Atrazine, Spring Burning, and Nitrogen for Improvement of Tallgrass Prairie

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Abstract

Spring application of atrazine [2-chloro-4-(ethylamino)-6-(isopropylamino)-*s*-triazine] (1.1 kg ha^{-1} a.i.), burning, and nitrogen (33 kg ha^{-1} as ammonium nitrate) were evaluated alone and in all combinations for improvement of mid-seral tallgrass prairie in northcentral Oklahoma. Studies were initiated in 1984 (Study I) and 1985 (Study II). Precipitation and successional status of the vegetation at treatment application were higher for Study II than for Study I. Atrazine effectively reduced forbs and annual grasses for 2 years after application. Atrazine stimulated warm-season perennial grasses but did not generally increase total herbage production. Burning was similar to atrazine for annual grass control in both studies. Burning was also similar to atrazine for forb control in Study I but had no impact on forb production in Study II. Burning increased perennial grass production only in the second year of Study I. Burning decreased total herbage production in the first year of Study I by reducing annual grasses and forbs but did not affect total herbage production on other dates. Nitrogen did not consistently increase perennial grass production but did increase forb production by 250–300% when applied alone. Both atrazine and burning rapidly shifted species composition in favor of desirable perennial grasses. Nitrogen was not as effective in changing species composition either alone or in combination with atrazine and burning. The number and complexity of treatment responses declined as successional status and/or precipitation improved.

Key Words: atrazine, burning, prescribed fire, nitrogen, tallgrass prairie, range improvement, herbicides

Three vegetation manipulation tools of interest in the tallgrass prairie are the herbicide atrazine [2-chloro-4-(ethylamino)-6-(isopropylamino)-*s*-triazine], prescribed burning, and nitrogen fertilization. Atrazine effectively controls cool-season grasses and increases yields of warm-season grasses (Morrow et al. 1977, Houston 1977, Baker and Powell 1978, Waller and Schmidt 1983, Rehm 1984). Late-spring burning favors desirable tallgrasses, especially big bluestem (*Andropogon gerardii* Vitman) and indiangrass (*Sorghastum nutans* (L.) Nash) while reducing forbs, cool-season perennial grasses, and annual grasses (Gay and Dwyer 1965, Graves and McMurphy 1969, Owensby and Smith 1979, Towne and Owensby 1984). Nitrogen fertilization has produced variable results depending on site, initial species composition, and other practices applied. However, nitrogen fertilization alone often increases total herbage production but may cause undesirable changes in species composition by favoring forbs and weedy cool-season grasses (Graves and McMurphy 1969, Taliaferro et al. 1975, Rehm et al. 1976, Baker and Powell 1978, Owensby and Smith 1979, Powell et al. 1979).

Few studies have addressed combinations of atrazine, prescribed burning, and nitrogen fertilization on tallgrass prairie in mid-seral successional status. The objective of these studies was to determine the effects of atrazine, spring burning, and nitrogen fertilization applied alone, and in combination, on total herbage production and species composition of tallgrass prairie in mid-seral successional status.

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Study Area

The research was conducted in northcentral Oklahoma, approximately 16 km west of Stillwater (36°N; 97°W). Average annual precipitation totals 831 mm with 75% falling during the April–October growing season. Mean annual temperature is 15.5° C with average monthly temperatures of 2.3° C in January and 27.6° C in July.

The study site was located on a Grainola loam with a 3–5% slope and a western exposure. The Grainola soil is a fine, mixed, thermic Vertic Haplustalf; has a clay loam subsoil at 20–40 cm; and is classified as a Shallow Prairie range site. The potential natural community on this site would consist of 20–30% little bluestem (*Schizachyrium scoparium* (Michx.) Nash); 25–35% tallgrasses including big bluestem, switchgrass (*Panicum virgatum* L.), and indiangrass; 20–30% other perennial grasses including tall dropseed (*Sporobolus asper* (Michx.) Kunth), Scribner's panicum (*Dicanthelium oligosanthes* (J.A. Schultes) Gould), and sideoats grama (*Bouteloua curtipendula* (Michx.) Torr.); and 5–10% forbs. The study site had been grazed heavily for several years. In the summer before treatment application, the vegetation on this site consisted of 12% little bluestem and tallgrasses, 12% sideoats grama, 16% other perennial grasses, 52% annual broomweed (*Amphiachyris dracunculoides* (DC.) Nutt.) and 8% other forbs. Plant scientific names are taken from USDA-Soil Conservation Service (1982).

Methods

Two studies were conducted on adjacent areas with identical procedures but different dates of initiation, 1984 (Study I) or 1985 (Study II). Three experimental factors (atrazine, spring burning, and nitrogen fertilization) were studied, each at two levels. Treatment levels for each factor were no atrazine or 1.1 kg ha^{-1} a.i. atrazine applied in late March, no burn or burn in April, and no nitrogen or 33 kg ha^{-1} N applied as ammonium nitrate in mid May. Burning conditions (air temperature, humidity, wind) for 1984 were 28° C, 50%, and south at 26 km h^{-1}, and for 1985 were 23° C, 39%, and northwest at 8 km h^{-1}. Treatments were arranged factorially in a randomized complete block design with 4 replications. Treatment plots were 4 × 7.5 m. The plots were not grazed during the study, but the vegetation was mowed to a 10–15 cm height and removed in January each year.

Each study was sampled in early June and mid-August for 2 years following treatment application. Two, 0.25-m^2 quadrats were clipped to ground level in each treatment plot on each sample date. The vegetation was hand-separated into big bluestem, little bluestem, other perennial grasses (primarily sideoats grama, Scribner's panicum, and indiangrass), annual grasses (primarily Japanese brome, *Bromus japonicus* Thunb., and sixweeks fescue, *Vulpia octoflora* (Walter) Rydb.), legumes (primarily slimflower scurfpea, *Psoralea tenuiflora* Pursh), and other forbs (primarily heath aster, *Aster ericoides* L., and western ragweed, *Ambrosia psilostachya* DC.). Vegetation from the quadrats was combined within treatment plot, oven-dried, and weighed in the laboratory.

Results from each study were analyzed separately. Standard analysis-of-variance procedures were used for all herbage components within individual dates (Steel and Torrie 1960). All dates within a given study were also subjected to a multivariate profile analysis (Morrison 1976) to test for interactions of treatment effects with year and season (June or August) for each herbage component. Such interactions were numerous, so results are discussed by date within each study. For presentation purposes, the vegetation data were combined into the categories of perennial grasses, annual grasses, forbs, and total herbage with important individual species responses discussed where appropriate. Data are presented only for the date of peak standing crop for each component (August for perennial grasses, forbs, and total herbage; June for annual grasses). Treatment means for the main effects of atrazine, burning, and nitrogen are presented for each vegetation component. When significant (P=.05) two or three-way interactions occurred, interaction means are presented in place of the respective main effect means. Interaction means were separated by the least significant difference (LSD) procedure (Steel and Torrie 1960).

Results and Discussion

Total amount and distribution of precipitation varied considerably during the three study years (Fig. 1). Precipitation in 1984 was

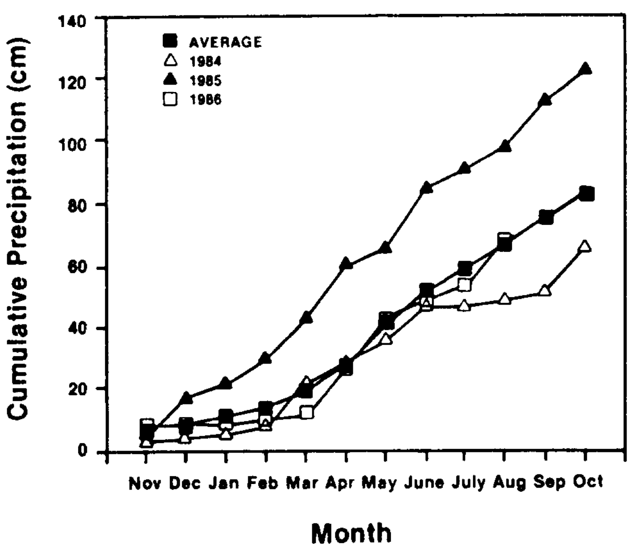

Fig. 1. *Cumulative precipitation for the study area. Long-term average precipitation measured at Stillwater, 16 km east of study site. Precipitation for 1984–86 measured 6 km southwest of study site. Precipitation year runs from 1 November of previous year through 31 October of current year (1984 = Nov. 1983–Oct. 1984 period).*

near average through June but the July–September period was very dry. Cumulative precipitation in 1985 was far above average for the entire year. In 1986 winter precipitation was below-average, but cumulative precipitation for the April–August period was close to the long-term average. Study I, therefore, had a precipitation sequence of an unfavorable year followed by a favorable year, while Study II had a favorable year followed by an average year.

Overall, vegetation responses in Study I were more numerous and complex than in Study II. Totaled over all vegetation components, there were 46 significant (P=.05) treatment effects in Study I, 16 (35%) of which were simple effects with no interactions. Study II produced only 32 significant effects, 18 (56%) of which were simple effects. Control plots in June of the treatment year in Study I consisted of 48% perennial grasses and 52% forbs and annual grasses. By the close of Study II, control plots averaged 87% perennial grasses and 13% forbs and annual grasses. As the grasses became dominant, fewer opportunities may have been available for significant treatment effects to occur. This would be especially true for treatments such as atrazine and burning which are expected to have more direct impact on species composition than total production. The comparison of control plots also indicated the value of growing-season rest and favorable precipitation alone for improving tallgrass prairie.

Annual broomweed contributed less than 1% of total herbage production for any treatment during both studies. This species contributed 52% of the total herbage in the summer just prior to initiation of Study I (1983). Annual broomweed is sensitive to mulch levels in tallgrass prairie (Towne and Owensby 1983). Stubble heights on all plots were never less than 10 cm during the course of these studies.

Table 1. Standing crop (kg ha^{-1}) of annual grasses in early June following 1984 spring application of atrazine, burning, and nitrogen to tallgrass prairie (Study I).

	First Year		Second Year	
	Spring Burning		Spring Burning	
Treatment	None	Burn	None	Burn
Atrazine (kg ha^{-1})				
0	220	60	1170	240
1.1	5	0	240	170
	OSL = .03[1]		OSL = .01	
	$LSD_{0.05}$ = 255		$LSD_{0.05}$ = 355	
Nitrogen (kg ha^{-1})				
0	130[2]		380[2]	
33	140		530	
	OSL = .92		OSL = .23	

[1]observed significance level.
[2]main effect of nitrogen.

Atrazine

Annual grasses were a significant portion of the plant community only in the high rainfall year of 1985, but atrazine reduced this component except in the second year of Study II (Table 1, 2). Atrazine and burning interacted on most dates; both controlled the

Table 2. Standing crop (kg ha^{-1}) of annual grasses in early June following 1984 spring application of atrazine, burning, and nitrogen to tallgrass prairie (Study II).

	First Year		Second Year	
	Spring Burning		Spring Burning	
Treatment	None	Burn	None	Burn
Atrazine (kg ha^{-1})				
0	980	120	210[2]	
1.1	85	5	220	
	OSL = .01[1]		OSL = .85	
	$LSD_{0.05}$ = 235			
Nitrogen (kg ha^{-1})				
0	230[3]		240	110
33	370		150	360
	OSL = .09		OSL = .01	
			$LSD_{0.05}$ = 190	

[1]observed significance level.
[2]main effect of atrazine.
[3]main effect of nitrogen.

annual grasses so there was little potential for an additive response when the factors were combined. Studies on the Great Plains (Morrow et al. 1977, Peterson et al. 1983) reported effective cool-season annual grass control at similar rates of atrazine with some carry-over effect into the following year. However, Hewlett et al. (1981) found no atrazine effect after the treatment year on mixed-grass prairie.

Atrazine reduced forb production only when nitrogen had been applied in Study I (Table 3). Forb production was reduced by atrazine in Study II regardless of treatment combination (Table 4). In both studies, forb reductions were larger in August than in June (data not shown). The total forb component was split evenly

Table 3. Standing crop (kg ha⁻¹) of forbs in August following 1984 spring application of atrazine, burning, and nitrogen to tallgrass prairie (Study I).

		First Year		Second Year	
		Spring Burning		Spring Burning	
Nitrogen (kg ha^{-1})	Atrazine (kg ha^{-1})	None	Burn	None	Burn
0	0	450	170	720	280
	1.1	330	170	460	290
33	0	1440	140	1610	270
	1.1	180	250	260	690
		OSL = .01[1]		OSL = .01	
		$LSD_{0.05}$ = 390		$LSD_{0.05}$ = 560	

[1]observed significance level.

between cool-season legumes, 90% of which was slimflower scurfpea, and warm-season nonleguminous forbs. Slimflower scurfpea has been shown to be resistant to twice the rate of atrazine used in this study (Houston 1977). This species was the dominant forb in early summer but senesced rapidly in July and August. The nonleguminous forbs normally become dominant in late summer but are more susceptible to atrazine. These factors explain the larger total forb response to atrazine in August. Unlike the current studies, Peterson et al. (1983) reported no atrazine affect on forb production the growing season after application.

Atrazine increased perennial grass production 730 kg ha^{-1} averaged over years and studies (Table 4). The positive responses of warm-season perennial grasses to atrazine agrees with the results of Waller and Schmidt (1983) and Rehm (1984), who worked with similar species. These workers also reported carry-over effects of atrazine applications; however, Waller and Schmidt (1983) applied atrazine at twice the rate used in the current study.

Total herbage production was not increased by atrazine in the first year of either study (Table 4). Increases in perennial grasses were offset by decreases in forbs and annual grasses. Atrazine increased total herbage production only when combined with burning and nitrogen in the second year of Study I (Table 4) and also increased total herbage production in the second year of Study II (Table 4). Working in high-seral tallgrass in the same geographical region, Baker and Powell (1978) reported increases of 700–1,000 kg ha^{-1} in total production in response to atrazine applied in June at 1.1 or 3.4 kg ha^{-1}. Most of these increases were attributable to the tallgrasses (switchgrass, indiangrass, and big bluestem) and were still significant in the second year. Waller and Schmidt (1983) and Rehm (1984) reported similar responses from April applications of atrazine. The major tallgrass present in the current study was big bluestem. This species contributed less than 10% of the total herbage at the start of Study I but had increased to 23% of the total herbage in atrazine plots by the end of Study II. The ability of this single species to influence overall yields was, therefore, limited early in the studies but steadily increased over time.

Burning

Burning effectively reduced annual grasses the first year in both studies (Table 1, 2). This reduction was still evident the second year after burning in Study I (Table 1). Forb production was generally reduced by burning in Study I, but reductions were only significant where nitrogen was added (Table 3). Within the forb category, legumes were either not affected or stimulated by up to 100% by burning, while other forbs (principally heath aster and western ragweed) were reduced 50–90% by burning. Spring burning did not reduce forb production in Study II (Table 4). The effect of burning on annual grasses and forbs was very similar to the effect of atrazine on these same components in Study I and is generally supported by other research (Graves and McMurphy 1965, Powell et al. 1979). There was no advantage in terms of herbaceous weed control in applying these treatments in combination. Burning was equal to atrazine for annual grass control in Study II but was not effective for forb control.

A single spring burn did not increase grass production until the second year in Study I (Table 4). Perennial grass production did not respond to burning in Study II (Table 4). Repeated spring burning has been shown to increase or maintain the major warm-season grasses of the tallgrass prairie (Graves and McMurphy 1969, Towne and Owensby 1984). Burning neutralized the positive effects of atrazine on perennial grass production in June of both years in Study I (data not shown). Atrazine converted green annual grasses and forbs to standing dead herbage. This resulted in a visually hotter and more continuous fire on atrazine plots. The

Table 4. Standing crop (kg ha⁻¹) of three vegetation components in August following spring application of atrazine, burning, and nitrogen to tallgrass prairie. Study I initiated 1984, Study II initiated 1985.

	Atrazine (kg ha^{-1})			Spring Burning			Nitrogen (kg ha^{-1})		
Herbage Component	0	1.1	OSL[1]	None	Burn	OSL	O	33	OSL
Study I									
Perennial Grasses									
First year	2150	2920	.01	2640	2430	.36	2290	2780	.04
Second year	3430	3950	.07	3390	3990	.04	3600	3780	.51
Forbs[2]									
Total Herbage									
First year	2860	3160	.22	3400	2620	.01	2620	3400	.01
Second year[3]									
Study II									
Perennial Grasses									
First year	4360	4830	.21	4370	4820	.23	4690	4500	.61
Second year	5060	6220	.02	5500	5770	.52	5300	5970	.16
Forbs									
First year	710	205	.01	480	430	.65	450	460	.93
Second year	560	330	.03	450	440	.94	490	400	.37
Total Herbage									
First year	5290	5050	.53	5070	5260	.61	5310	5030	.45
Second year	5680	6630	.03	6040	6270	.54	5860	6440	.17

[1]observed significance level.
[2]significant factor interactions present, see Table 3.
[3]significant factor interactions present, see Table 5.

more intense fire may have been responsible for neutralizing the atrazine effect on perennial grasses in early summer.

Spring burning was generally either negative or neutral in its impacts on total herbage production (Table 4, 5). Negative impacts the first year of Study I (Table 4) were a function of annual grass and forb reductions and agree with results of Powell et al. (1979) on low-seral tallgrass prairie. Workers in mid to high-seral tallgrass prairie have observed no effects on total production from spring burning unless excessive mulch is present (Gay and Dwyer 1965, Towne and Owensby 1984).

Table 5. Standing crop (kg ha^{-1}) of total herbage in August of the second year after 1984 spring application of atrazine, burning, and nitrogen to tallgrass prairie (Study I).

Nitrogen (kg ha^{-1})	Atrazine (kg ha^{-1})	Spring Burning	
		None	Burn
0	0	4610	4660
	1.1	4610	4070
33	0	5170	3990
	1.1	4130	5500
		OSL = .01[1]	
		$LSD_{0.05}$ = 1040	

[1]observed significance level.

Nitrogen

The addition of low levels of nitrogen to tallgrass prairie resulted in herbage increases of 0–1,800 kg ha^{-1} (Harper 1957, Gay and Dwyer 1965, McMurphy 1970, Owensby et al. 1970). Quite often, such fertilization resulted in large increases of cool-season grasses and forbs (Graves and McMurphy 1969, Owensby et al. 1970, Taliaferro et al. 1975, Rehm et al. 1976, Powell et al. 1979), but in at least one case such increases were minor (Baker and Powell 1978).

Nitrogen interacted with atrazine and burning to affect forb production in August of both years of Study I (Table 3). Nitrogen alone increased in forb production but both weed control treatments negated this effect. Similar results with burning and nitrogen have been reported for other tallgrass prairie studies (Graves and McMurphy 1969, McMurphy 1970, Owensby and Smith 1979). Forb production did not respond to nitrogen in Study II (Table 4), which may reflect the greater dominance of perennial grasses on the plant community as successional status improved.

Nitrogen fertilization significantly (P = .05) increased perennial grass production on only 1 of 4 sampling dates over both studies (Table 4). In contrast with other studies (Gay and Dwyer 1965, Graves and McMurphy 1969, Owensby and Smith 1979), nitrogen did not interact positively with burning to increase perennial grass production. Nitrogen also did not interact positively with atrazine, which agrees in general with Baker and Powell (1978) but not with Rehm (1984).

Nitrogen increased total herbage production the first year of Study I by 500 kg ha^{-1} (Table 4). In the second year, total herbage production was increased by 1,500 kg ha^{-1} but only when nitrogen was applied in combination with atrazine and burning (Table 5). Nitrogen did not significantly increase total herbage production in Study II (Table 4).

Management Implications

Atrazine and spring burning were similar as weed control treatments, but atrazine tended to have a greater positive effect on warm-season perennial grasses than burning. Both treatments quickly shifted species composition in favor of perennial grasses. Their combined application would have little advantage in terms of weed control but positive effects on perennial grasses were additive at peak standing crop. One advantage of combined application might be the use of atrazine to improve fuel conditions for burning when fuel levels are low and the proportion of green material is high. In other situations, the choice of treatments would depend on factors such as operator's preference and experience, relative costs and returns, need for eastern redcedar (*Juniperus virginiana* L.) control, and flexibility of grazing management for fuel accumulation. In considering relative returns, spring burning on tallgrass prairie increases average daily gain of stocker cattle 10–20% (Launchbaugh and Owensby 1978, Owensby and Smith 1979); whereas, the effect of atrazine on livestock performance is not known at this time.

Nitrogen application at levels used in these studies did not appear to be an effective treatment for range improvement. Nitrogen applied alone tended to maintain the existing balance between perennial grasses, forbs, and annual grasses. When applied in combination with the weed control treatments, nitrogen did not consistently increase perennial grass or total herbage production.

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