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REMNANT AND RESTORED PRAIRIE RESPONSE TO FIRE, FERTILIZATION, AND ATRAZINE

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Abstract. The effect of spring burning, fertilization, and atrazine on herbage yield of warm- and cool-season grasses, flowering stalk density, and seed yield of selected warm-season grasses was determined on a remnant prairie and a restored prairie located near Lincoln and Center, Nebraska, respectively. Sites were burned in mid-April 1987 and followed by application of fertilizer (112 kg N/ha at the remnant prairie and 112-22 kg N-P/ha at the restored prairie) and atrazine (2.2 kg active ingredient/ha). Herbage yield of warm-season grasses increased more than 100% following burning in combination with fertilization at both sites and atrazine application alone at the restored prairie. Warm-season grass flowering stalk density increased more than 3 and 2 times following burning combined with fertilization and fertilization only at the remnant and restored prairies, respectively. Germinable seed numbers increased over 600% following a combination of burning, fertilization, and atrazine application at the remnant prairie and more than doubled following atrazine application at the restored prairie. Evidence provided by this research indicates that spring burning, fertilization, and atrazine can be used to renovate and improve productivity of tallgrass prairie in Nebraska.

Key Words. prairie renovation, flowering stalk density, warm-season grasses, cool-season grasses, Nebraska

INTRODUCTION

Areas of remnant and restored tallgrass prairies occur throughout eastern Nebraska. Renovation of these prairies is often necessary because of encroachment of non-endemic cool-season grasses, Kentucky bluegrass (*Poa pratensis* L.) and smooth brome (*Bromus inermis* Leyss.), which compete with desirable warm-season native mid- and tall grasses. Generally, these cool-season species occur on prairies with a history of grazing mismanagement and/or where fire has been excluded.

Methods used to renovate degraded grasslands include spring burning, fertilization, and application of the herbicide, atrazine [6-chloro-N-ethyl-N'-(1-methylethyl)-1,3,5-triazine-2,4-diamine]. Vegetation composition and successional status were important factors influencing grassland community response to these treatments (Gillen *et al*. 1987). Time of spring burning and fertilizer application influenced the response of the warm-season grass component of grassland communities. Burning at the time of warm-season grass growth initiation favored warm-season grasses and suppressed undesirable cool-season plants that initiated growth earlier in the spring (Anderson *et al*. 1970). Warm-season grass herbage production increased following late spring application of nitrogen as compared to early spring application that promoted growth of less desirable introduced cool-season grasses (Rehm 1984). Atrazine selectively controlled cool-season grasses and some broadleaf plants and improved productivity of warm-season grasses (Morrow et al . 1977, Waller and Schmidt 1983).

Information regarding the combined effect of burning, fertilization, and atrazine application on remnant and restored tallgrass prairie is limited. Therefore, this study was conducted to evaluate the influence of these treatments alone and in combination on herbage yield of warm- and cool-season grasses, flowering stalk density, and seed yield of selected warm-season grasses.

METHODS

Study sites were established on a remnant native grassland located on Nine-Mile Prairie, 15 km northwest of Lincoln, Nebraska in Lancaster County and on a restored overgrazed pasture, 6 km east of Center, Nebraska in Knox County. The restored prairie was revegetated with a mixture of native warm-season grasses following a brief period of use as cropland in the 1950's. The remnant prairie had not been grazed since 1968, but had been burned in the spring at two- to three-year intervals. The restored prairie was grazed up to 1986, but had not been burned. The study sites were not grazed during the experiment. Soils on the remnant and restored prairie sites are classified as a Sharpsburg silty clay loam (montmorillonitic, mesic, Typic Argiudolls) and a Dickinson loamy sand (mixed, mesic, Typic Hapludolls), respectively. Common grasses on the sites included big bluestem (*Andropogon gerardii* Vitman-var. *gerardii* Vitman), indiangrass [*Sorghastrum nutans* (L.) Nash], switchgrass (*Panicum virgatum* L.), little bluestem [*Schizachyrium scoparium* (Michx.) Nash], sideoats grama [*Bouteloua curtipendula* (Michx.) Torr.], Scribner panicum [*Dicanthelium oligosanthes* (Schult.) Gould var. *scribnerianum* (Nash) Gould], smooth brome, and Kentucky bluegrass.

One-half of an area (148 x 54 m) was burned at the remnant and restored prairies on 18 April and 23 April 1987, respectively. After burning, three plots (74 x 18 m) were delineated within the burned and unburned areas at each site. In May 1987, one-half of each plot was fertilized with 112 kg/ha of nitrogen. In addition, 22 kg/ha of phosphorus was applied at the Center, Nebraska site because soils in this area are phosphorus deficient. Following fertilizer application, 2.2 kg active ingredient/ha of atrazine was applied to half of each fertilized and unfertilized plot in the burned and unburned areas.

After treatment application a subplot (4 x 8 m) was delineated within each plot to facilitate sampling. In early August 1987, a quadrat (0.5 m^2) was located along each of the longest sides of the sampling subplot within each plot. Vegetation within the quadrats was clipped to a 2 cm stubble height, separated by species, oven-dried, and weighed.

Flowering stalk density was determined in early October by counting number of big bluestem and indiangrass flowering stalks within two quadrats (0.5 m^2) randomly placed within each sampling subplot. After counting, flowering stalks of the two species within each sampling subplot were harvested by hand and air dried. Seeds were threshed, weighed, and stored at room temperature (25 C) until germinability was determined. One gram of threshed seed from each sampling subplot was placed in a petri dish between two pieces of filter paper. Five ml of a solution of 2% KNO_3 and 1% captan N-[(trichloromethyl)-thio]-4-cyclohexene-1,2-dicarboximide, a fungicide, were added to each petri dish. The petri dishes were placed in cold storage (5 C) for two weeks to break seed dormancy (Crosier 1970). Following cold storage, the petri dishes were placed in a germination chamber for four weeks where temperature and light alternated from 20 C and 30 C for 16 (dark) and 8 (light) hr, respectively. After four weeks, the total number of germinated seeds was determined. Total number of germinable seed produced within each sampling subplot was then calculated by multiplying number of germinated seed within a petri dish by weight of the threshed seed harvested from the appropriate sampling subplot.

The experiment was designed as a split block with three replications per treatment combination. Hierarchical analysis of variance was applied to warm- and cool-season grass herbage yields and flowering stalk density and yield of germinable seed of selected warm-season grasses. Sources of variation in descending order were burning, fertilization, and atrazine application. Since randomization associated with placement of the burning treatment was restricted at both sites, the main effect of burning could not be statistically tested. Remaining main effects and interactions were evaluated using standard analysis of variance procedures, and treatment means were compared using Fisher's protected least significant difference test (Steel and Torrie 1980).

RESULTS AND DISCUSSION

Forb response to the various treatments was not determined. Apparently, the technique used to sample the vegetation was not sensitive enough to characterize the forb component of the prairie communities. In other studies, atrazine had an adverse (Gillen *et al.* 1987) or no effect (Peterson *et al.* 1983) on forbs in grasslands of the southern Great Plains. In the following presentation, information will be limited to the response of warm- and cool-season grasses within the remnant and restored prairie study sites.

Warm- and Cool-Season Grass Yields

Warm-season grass yield at the remnant and restored prairies increased following a combination of burning and fertilization (Tables 1, 2, 3, and 4). The two-fold increase in yield was partially the result of removal of standing dead plant biomass and litter by burning. Standing dead and litter yields from unburned areas averaged 6,480 and 1,438 kg/ha as compared to only 333 and 311 kg/ha on the burned sites at the remnant and restored prairies, respectively. Although the main effect of burning cannot be statistically evaluated in this study, it is apparent that burning had an effect on the standing dead and litter biomass components of the remnant and restored prairies.

Excessive accumulation of standing dead and litter depressed plant yields by maintaining low soil temperatures (Sharrow and Wright 1977, Rice and Parenti 1978). Higher soil temperatures following burning stimulated plant growth initiation and enhanced soil microflora growth which hastened organic matter decomposition and increased nutrient availability (Neuenschwander and Wright 1984). Others have found that fire-induced removal of standing dead and litter increased tallgrass productivity by im-

Table 1. Mean dry matter yields (kg/ha) of warm-season grasses, cool-season grasses, and standing dead and litter at the remnant prairie near Lincoln, Nebraska.

Treatment[1]	*Warm-season grasses*	*Cool-season grasses*	*Standing dead and litter*
		kg/ha	
BFA	10,049	125	350
BF	9,372	537	472
BA	5,548	90	258
B	5,146	281	255
FA	7,088	50	6,849
F	6,026	197	5,562
A	4,855	19	7,033
0	4,773	153	6,481
LSD (0.05)[2]	1,891	293	NS
LSD (0.05)[3]	NS	NS	504

[1]Treatments are: B = burned, F = fertilized with 112-0-0 kg N-P-K/ha, A = atrazine applied at 2.2 kg a.i./ha, and 0 = no treatment.
[2]Least significant difference (LSD) for comparing between means of fertilizer main treatment effect and means of fertilizer by burning treatment interaction.
[3]LSD for comparing between means of herbicide main effect and all interaction terms that include the herbicide effect.

Table 2. Mean squares and levels of significance for the treatment effects in the analysis of variance for dry matter yields of warm-season grasses, cool-season grasses, and standing dead and litter at the remnant prairie near Lincoln, Nebraska.

Source of variation[1]	*df*	*Warm-season grasses*	*Cool-season grasses*	*Standing dead and litter*
Burning (B)[2]	1	20383212	140975	226738243
Fertilizer (F)	1	55943784 **	50106 *	235541 NS
F X B	1	10300006 **	17550 NS	747231 NS
Error (a)	4	1008195	24237	632933
Herbicide (H)	1	1852926 NS	292737 NS	1109572 **
H X B	1	1624 NS	39091 NS	1438249 **
H X F	1	590509 NS	20662 NS	139843 NS
H X B X F	1	186949 NS	16214 NS	277780 NS
Error (b)	8	448045	58032	71512

[1]The ** and * indicate significance at the 0.01 and 0.05 levels of probability. NS indicates lack of statistical significance at these levels of probability.
[2]The main effect of burning could not be statistically evaluated.

Table 3. Mean dry matter yields (kg/ha) of warm-season grasses, cool-season grasses, and standing dead and litter at the restored prairie near Center, Nebraska.

Treatment[1]	*Warm-season grasses*	*Cool-season grasses*	*Standing dead and litter*
		kg/ha	
BFA	7,905	12	306
BF	4,944	373	260
BA	4,340	35	437
B	2,091	86	240
FA	5,458	77	1,843
F	1,379	433	952
A	3,401	6	1,635
0	2,355	180	1,325
LSD (0.05)[2]	1,259	NS	NS
LSD (0.05)[3]	2,142	239	NS

[1]Treatments are: B = burned, F = fertilized with 112-22-0 kg N-P-K/ha, A = atrazine applied at 2.2 kg a.i./ha, and 0 = no treatment.
[2]Least significant difference (LSD) for comparing between means of fertilizer main treatment effect and means of fertilizer by burning treatment interaction.
[3]LSD for comparing between means of herbicide main effect and all interaction terms that include the herbicide effect.

Table 4. Mean squares and levels of significance for the treatment effects in the analysis of variance for dry matter yields of warm-season grasses, cool-season grasses, and standing dead and litter at the restored prairie near Center, Nebraska.

Source of variation[1]	*df*	*Warm-season grasses*	*Cool-season grasses*	*Standing dead and litter*
Burning (B)[2]	1	16770495	13614	7634078
Fertilizer (F)	1	21086626 **	130420 NS	28635 NS
F X B	1	10690413 **	1380 NS	1107 NS
Error (a)	4	446891	33098	627218
Herbicide (H)	1	40056651 **	332762 **	782865 NS
H X B	1	2786 NS	5198 NS	343827 NS
H X F	1	5262381 NS	90921 *	69876 NS
H X B X F	1	2018516 NS	6286 NS	200531 NS
Error (b)	8	1293842	16149	182951

[1]The ** and * indicate significance at the 0.01 and 0.05 levels of probability. NS indicates lack of statistical significance at these levels of probability.
[2]The main effect of burning could not be statistically evaluated.

proving the light environment of emerging shoots (Knapp 1984, Hulbert 1988).

Cool-season grass yields were low at both sites when sampled in early August. However, despite time of sampling, yield of cool-season grasses was increased by fertilization at both sites and declined following atrazine application at the restored prairie (Tables 1, 2, 3, and 4). Others determined that atrazine selectively controlled cool-season grasses, but did not have an adverse affect on most warm-season grasses (Waller and Schmidt 1983, Rehm 1984, Gillen *et al.* 1987). As a result of this selectivity, application of atrazine is an effective practice to rejuvenate warm-season grasses in prairie communities dominated by less desirable cool-season grasses.

Table 5. Mean flowering stalk density (number/m²) and germinable seed numbers (number/m²) of selected warm-season grass at remnant and restored prairies in eastern Nebraska.

Treatment[1]	*Flowering Stalk Density*		*Germinable Seed Number*	
	Remnant	*Restored*	*Remnant*	*Restored*
	Number/m²			
BFA	109	49	2,822	534
BF	86	29	1,201	166
BA	56	23	707	597
B	45	13	754	350
FA	37	21	475	631
F	20	12	316	87
A	38	12	466	577
0	21	6	389	225
LSD (0.05)[2]	28	12	NS	NS
LSD (0.05)[2]	22	NS	614	565

[1]Treatments are: B = burned, F = fertilized with 112-0-0 (remnant prairie) or 112-22-0 (restored prairie) kg N-P-K/ha, A = atrazine applied at 2.2 kg a.i./ha, and 0 = no treatment.
[2]Least significant difference (LSD) for comparing between means of fertilizer main treatment effect and means of fertilizer by burning treatment interaction.
[3]LSD for comparing between means of herbicide main effect and all interaction terms that include the herbicide effect.

Flowering Stalk Density and Germinable Seed Number

Flowering stalk density increased at both sites when burning was combined with fertilization, but only at the remnant prairie when atrazine was applied (Tables 5 and 6). At the remnant prairie, the increase due to burning and fertilization (30 to 98 stalks/m²), was greater than that attributed to atrazine application alone (43 to 60 stalks/m²). Increases in tallgrass flowering stalk density following burning may be explained in part by plant growth enhancement caused by standing dead and litter removal. The positive influence of atrazine on flowering stalk density may result from suppression of competing plants, such as, cool-season annual and perennial grasses, and/or a stimulatory effect of the herbicide on plant growth and development. Reis (1976) determined that sublethal doses of S-triazine herbicides enhanced physiological processes within perennial and annual grasses.

Influence of treatments on germinable seed yield varied by site. At the remnant prairie, number of germinable seeds increased 7-fold following treatment with a combination of burning, fertilizer, and atrazine as compared to no treatment (Tables 5 and 6). Others have observed that burning and fertilization improved warm-season grass seed yield. Burton (1944) found that seed yield of the introduced grasses bahiagrass (*Paspalum notatum* Flugge) and bermudagrass [*Cynodon dactylon* (L.) Pers.] increased following burning. In cultivated grass seed production fields, nitrogen fertilization and burning increased seed production of several grasses including switchgrass, big bluestem, little bluestem, and indiangrass (Cornelius 1950). In contrast to the remnant prairie, germinable seed numbers at the restored prairie site were significantly affected only by atrazine. Atrazine treated areas produced 585 seeds/m² as compared to only 207 seeds/m² from areas not treated with atrazine.

In this study, depending on site and plant parameter evaluated, spring burning, fertilization, and atrazine enhanced tallgrass productivity. These treatments not only facilitated prairie renovation, but also improved seed yield of selected warm-season grasses. Feasibility of atrazine use as part of a renovation program depends on whether the objective is to suppress introduced cool-season grasses and restore warm-season grass dominance or promote forb population expansion. Although not conclusively determined in this study, other research (Gillen *et al.* 1987) indicated that atrazine application should be avoided if rejuvenation of the forb component of the prairie community is a primary objective of a renovation program.

Table 6. Mean squares and levels of significance for the treatment effects in the analysis of variance for flowering stem density and germinable seed number of selected warm-season grasses at remnant and restored prairies in eastern Nebraska.

Source of variation[1]	*df*	*Flowering stem density*		*Germinable seed number*	
		Remnant	*Restored*	*Remnant*	*Restored*
Burning (B)[2]	1	12150	1430	5675875	11417
Fertilizer (F)	1	3220 **	1175 *	2431351 NS	27900 NS
F X B	1	3553 **	225 *	2487128 NS	16426 NS
Error (a)	4	228	40	1328334	49633
Herbicide (H)	1	1734 **	642 NS	1297902 **	718382 *
H X B	1	1 NS	86 NS	621400 *	18792 NS
H X F	1	54 NS	93 NS	1082024 *	43752 NS
H X B X F	1	48 NS	15 NS	1004939 *	5070 NS
Error (b)	8	48	173	106475	85717

[1]The ** and * indicate significance at the 0.01 and 0.05 levels of probability. NS indicates lack of statistical significance at these levels of probability.
[2]The main effect of burning could not be statistically evaluated.

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