was a Shelby clay loam, fine-loamy, mixed, mesic, Typic Argiudoll and at the Virginia site was a Pawnee clay loam. Management of the tallgrass prairie near Lincoln was similar to that used in Study 1, except that the site was burned by a wildfire on 10 March 1988. Management of the Virginia site was the same as the Virginia-G site used in Study 2.

Twelve plots, each 10 × 20 m, were established at the Lincoln and Virginia sites in April 1989 and again in 1990. The plot areas used in 1990 had not been treated the previous year. In 1989, 3 of the plots were not burned while 3 plots were burned on either 31 March, 19 April, or 15 May at Lincoln and 5 April, 20 April, or 16 May at Virginia. In 1990, 3 plots were not burned while 3 plots were burned on either 2 April, 27 April, or 14 May at Lincoln and on 27 March, 24 April, or 17 May at Virginia. Each of the main plots were divided into four 5 × 10-m subplots. Atrazine at 2.2 kg a.i. ha^{-1} was applied on 25 and 26 April 1989 at Virginia and Lincoln, respectively, to 2 randomly selected subplots in each main plot. Fertilizer at a rate of 67-22 kg N-P ha^{-1} was applied on 18 and 19 May 1989 at Virginia and Lincoln, respectively, within each main plot to 1 subplot that had been treated with atrazine and 1 that had not been treated with atrazine. Plots included in the experiments conducted in 1990 were treated with atrazine on 12 and 16 April 1990 at Virginia and Lincoln, respectively, and fertilizer was applied on 18 May 1990 at both sites. Rates of atrazine and fertilizer applied in 1990 were the same as those applied in 1989. Density of big bluestem and indiangrass stems with inflorescences was determined by counting number of stems in two 0.5-m^2 quadrats randomly located in each subplot in late September 1989 and mid-October 1990 at sites treated in the spring of 1989 and 1990, respectively. Big bluestem and indiangrass inflorescences within a 2 × 2-m area located in the center of each subplot were harvested after stems were counted.

Grass Seed Germinability Determination

Big bluestem and indiangrass inflorescences harvested in each of the 3 studies were dried at 25 to 30° C for 14 days. Caryopses were threshed from inflorescences by hand, weighed, and stored at 25° C for 150 days. After storage 1-g subsamples of the caryopses harvested from each of the subplots were placed in separate germination dishes. Five milliliters of a solution of 2% KNO_3 and 1% captan {N-[(trichloromethyl)-thio]-4-cyclohexene-1,2-dicarboximide}, a fungicide, were added to each dish. Dishes were stored at 5° C for 14 days to break seed dormancy (Crosier 1970). Following cold storage, dishes were placed in a germination chamber where temperature and light alternated from 20 and 30° C for 16 (dark) and 8 (light) hours, respectively. At 7-day intervals for 28 days the number of germinated seed were counted and discarded. Number of germinable seed per unit area produced was calculated by multiplying number of germinated seed within a dish by weight of the caryopses harvested.

Botanical Composition

The prairies used in these studies were in good to excellent condition as indicated by botanical composition (Table 1). The Bloomfield site was dominated by indiangrass and little bluestem [*Schizachyrium scoparium* (Michx.) Nash], with each comprising 40% of the warm-season grasses. Big bluestem was uncommon at the Bloomfield site. At Lincoln, big bluestem constituted 60% or more of the herbage with indiangrass as the next most common species except on the site treated in 1988. Big bluestem, indiangrass, tall dropseed [*Sporobolus asper* (Michx.) Kunth], and prairie dropseed [*Sporobolus heterolepis* (A. Gray) A. Gray], were the most common grasses at Virginia. The cool-season grass component of the 9 grassland environments evaluated in these studies ranged from 1 to 10% except at the Virginia sites in 1989 and 1990 which contained 22 and 16% cool-season grasses, respectively. The most common cool-season grasses were smooth brome (*Bromus inermis* L.), Kentucky bluegrass (*Poa pratensis* L.), Scribner's panicum [*Dicanthelium oligosanthes* (Schult.) Gould var. *scribnerianum* Nash], and Wilcox's panicum [*Dicanthelium oligosanthes* (Schult.) Gould var. *wilcoxianum* (Vasey) Gould and Clark].

Experiment Design and Data Analyses

Study 1 was designed as a randomized complete block arranged as a split-split plot. Burning treatments constituted the whole plots and were not replicated. Fertilizer and atrazine treatments were the subplots and sub-subplots, respectively, and were replicated 3 times within the burned and unburned whole plots. Because whole plots were not replicated an error term could not be generated to test the main effect of burning. Despite the restriction in placement of burn treatments, appropriate error terms could be developed as described by Anderson and McLean (1974) to test fertilizer and atrazine main effects and interactions with each other and burning. Testing the interactions that include burning is appropriate if the differences observed in plant response resulted from burning and not from other factors unique to the burned or unburned whole plots. Given the similarity in botanical composition, soil characteristics, and management history between the whole plots at each site, we were confident that interactions with burning could be tested. Data from burned and unburned whole plots at each site were pooled after the error variances were determined to be equal. Equality of error variances was determined using a F-test where $P \leq 0.05$ (Steel and Torrie 1980). Studies 2 and 3 were designed as randomized complete blocks arranged as split plots with 4 and 3 replications per treatment combination, respectively. Burning treatments were the whole plots and fertilizer and atrazine treatments were randomly assigned to subplots within the replicated whole plots. Hierarchial analysis of variance was used in each study to determine the influence of main effects (except main effect of burning in Study 1) and interactions on big bluestem and

Table 1. Botanical composition of tallgrass prairies near Bloomfield, Lincoln, and Virginia, Nebr.[1]

	1987		1988		1989			1990	
Species or category	Bloomfield	Lincoln	Lincoln	Virginia-G	Virginia-H	Lincoln	Virginia	Lincoln	Virginia
	%								
Big bluestem	0	68	78	19	11	60	42	62	47
Indiangrass	40	13	2	28	29	16	14	14	15
Prairie/tall dropseed	0	0	0	41	12	1	11	0	4
Other warm-season grasses	48	12	7	2	36	4	6	18	16
Smooth brome	7	0	0	0	4	0	7	NH	NH
Kentucky bluegrass	NH[2]	NH	9	1	1	1	9	NH	NH
Scribner's/Wilcox's panicum	3	1	0	4	3	1	6	NH	NH
Other cool-season grasses	0	1	0	0	0	1	0	1	16
Sedge	1	3	0	2	2	6	4	1	2
Forbs	1	2	4	3	2	10	1	4	0

[1]Expressed as a percent of total herbaceous vegetation standing crop harvested from plots in mid-July of the year indicated. Plots harvested had not been treated with fire, fertilizer, or atrazine.
[2]Not harvested separately (NH).

Table 2. Reproductive stem density of indiangrass in the fall following application of fire and fertilizer to tallgrass prairies near Bloomfield and Virginia, Nebr.

Spring burning	Fertilizer[1]	1987[2] Bloomfield	1988[2] Virginia-H
		no. m^{-2}	
None	None	7	7
None	Fertilized	15	5
Burn	None	15	8
Burn	Fertilized	38	13
	LSD (0.05)	7	4

[1]Fertilizer rates: 110–22 kg N-P ha^{-1} applied at Bloomfield in 1987 and Virginia-H in 1988, 110 kg N ha^{-1} applied at Lincoln in 1987, and 67-22 kg N-P ha^{-1} applied at Lincoln and Virginia in 1989 and 1990.
[2]Stem density averaged over atrazine treatment.

indiangrass reproductive stem density and germinable seed number. Treatment means were compared using Fisher's-protected least significant difference ($\alpha = 0.05$) (Steel and Torrie 1980).

Results and Discussion

Grass reproductive stem density response to fire, fertilizer, and atrazine treatments varied by species and environment. Improvement practices increased stem density of big bluestem in 5 environments and indiangrass in 4 environments evaluated in these studies (Tables 2, 3, 4, and 5). Big bluestem reproductive stem density was not influenced by treatment in 3 environments and big bluestem was not abundant enough at Bloomfield to adequately assess its response to the treatments. Burning in mid-May 1989 increased big bluestem reproductive stem density as compared to the density on unburned areas or those areas burned in late March or early April (Table 4). Burning has been shown to increase reproductive stem density of warm-season grasses (Hulbert 1988, Ehrenreich and Aikman 1963, Kucera and Ehrenreich 1962, Curtis and Partch 1950). Increased stem density following burning has been attributed to the positive effects of fire-induced removal of standing dead and mulch (Knapp and Seastedt 1986). Removing plant debris has been found to stimulate plant growth by improving the light environment of emerging shoots and causing the soil to warm earlier in the spring than soil in unburned areas (Knapp 1984). Fertilizer increased stem density of big bluestem in Lincoln in 1989 and 1990 and in Virginia in 1989 (Table 5). Indiangrass stem density was less on fertilized areas in Virginia in 1990 than on unfertilized areas. The reason for this response was not determined. Atrazine increased stem density of big bluestem at Lincoln in 1988 when combined with burning and increased density of indiangrass stems in 1988 at the Virginia-G site on areas that were not burned (Table 3). The influence of atrazine on grass reproductive stem density has not been previously assessed; however, the positive effect of this herbicide on herbage yield of warm-season grasses has been documented (Samson and Moser 1982, Waller and Schmidt 1983, Masters et al. 1992).

Number of germinable seed produced by the grasses was influenced by treatment only in 1987 and 1990 (Tables 5 and 6; Fig. 2).

Table 3. Reproductive stem density of indiangrass (IN) and big bluestem (BB) in the fall following application of fire and atrazine in the spring to tallgrass prairies near Lincoln and Virginia, Nebr.

Spring burning	Atrazine	1988[1] Lincoln BB	1988[1] Virginia-G IN
	-kg ha^{-1}-	no. m^{-2}	
None	0	4	12
None	2.2	20	27
Burn	0	3	16
Burn	2.2	38	18
	LSD (0.05)	14	10

[1]Stem density averaged over fertilizer treatment.

Table 4. Reproductive stem density of indiangrass (IN) and big bluestem (BB) in the fall following application of fire in the spring to tallgrass prairies near Lincoln and Virginia, Nebr.

	1989[2]			1990[2]	
	Lincoln		Virginia	Lincoln	
Spring burning[1]	BB	IN	BB	BB	IN
	no. m^{-2}				
None	6	23	1	29	6
Early	17	12	8	70	24
Mid	27	18	5	88	21
Late	67	27	23	96	20
LSD (0.05)	42	9	14	33	12

[1]Burn dates: Early = late March and early April, Mid = mid to late April, and Late = mid-May in 1989 and 1990.
[2]Stem density averaged over fertilizer and atrazine treatments.

Table 5. Reproductive stem density and number of germinable seed of indiangrass (IN) and big bluestem (BB) harvested in the fall following application of fertilizer in the spring to tallgrass prairies near Lincoln and Virginia, Nebr.

	Stem density[1]				Seed Number[2]	
	1989		1990		1990	
	Lincoln	Virginia	Lincoln		Lincoln	
Fertilizer	BB	BB	BB	IN	BB	IN
kg N-P ha^{-1}	no. m^{-2}				no. m^{-2}	
0	21	6	50	24	333	113
67-23	38	13	91	11	724	59
LSD (0.05)	16	4	6	7	186	50

[1]Stem density averaged over burn and atrazine treatments.
[2]Seed number averaged over burn and atrazine treatments.

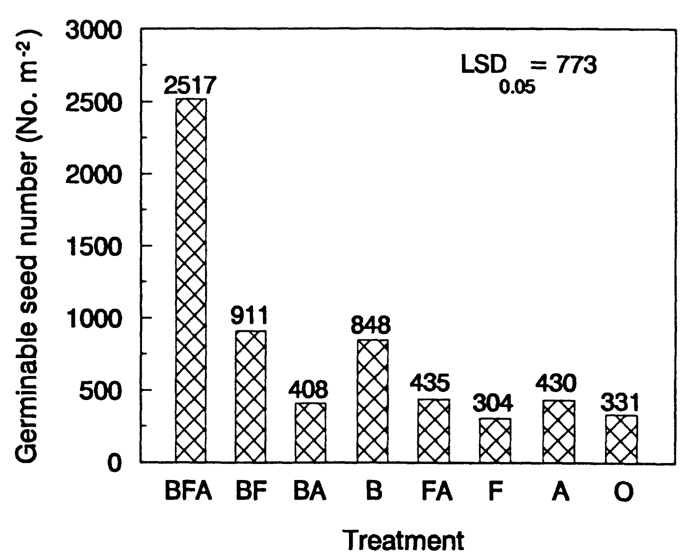

Fig. 2. Indiangrass germinable seed number harvested in the fall after applications of fire, fertilizer, and atrazine to a tallgrass prairie near Lincoln, Nebr., in the spring of 1987. Treatments are burned in the spring (B), fertilized with 110 kg N ha^{-1} (F), atrazine applied at 2.2 kg a.i.$^{-1}$ (A), and no treatment (O).

The positive response of grass seed production to treatments was facilitated by precipitation amounts that were above or near the long-term average through July in 1987 and 1990 (Fig. 1). No germinable seed were produced in 1988 and 1989 when precipitation was below average throughout the entire growing season. Upon inspection, seeds harvested in 1988 were shriveled with no obvious endosperm and those harvested in 1989 were immature with endosperm of reduced size. Delaying seed harvest in 1989 would not have enhanced seed maturation because the growing season ended within 24 hours after harvest when temperatures dropped below 0° C for a 5-hour period. The adverse effect of precipitation deficit on plant growth and development during the growing season probably accounted for poor seed fill during 1988 and 1989. Cornelius (1950) indicated that water was the primary factor limiting seed production of perennial warm-season grasses in tallgrass prairies. Insect damage to grass seed may have been another factor that influenced seed production in our studies. A cecidomyiid midge (*Contariana wattsii* Gagne) has been identified that reduced big bluestem seed yields by 40% (Carter et al. 1988).

No single treatment consistently increased number of germinable seed produced by big bluestem and indiangrass in 1987 and 1990. Atrazine influenced the number of indiangrass germinable seed produced at Bloomfield in 1987. Indiangrass produced 481 germinable seed m^{-2} (averaged across fire and fertilizer treatments) on areas treated with atrazine as compared to only 202 m^{-2} produced on areas that were not treated with atrazine. The positive influence of atrazine on grass seed production may have resulted from suppression of cool-season grasses and forbs (Masters et al. 1992) and herbicide-induced enhancement of warm-season grass growth (Reis 1976). At Lincoln in 1987, the combined effects of fire, fertilizer, and atrazine increased the number of germinable indiangrass seed to 2,517 seed m^{-2} as compared to 331 seed m^{-2} produced on untreated areas (Fig. 2), but treatments did not affect big bluestem seed number ($\bar{x}$ = 16 seed m^{-2}). Number of indiangrass seed produced at Lincoln in 1987 exceeded that of big bluestem, even though big bluestem was the dominant species (Table 1). Burning in mid-May 1990 increased number of germinable big bluestem seed at Virginia from 52 to 125 germinable seed m^{-2} (Table 6).

We compared yields from commercial certified seed production fields to amount of seed harvested from the native tallgrass prairies evaluated in these studies. Estimates of seed yields from commercial certified seed production fields in eastern Nebraska from 1987 through 1990 were obtained from the Nebraska Crop Improvement Association (R. Hammons, 1991, personal communication). The estimates ranged from 95 to 150 kg of clean pure live seed (PLS) ha^{-1} for big bluestem and 105 to 170 kg PLS ha^{-1} for indiangrass. To enable comparison of seed number in our studies with average seed yields from commercial seed production fields, germinable seed number were converted to weight using big bluestem and indiangrass seed weight estimates of 352 and 386 seed g^{-1} of fertile spikelets, respectively (R. Hammons, 1991, personal communication). We estimated the 2,517 germinable indiangrass seed m^{-2} (Fig. 2) harvested from the prairie site at Lincoln in 1987 was comparable to 65 kg PLS ha^{-1}, the 481 indiangrass seed m^{-2} produced after atrazine treatment at Bloomfield was comparable to 13 kg PLS ha^{-1}, and the 125 big bluestem seed m^{-2} (Table 6) produced on areas burned in mid-May at Virginia was roughly equivalent to 4 kg PLS ha^{-1}. The 724 big bluestem seed m^{-2} (Table 5) produced on fertilized areas at Lincoln was similar to 21 kg PLS ha^{-1}. Given these estimates, big bluestem and indiangrass seed yields from native prairies were substantially less than yields from commercial certified seed production fields.

Table 6. Number of germinable seed of indiangrass (IN) harvested in the fall following application of fire and atrazine in the spring to a tallgrass prairie near Lincoln, Nebr. and big bluestem (BB) harvested in the fall following application of fire in the spring near Virginia, Nebr.

		1990	
		Lincoln[2]	Virginia[3]
Spring burning[1]	Atrazine	IN	BB
	kg ha^{-1}	no. m^{-2}	
None	0	19	52
	2.2	49	—
Early	0	128	41
	2.2	87	—
Mid	0	46	39
	2.2	202	—
Late	0	82	125
	2.2	76	—
	LSD (0.05)	100	55

[1]Burn dates: Early = late March and early April, Mid = mid to late April, and Late = mid May.
[2]Germinable seed number averaged over fertilizer treatment.
[3]Germinable seed number averaged over fertilizer and atrazine treatments.

Conclusions

Application of improvement practices on good to excellent condition tallgrass prairies enhanced big bluestem and indiangrass seed production when precipitation was adequate. However, no single treatment or combination of treatments reliably increased seed production and the absolute amount of seed produced on these prairies was low compared to estimates of production from commercial certified seed fields. The tallgrasses did not produce germinable seed when precipitation was below the long-term average during the entire growing season, regardless of treatment or number of reproductive stems produced.

Under certain circumstances, such as high market demand for grass seed, it may be profitable to harvest seed from tallgrass prairies. In such instances applications of fire, fertilizer, and/or atrazine may improve the probability of increasing grass seed production. The feasibility of using atrazine as a component of a program to improve grass seed production on native prairies is tempered by the current suspension of this herbicide from use on rangeland. This suspension makes it illegal for producers to allow livestock to consume herbage from atrazine-treated rangeland.

In most situations, native prairies are not reliable sources of large quantities of grass seed. Native prairies are probably best used as a seed resource by those involved in activities requiring small quantities of seed from genetically diverse native prairie plants, such as, germplasm improvement programs and restoration or reclamation of small prairie refuges located close to remnant prairies. In contrast to native prairies, commercial certified grass seed production fields are a more reliable source of large quantities of seed from single grass species. Seed from commercial production fields are best used to revegetate large areas, such as highly erodible or marginal cropland (i.e., land enrolled in the Conservation Reserve Program) and severely degraded rangeland.

Literature Cited

Anderson, V.L., and R.A. McLean. 1974. Design of experiments: A realistic approach. Marcel Dekker, Inc. N.Y.

Carter, M.R., G.R. Manglitz, M.D. Rethwisch, and K.P. Vogel. 1988. A seed midge pest of big bluestem. J. Range Manage. 41:253–254.

Cornelius, D.R. 1950. Seed production of native grasses under cultivation in eastern Kansas. Ecol. Monogr. 20:1–29.

Crosier, W.F. (ed.). 1970. Rules for testing seeds. Proc. Assoc. Off. Seed Analysts Graphic Publ. Co. Lake Mills, Iowa.

Curtis, J.T., and M.L. Partch. 1950. Some factors affecting flower production in *Andropogon gerardii.* Ecology 31:488–89.

Ehrenreich, J.H., and J.M. Aikman. 1963. An ecological study of the effect of certain management practices on native prairie in Iowa. Ecol. Monogr. 33:113–130.

Gillen, R.L., D. Rollins, and J.F. Stritzke. 1987. Atrazine, spring burning, and nitrogen for improvement of tallgrass prairie. J. Range Manage. 40:444–447.

Herbel, C.H., P.L. Sims, W.A. Laycock, R.J. Lorenz, R.A. Evans, and K.G. Renard. 1982. Range research: An assessment of current problems and a strategy for the future. USDA-SEA Admin. Rep.

Hulbert, L.C. 1988. Causes of fire effects in tallgrass prairie. Ecology 69:46–58.

Knapp, A.K. 1984. Post-burn differences in solar radiation, leaf temperature and water stress influencing production in a lowland tallgrass prairie. Amer. J. Bot. 71:220–227.

Knapp, A.K., and T.R. Seastedt. 1986. Detritus accumulation limits productivity of tallgrass prairie. BioScience 36:662–668.

Kucera, C.L., and J.H. Ehrenreich. 1962. Some effects of annual burning on central Missouri prairie. Ecology 43:334–336.

Masters, R.A., K.P. Vogel, and R.B. Mitchell. 1992. Response of central great plains tallgrass prairies to fire, fertilizer, and atrazine. J. Range Manage. 45:291–295.

Reis, S.K. 1976. Subtoxic effects on plants, p. 311–340. *In:* Audus, L.J. (ed.), Herbicides: Physiology, biochemistry, ecology. Academic Press, London.

Samson, J.F., and L.E. Moser. 1982. Sod-seeding perennial grasses into eastern Nebraska pastures. Agron. J. 74:1055–1060.

Steel, R.G.D., and J.H. Torrie. 1980. Principles and procedures of statistics. McGraw-Hill Book Co. N.Y.

Vogel, K.P., H.J. Gorz, and F.A. Haskins. 1989. Breeding grasses for the future, p. 105–122. *In:* Sleper, D.A. (ed.), Contributions from Breeding Forage and Turf Grasses. Crop Sci. Soc. of Amer., Spec. Pub. 5. Madison, Wisc.

Waller, S.S., and D.K. Schmidt. 1983. Improvement of eastern Nebraska tallgrass range using atrazine and glyphosate. J. Range Manage. 36:87–90.