Atrazine and fertilizer effects on Sandhills subirrigated meadow

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Abstract

Many Nebraska Sandhills subirrigated meadows have shifted to predominantly cool-season grasses. Meadows are often cut in July when forage quality of cool-season is lower than that of warm-season species. The objective of this research was to evaluate a one-time application of atrazine [6-chloro-N-ethyl-N′-(1-methylethyl)-1,3,5-triazine-2,4-diamine] in restoring dominance of warm-season grasses and to determine if nitrogen (N) with and without phosphorus (P) would enhance or prolong the atrazine effect on species composition, yield, crude protein, and in vitro dry matter digestibility (IVDMD). Atrazine was applied once at 0, 2.2, and 3.3 kg/ha in spring or fall 1983 and 1984 to a Gannett fine sandy loam (coarse loamy mixed mesic Typic Haplaquoll). The year after atrazine application one-half of each spring-treated plot was fertilized with N (50 kg/ha). One-half of the fertilized area received P (18 kg/ha). Both spring and fall applied atrazine decreased cool-season grass species composition and yield. Spring-applied atrazine reduced first-year yields, but yields recovered by the end of the second year. Conversion of plots to warm-season grasses increased crude protein in mid-July for 2 growing seasons. Percentage IVDMD was increased the year of atrazine application on both sets of plots and also the year following application on the 1983-treated plots. A single fertilizer application did not enhance or prolong the effect of atrazine on forage quality. Cool-season grasses regenerated in atrazine-treated plots after 2 years so changes in yield and quality were only temporary, making atrazine use in subirrigated meadows uneconomical.

Key Words: Yield, IVDMD, crude protein, nitrogen, phosphorus, warm-season grasses, cool-season grasses, species composition

Historically, most Nebraska Sandhills subirrigated meadows were dominated by tall, warm-season grasses (Rydberg 1895, Tolstead 1942) and ranchers introduced cool-season grasses early in the 20th century (Brouse 1930). Hay is harvested in mid-summer because most meadows are too wet for earlier harvest, so cool-season forage is nearly mature. Warm-season grasses have the potential to produce higher hay yield and quality than cool-season grasses with a summer harvest (Keim et al. 1932), but only remnants of warm-season grasses remain (Ehlers et al. 1952).

Atrazine [6-chloro-N-ethyl-N′-(1-methylethyl)-1,3,5-triazine-,2,4-diamine] restored warm-season grass dominance in eastern Nebraska upland pasture that had shifted to cool-season grasses where remnant warm-season grasses were present (Samson and Moser 1982, Waller and Schmidt 1983, Dill et al. 1986). Nitrogen (N) and phosphorus (P) have been used in combination with atrazine to renovate warm-season grass pastures (Baker and Power 1978, Rehm 1984). McConnell and Waller (1986) reported that repeated annual atrazine (2.2 kg/ha) applications in combination with N and P shifted the period of optimum forage quality from spring and fall to mid-summer on native subirrigated meadows of eastern Nebraska.

Results from fertilizer experiments on subirrigated meadows were often variable depending on species composition, soil factors, growing conditions, and rate and time of application (Brouse et al. 1955, Brouse and Burzlaff 1968).

The purpose of this research was to determine if single applications of atrazine could be used to restore warm-season grass dominance in Sandhills subirrigated meadows and to determine if common fertilization programs (50 kg N/ha and 50 kg N + 18 kg P/ha) would enhance or prolong the effect of atrazine on yield, species composition, crude protein, and in vitro dry matter digestibility (IVDMD).

Materials and Methods

Experiments were conducted from 1983 through 1985 at University of Nebraska's Gudmundsen Sandhills Laboratory (GSL), located in Grant County, 12 km northeast of Whitman, Nebr. The GSL lies in a precipitation zone of 500–560 mm per year, of which 75–80% falls during the growing season from April through September. Precipitation recorded for 1983–1985 at GSL for April through August is given (Table 1). Soil at the study site was a Gannett fine sandy loam (coarse loamy mixed mesic Typic Haplaquoll). Soil properties for the top 30 cm are: texture of 70% sand, 18% silt, and 12% clay; 6% OM; Bray and Kurtz #1 P level of 1 mg/kg; 1 M $NH_4C_2H_3O_2$ extracted K level of 135 mg/kg and a pH (1:1 soil-water ratio) of 8.3 Kentucky bluegrass (*Poa pratensis* L.) timothy (*Phleum pratense* L.), quackgrass (*Agropyron repens* L.), redtop bent (*Agrostis stolonifera* L.) and red clover (*Trifolium pratense* L.) were the major components of the plant community

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Table 1. Growing season precipitation (mm) at the Gudmundsen Sandhills Laboratory April through August for 1983–1985, and 30 year average from Arthur, Nebraska.[1]

Month	Year 1983	1984	1985	30-year Average
April	53	64	32	46
May	78	19	47	86
June	159	177	17	88
July	117	86	36	84
August	98	16	51	54
Total	505	362	183	358

[1]Data obtained from the Climatological Data for Nebraska, National Oceanic and Atmospheric Administration, National Climatic Center, Asheville, NC.

prior to treatment.

In 1983 and 1984, a single atrazine application was made in late May (spring) or late August (fall) in a water solution (200 L/ha), at 0, 2.2, and 3.3 kg/ha in a randomized complete block design with 3 replications (6 × 12 m plots). Season of atrazine application was analyzed as a split plot within the year of atrazine application (no fertilizer treatments). There was no significant effect due to season of herbicide application. One-half of each spring-treated plot (6 × 6 m) was fertilized the second growing season with 50 kg/ha of N as NH_4NO_3 (34-0-0). One-half of the fertilized area (3 × 6 m) received 18 kg/ha of P as triple superphosphate (0-45-0). Fertilizer was hand broadcast during the second week of May for the untreated plots dominated by cool-season grasses, and the second week of June for the warm-season dominated atrazine-treated plots. The purpose of the fertilizer treatments was to stimulate the dominant vegetation so that yields of a cool-season system could be compared to yields of the warm-season system. The warm-season plots (atrazine-treated) and the cool-season plots (untreated) were each fertilized at the optimum time (Rehm et al. 1976). The field plot design was a split plot. Whole plot treatments were the spring applied atrazine levels arranged in a randomized complete block. Split plot treatments were fertilizer treatments (O, N, NP). This experiment was initiated twice, once in 1983 and once in 1984. Repeated measurements were taken on each subplot in 1983, 1984, and 1985 for the experiment initiated in 1983 and in 1984 and 1985 for the experiment initiated in 1984. Yield and species composition were determined during August of each year.

Relative species composition was determined using the method outlined by Dill et al. (1986). In plots not receiving fertilizer, 2 transects were randomly located in the middle of each unfertilized plot 2 m apart. Ten rods (1 m) were randomly placed at ground level perpendicular to each transect. Since fertilized subplots were not as wide, only 1 transect was located near the middle of the subplot and 10 rods were randomly located as in the unfertilized plots. Each plant base touching the rod was counted. Species counts were combined into categories of (1) major warm-season grasses comprised of big bluestem (*Andropogon gerardii* Vitman) and indiangrass [*Sorghastrum nutans* (L) Nash.)], (2) other warm-season grasses, (3) cool-season grasses, (4) forbs, and (5) rushes. Percent species composition for each category was determined by dividing counts in each category by total number of plants touching the rod.

Yield was determined by randomly locating 2 (0.6 m²) quadrats within each plot and hand clipping herbage at ground level. A 15-cm by 60-cm subsample of the clipped material in each quadrat was separated into categories of warm-season grasses, cool-season

Table 2. Species composition (%) of subirrigated meadow plots treated with atrazine and fertilized the year following with O (control), 50 kg/ha N or 50 kg/ha N and 18 kg/ha P.
A: Treated with atrazine in May 1983, fertilized in 1984, and sampled in August 1983–1985.
B: Treated with atrazine in May 1984, fertilized in 1985, sampled in August 1984–1985.

Year	Atrazine (kg/ha)	Warm-season grasses O	N	N+P	Cool-season grasses O	N	N+P	Rushes O	N	N+P	Forbs O	N	N+P
A	1983 Atrazine-treated plots												
1983	0	39	—	—	38	—	—	8	—	—	15	—	—
1984	0	13	12	13	57	67	63	8	7	9	22	14	15
1985	0	11	6	8	69	73	75	9	12	8	11	9	9
1983	2.2	65	—	—	27	—	—	7	—	—	1	—	—
1984	2.2	51	47	41	31	36	40	12	12	11	6	5	8
1985	2.2	20	23	14	56	54	67	15	11	8	9	12	11
1983	3.3	71	—	—	28	—	—	11	—	—	<1	—	—
1984	3.3	49	47	48	21	30	31	10	16	14	9	7	7
1985	3.3	30	24	22	47	50	60	13	13	13	10	13	5
	Standard Errors												
	1983		2.6			2.7			2.1			4.3	
	1984[1]		3.9			4.7			2.0			3.4	
	1985[1]		3.8			5.5			2.3			0.8	
B	1984 Atrazine-treated plots												
1984	0	22	—	—	59	—	—	4	—	—	15	—	—
1985	0	24	21	19	65	70	72	6	6	6	5	3	3
1984	2.2	81	—	—	7	—	—	11	—	—	1	—	—
1985	2.2	62	66	69	18	13	13	11	12	10	9	8	8
1984	3.3	80	—	—	0	—	—	11	—	—	1	—	—
1985	3.3	66	64	70	11	12	12	7	10	6	16	14	12
	Standard Errors												
	1984		8.7			2.0			2.7			4.3	
	1985[1]		7.4			2.9			2.6			2.0	

[1]Standard errors are for fertilizer treatments within atrazine levels.

grasses, forbs, and rushes. Samples were oven dried in a forced-air oven at 65° C for 48 hours and weighed. After quadrats were harvested, the rest of the plot was clipped with a sicklebar mower and the forage removed. Restricted randomization was used in subsequent years to avoid hand clipped areas.

Forage samples were hand clipped (2.5 cm) in mid-July from the middle two-thirds of each plot to determine quality at the time hay is generally harvested. Samples were dried for 48 hours at 65° C in a forced-air oven, and ground in a Wiley mill to pass a 1-mm screen. Kjeldahl N was determined colorimetrically (Bremner and Mulvaney 1982), and percentage protein estimated (N $\times$ 6.25). Analysis for IVDMD was determined by the two-stage direct acidification method (Marten and Barnes 1980).

Species composition data were analyzed using multivariate analysis of variance to detect overall differences among treatments and among years (Stroup and Stubbendieck 1983). In the multivariate analysis, only the groups of major warm-season grasses, other warm-season grasses, cool-season grasses, and rushes were used. The forbs category was not included in the analysis because unequal variances were created when atrazine eliminated red clover, the major component of the forbs category from treated plots. The effect of atrazine on species composition was evaluated on unfertilized areas as a split plot in time. The effect of fertilizer on species composition was evaluated as a split-split plot in atrazine level and time. Treatment differences were evaluated using Wilks' criterion test statistic. Yield data were analyzed using univariate analysis of variance for the warm-season grasses, cool-season grasses, forbs, rushes, and hay yield categories. Preplanned orthogonal contrasts were used to compare treatments for species composition, yield, crude protein, and IVDMD. Statistical significance was declared at $P = 0.05$.

Results and Discussion

Species Composition

Atrazine

There was no statistical difference in response to atrazine between treatment years. Atrazine shifted species composition [Wilkes criterion: P = 0.05 (1983), P = 0.01 (1984) Table 2]. The shift in composition was due to a decrease of cool-season grasses and an increase in warm-season grasses in the year of treatment (Table 2, unfertilized). Most of the increase in warm-season grasses was due to big bluestem and indiangrass since they were the major rem-

Table 3. Yield (kg/ha) of warm-season grasses, cool-season grasses and total yield for subirrigated meadow plots treated with atrazine and fertilized the year following treatment with O (control), 50 kg/ha N or 50 kg/ha N and 18 kg/ha P.
A: Treated with atrazine in May 1983, fertilized in 1984, and sampled in August 1983–1985.
B: Treated with atrazine in May 1984, fertilized in 1985, and sampled in 1984 and 1985.

Year sampled	Interaction/contrasts	Atrazine rate (kg/ha)	Warm-season grasses Control	N	NP	P>F	Cool-season grasses Control	N	NP	P>F	Yield Control	N	NP	P>F
A.	1983 Atrazine-treated plots													
1983		0	740	—	—		2890	—	—		4690	—	—	
		2.2	1270	—	—		780	—	—		2150	—	—	
		3.3	1610	—	—		390	—	—		2070	—	—	
	Control vs. atrazine[1]					.04				<.01				<.01
	2.2 vs 3.3					NS				NS				NS
1984		0	370	500	660		3780	4090	4370		5400	6080	6110	
		2.2	2600	3950	3340		2160	2520	2700		5260	6840	6480	
		3.3	3640	3940	5110		1470	2060	1320		5670	6486	7010	
	Atr $\times$ fert interaction					NS				NS				NS
	Control vs. atrazine					.01				NS				NS
	2.2 vs 3.3					NS				NS				NS
	Control vs. fertilizer[2]					.01				NS				.02
	N vs NP					NS				NS				NS
1985		0	690	580	530		3130	3540	3650		4310	4460	4600	
		2.2	1340	1650	1260		2540	2400	2820		4330	4540	4480	
		3.3	1590	1760	900		2030	3100	2600		4030	5340	3860	
	Atr $\times$ fert interaction					NS				NS				NS
	Control vs. atrazine					<.01				NS				NS
	2.2 vs 3.3					NS				NS				NS
	Control vs. fertilizer					NS				NS				NS
	N vs NP					NS				NS				NS
B.	1984 Atrazine-treated plots													
1984		0	470	—	—		3110	—	—		4490	—	—	
		2.2	3060	—	—		10	—	—		3230	—	—	
		3.3	2964	—	—		5	—	—		3020	—	—	
	Control vs. atrazine					<.01				<.01				.05
	2.2 vs 3.3					NS				NS				NS
1985		0	900	900	990		2550	3500	3910		3770	4650	5150	
		2.2	3070	4060	4130		390	100	150		3960	4520	4820	
		3.3	3360	3570	3580		120	100	360		3960	4490	4310	
	Atr $\times$ fert interaction					NS				.01				NS
	Control vs. atrazine					<.01				<.01				NS
	2.2 vs 3.3					NS				NS				NS
	Control vs. fertilizer					NS				.03				.03
	N vs NP					NS				NS				NS

[1]Control versus the average effect of 2.2 and 3.3 kg/ha atrazine application.
[2]Control versus the average effect of N and NP fertilizer application.

nants. A significant negative correlation ($r = -0.95$ and $r = -0.87$ for 1983 and 1984 respectively) occurred between the decrease in percentage composition of cool-season grasses and the increase in percentage composition of major warm-season grasses. Other warm-season grasses (not shown) and rushes were variable and did not exhibit a significant response to atrazine. Forbs, primarily red clover, were nearly eliminated with atrazine during both treatment years. No significant difference in species composition occurred between 2.2 and 3.3 kg/ha atrazine rates when analyzed over all species groups.

Differences in species composition still existed the second growing season after treatment between untreated and atrazine-treated plots. However, changes in species composition were temporary. A year × treatment interaction occurred with both 1983 and 1984 treated plots. Between 1983 and 1984, cool-season grasses increased and warm-season grasses decreased on untreated plots. Above-average rainfall during April and June of 1984 (Table 1) apparently favored cool-season grasses. Cool-season grass increase between 1983 and 1984 was not as dramatic on atrazine-treated plots. However, cool-season grasses increased sharply and warm-season grasses decreased from 1984 to 1985 on both 1983 and 1984 treated plots while untreated plots remained unchanged.

By the third growing season after application, species composition of warm- and cool-season grasses was rapidly approaching the untreated condition (Table 2). Cool-season grasses did not invade from the edges but uniformly throughout the plot, indicating that some rhizomes evidently survived. Reproduction by new seedlings would be minimal with the heavy thatch over subirrigated meadows. Red clover did not reestablish on atrazine-treated plots after 3 growing seasons. Black medic (*Medicago lupulina* L.) accounted for much of the forb population in 1984 and was particularly abundant in 1985. Scattered alfalfa (*Medicago sativa* L.) plants survived the atrazine treatments.

Fertilizer

Fertilizer had no effect on species composition of the meadow during the year of fertilizer application, and no atrazine × fertilizer interaction occurred for any species group on either the 1984 or 1985 fertilized plots (Table 2). The combination of P with N stimulated cool-season grasses, primarily Kentucky bluegrass, beyond that of N only the year following fertilizer application on atrazine-treated plots (Table 2). Similarly, Brouse et al. (1955) and Mader (1956) reported that P with N stimulated Kentucky bluegrass.

Forage Yield and Quality

Atrazine

Warm-season grass yields were higher in plots treated with atrazine than the untreated area the treatment year (Table 1). Cool-season grass yields, forbs (not shown), and total August yield were lower in treated areas. There was no difference in yield response between atrazine rates. Warm-season grass yields remained higher in atrazine-treated plots than untreated plots the year fol-

Table 4. Protein concentration and IVDMD values for mid-July samples from subirrigated meadow plots treated with atrazine and fertilized the year following with O (control), 50 kg/ha N or 50 kg/ha N and 18 kg/ha P.
A: Treated with atrazine in May 1983, fertilized in 1984, and sampled in mid-July 1984 and 1985.
B: Treated with atrazine in May 1984, fertilized in 1985, and sampled in mid-July 1985.

	Atrazine rate	Protein (%)				IVDMD (%)			
Year sampled	(kg/ha)	Control	N	NP	P>F	Control	N	NP	P>F
A.				1983 Atrazine-treated plots					
1984	0	6.4	7.5	8.2		56.0	56.7	56.5	
	2.2	7.4	7.8	8.9		59.4	57.6	58.1	
	3.3	7.4	9.0	9.4		60.4	58.9	60.1	
Atr × Fert interaction					NS				NS
Control vs. atrazine[1]					.03				.01
2.2 vs 3.3					NS				.05
Control vs. fertilizer[2]					.01				NS
N vs NP					NS				NS
1985	0	6.5	6.8	6.2		50.9	50.8	53.5	
	2.2	6.5	6.3	6.8		52.8	52.5	51.5	
	3.3	6.8	6.4	5.8		51.7	54.2	52.7	
Atr × Fert interaction					.03				NS
Control vs. atrazine					NS				NS
2.2 vs 3.3					NS				NS
Control vs. fertilizer					NS				NS
N vs NP					NS				NS
B.				1984 Atrazine-treated plots					
1984	0	7.3	——	——		55.4	——	——	
	2.2	10.6	——	——		58.2	——	——	
	3.3	11.3	——	——		56.9	——	——	
Control vs. atrazine					<.01				.04
2.2 vs 3.3					NS				NS
1985	0	7.2	8.5	8.1		51.0	55.0	54.9	
	2.2	8.1	9.5	9.4		53.2	55.1	57.4	
	3.3	7.7	9.1	9.1		53.7	54.6	57.1	
Art × Fert interaction					NS				NS
Control vs. atrazine					.01				NS
2.2 vs 3.3					NS				NS
Control vs. fertilizer					.01				.01
N vs NP					NS				NS

[1]Control versus the average effect of 2.2 and 3.3 kg/ha atrazine application.
[2]Control versus the average effect of N and NP fertilizer application.

lowing treatment. However, this effect was only temporary. Warm-season grass yields for 1985 were lower than 1984 yields in the 1983 treated plots. During this period cool-season grass yields increased. Apparently, warm-season grasses were unable to maintain a competitive advantage without repeated atrazine application.

The change of the atrazine-treated plots from cool- to warm-season grasses increased crude protein the treatment year (1984) (Table 4). This response was still evident the year after treatment for both treatment years. Atrazine-treated plots had higher IVDMD the treatment year (1984). However, this response was only maintained the year following treatment in 1983-treated plots.

Atrazine and Fertilizer

Fertilizer increased yield and crude protein the year of application (Table 4). However, residual fertilizer effects were not detected with a mid-July harvest. Brouse and Burzlaff (1968) reported no significant residual effects of N fertilizer applied alone below 88 kg/ha. In this study, response to fertilizer was temporary and inconsistent, reflecting a combination of environmental factors and management rather than treatment. Fertilizer did not extend or enhance the atrazine effect. It altered warm-season grass yield and crude protein without affecting vegetation composition and/or warm-season grass persistence.

Conclusion

Atrazine at 2.2 or 3.3 kg/ha was effective in shifting species composition of the subirrigated meadow from cool- to warm-season grasses. May or August applications were equally effective. However, control of cool-season grasses by a single atrazine application was temporary. Cool-season grasses regained dominance after 2 years. Total yield was reduced the year of treatment. However, in the second growing season, increased warm-season grass compensated for the loss of cool-season grass yield. Warm-season grass dominance increased crude protein at a mid-July harvest. This benefit was lost when the meadow reverted back to cool-season dominance. Nitrogen fertilizer boosted yields and increased crude protein the year of fertilization. Percentage IVDMD appeared to be more sensitive to the stage of grass maturity than treatment effect, and varied by year. Conversion of subirrigated meadows from cool- to warm-season grasses shifted the period of optimum forage quality from spring and fall to mid-summer. However, since this shift was only temporary, use of atrazine would not be recommended for subirrigated meadows in the Sandhills.

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