Species Susceptibility to Atrazine Herbicide on Shortgrass Range

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Highlight: Atrazine was applied at 2 kg/ha for three consecutive years on shortgrass range in northeastern Colorado. The atrazine controlled all annual plant species, greatly reduced frequency of occurrence of cool-season perennial grasses, and increased drought survival of warm-season perennial grasses and two warm-season perennial forbs. Other species varied in their susceptibility to atrazine. The species frequency method of vegetation sampling used in this study provided reliable data for 27 of the approximately 100 species encountered on this range.

Herbicide treatments for controlling undesirable plants are usually aimed at a particular target species, even though other species may be affected. On rangelands with a high diversity of species the problem of unwanted effects on nontarget species may be severe. Determining effects of chemicals on all species on a range site, or even on important species only, seldom has been done in the past. This was due both to lack of interest and to inadequate methods. The frequency method (Hyder et al. 1965) provides an accurate way for determining effects of chemicals on abundance of all major herbaceous species of shortgrass range and on many minor ones, including small shrubs, half-shrubs, and succulents. Other methods of measurement, such as density, list count, or crown cover, are available for trees, large shrubs, and woody plants. The equipment used in the frequency method at this location has recently been redesigned for increased reliability and ease of use (Hyder et al. 1975b).

Atrazine (2-chloro-4-ethlamino-6-isopropylamino-*s*-triazine) has plant growth-regulating properties as well as herbicidal activity. Stimulation of protein production in blue grama (see Table 2 for botanical names of species mentioned) by atrazine (Houston and van der Sluijs 1973; 1975) and increased drought resistance (Hyder et al. 1976) may be as economically valuable on shortgrass range as the control of undesirable species (Houston and Hyder 1975). However, before the application of atrazine can be recommended, we must know its effects on botanical composition of the range, particularly the effects on the valuable forage species.

Methods

Twenty-four paddocks of native range, each of 1.4 hectares, at the Central Plains Experimental Range were selected for study in 1970. These paddocks were previously used in a fertilization-and-grazing study (Hyder et al. 1975a). The

Table 1. Monthly precipitation (cm) for the cropyears (September through August) 1970–73, cropyear totals, and 35-year mean at Central Plains Experimental Range, Nunn, Colo.

Cropyear	Month												Crop-year total[1]
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	
1969–70	3.1	7.1	0.3	T	0.1	0.1	3.3	3.4	2.1	2.9	4.0	0.6	27.1
1970–71	3.8	2.9	0.4	0.6	1.1	0.8	2.3	7.2	4.2	3.1	1.5	0.9	28.8
1971–72	5.4	0.4	0.1	T	0.9	T	1.0	1.5	3.1	8.3	4.5	9.3	34.9
1972–73	4.3	1.4	1.6	1.0	0.3	T	1.8	3.5	1.5	2.3	6.8	1.5	27.3
35-year mean, 1939–73	2.9	1.8	0.7	0.4	0.7	0.5	1.5	2.8	5.3	6.1	4.7	3.8	31.2

[1]Totals may not agree with sum of monthly precipitation because of rounding off.

Tab.e 2. Botanical composition of frequency of occurrence in 1970.

Species	Mean frequency[1] (%)
Perennials	
Blue grama (*Bouteloua gracilis* (H.B.K.) Lag. ex Steud.)	85[2]
Scarlet globemallow (*Sphaeralcea coccinea* (Pursh.) Rydb.)	53
Sun sedge (*Carex heliophila* Mackenz.)	24
Plains pricklypear (*Opuntia polyacantha* Haw.)	22
Woody buckwheat (*Eriogonum effusum* Nutt.)	19
Red threeawn (*Aristida longiseta* Steud.)	18
Hairy goldaster (*Heterotheca villosa* (Pursh.) Skinners)	17
Sand dropseed (*Sporobolus cryptandrus* (Torr.) A. Gray)	16
Rush skeletonplant (*Lygodesmia juncea* (Pursh.) D. Don)	13
Needleandthread (*Stipa comata* Trin. and Rupr.)	12
Scarlet gaura (*Gaura coccinea* Nutt. ex Pursh.)	12
Western wheatgrass (*Agropyron smithii* Rydb.)	10
Bottlebrush squirreltail (*Sitanion hystrix* (Nutt.) J. G. Smith)	8
Eveningprimrose (*Oenothera coronopifolia* Torr. & Gray)	8
Rubber rabbitbrush (*Chrysothamnus nauseosus* (Pall.) Gritt)	7
Textile onion (*Allium textile* Nels & Macbr.)	6
Slimflower scurfpea (*Psoralea tenuiflora* Pursh.)	5
Annuals	
Sixweeks fescue (*Vulpia octoflora* (Walt.) Rydb.)	42
Greenflower pepperweed (*Lepidium densiflorum* Schrad.)	41
Slimleaf goosefoot (*Chenopodium leptophyllum* Nutt.)	35
Tansyleaf aster (*Aster tanacetifolius* H.B.K.)	25
Woolly plantain (*Plantago purshii* Roem. & Schult.)	21
Tumbling russianthistle (*Salsola iberica* Sennen et Pau.)	12
Ridgeseed spurge (*Euphorbia glytosperma* Engelm.)	12
Redowski sticktight (*Lappula redowski* (Hornem.) Greene)	12
Smallflower cryptantha (*Cryptantha minima* Rydb.)	7
Ragleaf goosefoot (*Chenopodium incisum* Poir.)	7

[1]Quadrat size 41 cm × 41 cm.
[2]Quadrat size 5.1 cm × 5.1 cm for this species only.

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Central Plains Experimental Range is located 20 km northeast of Nunn, Colo.

The vegetation is dominated by blue grama. Other important species are scarlet globemallow, plains pricklypear, red threeawn, woody buckwheat, sixweeks fescue, sand dropseed, needleandthread, and sun sedge.

Twelve paddocks, selected at random, were sprayed with 2.0 kg/ha (1.75 lb/acre) active ingredient of atrazine in late fall of 1970, 1971, and 1972. Twelve paddocks were untreated. The atrazine was applied as an 80% wettable powder in aqueous suspension at a rate of 140 liters/ha (15 gal/acre). No surfactant was added. The liquid mixture was applied with a commercial spraying machine.

In each paddock, all species on the two permanently marked macroplots of 30.5 m by 22.9 m (100 ft × 75 ft) were sampled in June 1970, 1971, 1972, and 1973 wth 250 quadrat placements on each macroplot, for a total of 12,000 quadrat placements each year. Quadrat size was 41 cm × 41 cm for all species except blue grama. Quadrat size for blue grama was 5.1 cm × 5.1 cm.

Analyses of frequency data for most abundant species were by conventional analysis of covariance. The data obtained for these species in 1971, 1972, and 1973 were adjusted to the frequency present in 1970. Species with a frequency of less than 20% in 1970 were also tested by the 1% confidence limits of a binominal. For most of these species, only those macroplots with a mean frequency of 5% or more in 1970 were used for comparisons of treatments. To determine species susceptibilities, mean frequencies were transformed to apparent plant density (d) by the equation (Greig-Smith 1957):

$$d = -\log_e (1-p/100)$$

(p = frequency percentage)

The concept of apparent plant density is valid only for single-stemmed species and those that do not form a bunch or sod type of growth. Apparent plant density is not valid for most grasses, but for comparison of treatment effects on a single species, it is valid.

Hyder (1971) pointed out that the transformation from frequency to density holds true only where individuals of a species are dispersed at random. He showed that counting one herbaceous species on mixed-grass prairie provided a more thorough sample than frequency, but both methods placed the species in the same position relative to density of other species.

Precipitation was below average during the summers of 1970 and 1971 and continued low from the fall of 1971 through spring of 1972. It was above average during summer and fall of 1972 and then below average through most of the summer of 1973 (Table 1). Severe drought was experienced during the summers of both 1971 and 1972, despite the favorable moisture in July and August of 1972. The drought effects showed up in vegetation responses in the following years of 1972 and 1973.

Table 3. Approximate susceptibilities of 27 species to atazine as shown by comparisons of plant density, 1971–73. Densities were derived from frequency of occurrence.

Susceptibility and species	Plant classification[1]	Number of quadrats[2]	Percentage of control treatment			
			1971	1972	1973	Mean
Highly susceptible		(× 1,000)				
Redowski sticktight	ACF	4	−100*[3]	−100*	−100*	−100
Smallflower cryptantha	AWF	3	−100*	−100*	−100*	−100
Slimleaf goosefoot	AWF	4	−100*	−100*	–[4]	−100
Ragleaf goosefoot	AWF	12	−100*	–	–	−100
Sixweeks fescue	ACG	4	−99*	−100*	−100*	−100
Greenflower pepperweed	ACF	4	−98*	−100*	−100*	−99
Woolly plantain	ACF	4	−98*	−99*	−100*	−99
Ridgeseed spurge	AWF	4	−96*	−94*	−100*	−97
Tansyleaf aster	ACF	12	−92*	−92*	−98*	−94
Tumbling russianthistle	AWF	3	−99*	−83*	−93*	−92
Eveningprimrose	PWF	3	−72*	−100*	−100*	−91
Bottlebrush squirreltail	PCG	0.5	−80*	−84*	−88*	−83
Moderately susceptible						
Textile onion	PWF	3	−89*	−23	–	−56
Needleandthread	PCG	12	−19*	−58*	−67*	−48
Western wheatgrass	PCG	12	−22*	−41*	−71*	−45
Scarlet gaura	PWF	3	−38*	−27	−70	−45
Rubber rabbitbrush	PWH	2	−45*	−41*	+13	−24
Not susceptible						
Sun sedge	PCG	12	+4	−20*	−4	−7
Scarlet globemallow	PWF	12	+7	−10	−17*	−7
Woody buckwheat	PWF	12	+10	+4	+4	+6
Plains pricklypear	PCC	12	+2	+9	+24*	+12
Blue grama	PWG	12	+2	+9	+36	+16
Slimflower scurfpea	PWF	4	+26	+30	0[5]	+19
Rush skeletonplant	PWF	6	−2	+19*	+59*	+25
Red threeawn	PWG	12	+20*	+77*	+150*	+82
Sand dropseed	PWG	12	+92*	+187*	+843*	+374
Hairy goldaster	PWF	0.5	+45	+415*	+753*	+404

[1]For first letter A—annual, P—perennial; for second letter C—cool season, W—warm season; for third letter G—grass, F—forb, H—half-shrub, and C—cactus or succulent (from Dickinson and Baker 1972).

[2]Total number of quadrat placements used for comparisons.

[3]Asterisk denotes a statistically significant difference in frequency of occurrence from untreated control. For species with 12,000 quadrat placements, treatments compared by analysis of covariance ($P = 0.05$); other species compared by 1% confidence limits of a binomial.

[4]Dash indicates that frequency of occurrence was too low for evaluation.

[5]0 indicates no change in density between the two treatments (frequencies were identical).

Results

Blue grama was the most abundant species in 1970, prior to treatment application (Table 2). The second most abundant species was the perennial forb scarlet globemallow; and the next three most abundant were the annual species sixweeks fescue, greenflower pepperweed, and slimleaf goosefoot.

Susceptibilities to atrazine differed greatly between annual and perennial species and between warm-season and cool-season perennial grasses (Table 3). The ten species most susceptible to the atrazine treatments were annuals. The 17 least susceptible species were perennials. Only 2 perennials, eveningprimrose and bottlebrush squirreltail, were highly susceptible to atrazine. The remaining 15 perennial species were only moderately susceptible or not susceptible.

Sun sedge, an important cool-season perennial, did not respond to either the atrazine treatments or to weather over the 4 years of study. Apparently, sun sedge was tolerant to atrazine. Scarlet globemallow, woody buckwheat, plains pricklypear, and slimflower scurfpea were not susceptible to atrazine, and the last three species also showed little response to weather.

The cool-season, perennial grasses rapidly decreased during the study on the atrazine treatments, but maintained a more-or-less constant frequency on the untreated controls (Table 4). Frequency of bottlebrush squirreltail decreased from 7% in 1970 to 1% in 1973 on the atrazine treatments, while on the untreated controls it remained at 8% throughout the experiment. When treated with atrazine, western wheatgrass decreased from 11% frequency in 1970 to 2% in 1973, but remained constant on the untreated controls. Frequency of needleandthread decreased from 16% to 4% on the atrazine treatments, and increased from 9% to 12% on the untreated controls.

The atrazine treatments protected the

Table 4. Frequency percentages of some perennial grasses and forbs showing effects of atrazine, 1970–73, in June. 1970 data are pretreatment.

Classification and species	Atrazine rate (kg/ha)	Percentage frequency[1]			
		1970	1971	1972	1973
Perennial cool-season					
Bottlebrush squirrel	0	8	8	8	8
	2	7	2*[2]	1*	1*
Needleandthread	0	9	9	10	12
	2	16*	8*	4*	4*
Western wheatgrass	0	8	9	9	8
	2	11*	7*	4*	2*
Perennial warm-season					
Blue grama	0	88	80	67	56
	2	82	80	70	68
Rush skeletonplant	0	14	12	7	6
	2	13	11	9*	9*
Red threeawn	0	17	14	7	5
	2	19*	17*	12*	13*
Sand dropseed	0	20	12	9	2
	2	12*	22*	23*	18*
Hairy goldaster	0	15	12	4	2
	2	20	17	19*	12*

[1]Rounded to nearest 1%.
[2]Asterisk denotes significant difference in frequency present the year shown ($P=0.05$ for species with 12,000 quadrat placements—Table 3. These species tested by analysis of covariance. Other species tested by 1% confidence limits of a binomial.

warm-season perennial grasses from drought effects in 1972 and 1973. Blue grama frequency decreased slowly from 82% in 1970 to 68% in 1973 where treated with atrazine. On the untreated controls, drought reduced blue grama frequency more rapidly, from 88% to 56%. Red threeawn decreased from 19% frequency in 1970 to 13% in 1973 on the atrazine treatments, as compared with decreases from 17% to 5% on the untreated controls. Sand dropseed increased in frequency on the atrazine treatments from 12% in 1970 to 23% in 1972, and then decreased to 18% in 1973. On the untreated controls, drought rapidly reduced sand dropseed frequency from 20% to 2%.

Rush skeletonplant and hairy goldaster, both warm-season perennial forbs, also were protected by atrazine from drought effects. Rush skeletonplant decreased slowly on the atrazine treatments, from 13% frequency in 1970 to 9% in 1973. On the untreated controls, drought reduced rush skeletonplant more rapidly, from 14% frequency to 6%. Hairy goldaster decreased from 20% frequency in 1970 on the atrazine treatments to 12% in 1973. On the untreated controls, this species decreased from 15% in1970 to 2% in 1973.

Discussion

Previous studies on shortgrass range found that atrazine treatments did not affect overall forage yields (Houston and van der Sluijs, 1973; 1975). However, the seasonal growth pattern of forage may have been modified. With the loss of cool-season species, the season of green grass growth and good animal gains could be shortened, beginning later in the spring and ending earlier in the fall. However, Hyder et al. (1975a) reported that on these same ranges, where cool-season species are not a major component, the best forage quality was obtained in June and July, and the greatest productivity was obtained in August and September. This would imply that the losses of cool-season species, on this range at least, would have little or no effect on animal productivity.

In the shortgrass plains, western wheatgrass is found mostly on bottomland, overflow sites and the other cool-season grasses on uplands. By omitting application of atrazine on the highly productive overflow sites, the desirable western wheatgrass could be retained there.

Red threeawn is an undesirable species. Its palatability and grazing use are low. Nitrogen fertilizers reduce red threeawn (Hyder and Bement 1972). Applications of N fertilizer where threeawn is abundant may reduce the atrazine-induced increases and prevent red threeawn from presenting a greater problem.

Of the nongrass perennials, probably only scarlet globemallow is a valuable forage species. The rate of loss of this species is low. Its loss may be lessened by either lower rates of application of atrazine or applications in intermittent years. Of the annual species, only Russian thistle is a desirable forage plant. Loss of this species is probably a loss of forage.

Considering all species, probably the most serious forage changes are the losses of bottlebrush squirreltail and needleandthread. Lower rates of atrazine, intermittent applications, or both may reduce these losses, or separate seeded pastures of cool-season species may be provided.

The frequency method used for sampling vegetation in this study provided reliable data for 27 of the over 100 species found. This method is rapid, but requires personnel trained in identification of species and a large number of quadrat placements. The method provides an account of many species with a sampling time about equal to that required for list counting one species (Hyder 1971).

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