Selective Control of Annual Bromes in Perennial Grass Stands

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Abstract

Three soil-active herbicides: atrazine [6-chloro-N-ethyl-N[1]-(1-methyethyl)-1,3,5-triazine-2,4-diamine]; propham (1-methylethyl phenyl carbamate); and pronamide [3,5-dichloro(N-1,1-dimethyl-2-propynyl)benzamide] were applied in the fall, postemergence to annual bromegrasses at 2 rates. These herbicides were evaluated for their efficacy in selective control of cheatgrass (*Bromus tectorum* L.) and Japanese brome (*Bromus japonicus* Thunb.) in perennial stands of crested wheatgrass (*Agropyron cristatum* [L.] Gaertn.), pubescent wheatgrass (*Thinopyrum intermedium* Host), Russian wildrye (*Psathrostachys juncea* [Fisch.] Nevski), and western wheatgrass (*Pascopyrum smithii* (Rydb.) Löve) and blue grama (*Bouteloua gracilis)* [H.B.K.] Lag. Ex Griffiths. Yields of annual bromegrasses and perennial grasses and crude protein (CP), phosphorus and total nonstructural carbohydrate (TNC) content of perennial grasses were measured 2 consecutive years after the single herbicide application. Yields of annual bromegrasses from the 3 herbicide treatments averaged 91 and 47% less than those of the control the first and second year posttreatment, respectively. Pronamide provided substantially better control the second year posttreatment than the other 2 herbicides. Yields of perennial grasses in the majority of the herbicide treatment-study site combinations were significantly increased the first year posttreatment ($P<0.10$). Crude protein of perennial grasses was increased in the atrazine treatment. Atrazine at 0.6 kg/ha was the most cost-effective herbicide for decreasing competition of annual bromegrasses and increasing yield of perennial grasses.

Key Words: herbicides, atrazine, propham, pronamide, forage quality, forage yields

Cheatgrass (*Bromus tectorum* L.) often supplies much of the spring forage on western grazing lands, but production fluctuates widely (Hull and Pechanec 1947). The optimum period for grazing is usually short because of its early maturation. Mature seed contains long, stiff awns that often puncture mouth and throat tissue of livestock reducing feed intake and subsequent weight gain (Morrow and Stahlman 1984).

Cheatgrass is also recognized as a serious competitor with rangeland grasses (Young and Evans 1973). It readily establishes in the fall, tolerates cold winter temperatures, and produces an abundance of seed (Rydrych and Muzik 1968). The establishment of desirable grass species in a cheatgrass stand is difficult (Evans 1961).

Nonselective control of cheatgrass, particularly for seedling establishment, has been studied extensively on rangeland (Eckert et al. 1974). Although selective control has received less attention as a management tool (Houston 1977), it has the potential to reduce the competitiveness of the less desirable cheatgrass and increase the yields of the existing desirable perennial grass species. Atrazine [6-chloro-N-ethyl-N[1]-(1-methyethyl)-1,3,5-triazine-2,4-diamine] has plant growth-regulating properties as well as herbicidal activity (Houston 1977). Stimulation of protein production on shortgrass range by atrazine has been reported to be economically valuable in addition to control of the undesirable species (Houston and Hyder 1976). The purpose of this study was to evaluate the postemergent effect of 3 soil active herbicides: atrazine, propham (1-methylethyl phenylcarbamate), and pronamide [3,5-dichloro(N-1,1-dimethyl-2-propynyl)benzamide], applied at low rates to determine if annual bromegrasses could be controlled without damaging yields of desirable perennial species in both introduced species and native grass stands. Crude protein (CP), phosphorus and total nonstructural carbohydrate (TNC) content of crested wheatgrass (*Agropyron cristatum* [L.] Gaertn.), pubescent wheatgrass (*Thinopyrum intermedium* Host)[1], Russian wildrye (*Psathrostachys juncea* [Fisch.] Nevski)[1], and a combined sample of western wheatgrass (*Pascopyrum smithii* [Rydb.] Löve)[1] and blue grama (*Bouteloua gracilis* [H.B.K.] Lag. ex Griffiths) were examined within the herbicide treatments.

Study Areas

The research was conducted at the Fort Keogh Livestock and Range Research Laboratory (46°22'N 105°5') near Miles City in southeastern Montana. Herbicide efficacy was tested in established stands of crested wheatgrass, pubescent wheatgrass, Russian wildrye, and a mixed stand of native western wheatgrass and blue grama. All 4 sites were infested with cheatgrass and also had some Japanese brome (*Bromus japonicus* [Thunb.] ex Murr.) present.

Deep, well-drained soils formed from alluvial sediments characterized each of the 4 study locations. These Borollic Camborthids included 2 separate series, the Yamac and Kobar, which are classified as a loam and a silty clay loam, respectively. There were not any obvious visual differences reflected in the vegetation between the 2 soil series, and both were relatively fertile and represented highly productive range sites.

Topography is nearly level and existing native vegetation prior to seeding consisted of western wheatgrass, green needlegrass (*Stipa viridula* Trin.), needle-and-thread grass (*Stipa comata* Trin. and Rupr.), Sandberg bluegrass (*Poa sandbergii Vasey), and blue grama with some silver sagebrush (Artemisia cana* Pursh.). When crested wheatgrass, Russian wildrye and pubescent wheatgrass were seeded in 1977, alfalfa (*Medicago sativa* L.) was interseeded into the stands, but few plants remained in the grass stands during the study period. The native western wheatgrass-blue grama site was not interseeded. A long history of heavy livestock use may have contributed to the annual brome invasion on this site and decreases in alfalfa in the seeded grass stands.

Methods

A single postemergent application of atrazine at 0.6 and 1.1 kg/ha, propham at 3.4 and 6.7 kg/ha, and pronamide at 0.6 and 0.8 kg/ha was made in October of 1982. All herbicides were tank-mixed with water and applied on 9.1 × 9.1 m plots using a 3.7 m hand-propelled, cart-type boom sprayer. Two replications were established at each study site with 6 treated plots (3 herbicides, 2 rates) and an untreated control for each replication. Annual brome seedlings were about 25 to 50 mm tall at the time of treatment.

Herbage yields were estimated by clipping 3, 0.18-square meter

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[1]Nomenclature of the wheatgrasses and Russian wildrye follows that proposed by Dewey (1984).

subplots at ground level in each of the main plots during early July in 1983 and 1984. This sampling period corresponded to peak standing crop. The 3 subplots were randomly located within the main plot and oriented in the direction of the drill rows. Oven-dried herbage samples were separated into annual brome-grasses, dominant perennial grass, and perennial forbs and other grasses.

Samples of the dominant perennial grass from each site were also analyzed for percent CP, phosphorus, and TNC using the Technicon Autoanalyzer[2] (Technicon Autoanalyzer II Methodology 1977). Nitrogen is reported as percent CP (% N × 6.25). Each sample was a composite of 3 subsamples taken within each replication of the respective herbicide treatments. Forage quality estimates are reported by individual herbicide treatments.

Effects of herbicides on yield were tested by analysis of variance in a 3 × 2 factorial arrangement of treatments in a randomized block design. The model included site, treatments, plots and rate within treatments as main effects and the appropriate 2-factor interactions. Where F ratios were significant ($P<0.10$), linear contrasts (Steel and Torrie 1960) were made to compare the difference in mean yield of the different plant groups between the control and the average of the low and high rates within each herbicide for each plant category. Linear contrasts were also made to separate the means of rates within a herbicide.

A 1-way classification using a completely random design (Steel and Torrie 1960) was used to analyze percent CP, phosphorus and TNC content of the perennial grasses in each herbicide treatment and a control. The least significant difference (LSD) procedure was used to compare means of the 6 herbicide treatments to the control.

[2]Mention of a trade name, proprietary product, or specific equipment does not constitute a guarantee or warranty by the USDA and does not imply its approval to the exclusion of other products that may be suitable.

Results and Discussion

Analysis of forage yield data revealed a significant treatment × study site interaction ($P<0.10$), therefore, each site will be discussed separately.

Crested Wheatgrass Site

Yields of annual bromegrasses in crested wheatgrass stands treated with herbicides averaged 98 and 63% less than the control plots in 1983 and 1984, respectively (Table 1). Greatest control of bromegrasses was obtained in 1983 (first year posttreatment) with pronamide and atrazine at the 0.8 and 1.1 kg/ha rates, respectively.

In 1983, average yields of crested wheatgrass (dominant perennial grass) were significantly less in the pronomide-treated plots but were significantly higher in the atrazine and propham treatments in comparison to the control ($P<0.10$; Table 1). This was also observed in 1984, except yields in the atrazine-treated and control plots were similar. The lower rate of propham resulted in significantly greater yields of crested wheatgrass than the higher rate both years ($P<0.10$). The lower rate of atrazine also resulted in a higher yield in 1983 but lower the next. There was no effect of rate of pronamide in 1983, but in 1984, yields from the lower-rate treatment were higher.

Forb and other grass yields between the control and herbicide treatments were variable both years (Table 1). Although standard errors were large for this forage class, yields were greater in the higher-rate pronamide treatment both years and in the higher rate propham treatment in 1984 ($P<0.10$).

Atrazine applications have been used successfully for establish-

Table 1. Annual grass, perennial grass, and forb and other grass yields in herbicide-treated plots and controls at the 4 study sites, 1983 and 1984[1].

		Herbicide and rate (kg/ha)						
		Atrazine		Propham		Pronamide		
Forage class	Year	0.6	1.1	3.4	6.7	0.6	0.8	Control[2]
		Yields (kg/ha)						
		Crested wheatgrass site						
Annual grass	1983	31^{a}	4b	11^{a}	17^{a}	9^{a}	4^{b}	796^{a,p,n}
	1984	139^{a}	346^{b}	454^{a}	182^{b}	143^{a}	20^{b}	579^{a,p,n}
Perennial grass	1983	1231^{a}	945^{b}	1096^{a}	552^{b}	475^{a}	687^{a}	723^{a,p,n}
	1984	381^{a}	1286^{b}	2000^{a}	361^{b}	692^{a}	113^{b}	872^{p,n}
Forbs and ther grasses	1983	109^{a}	133^{a}	113^{a}	589^{a}	505^{a}	689^{b}	218^{n}
	1984	101^{a}	183^{a}	73^{a}	302^{b}	613^{a}	864^{b}	671^{a,n}
		Pubescent wheatgrass site						
Annual grass	1983	3^{a}	15^{a}	6^{a}	4^{a}	65^{a}	4^{a}	592^{a,p,n}
	1984	127^{a}	102^{a}	353^{a}	315^{a}	54^{a}	27^{a}	196^{n}
Perennial grass	1983	542^{a}	351^{a}	4^{a}	407^{a}	893^{a}	225^{a}	81^{a,n}
	1984	224^{a}	29^{a}	266^{a}	5^{a}	93^{a}	274^{a}	73
Forbs and other grasses	1983	1018^{a}	1369^{a}	1398^{a}	984^{a}	1331^{a}	1316^{a}	541^{n}
	1984	1088^{a}	1887^{b}	761^{a}	714^{a}	1505^{a}	847^{a}	878
		Russian wildrye site						
Annual grass	1983	139^{a}	78^{a}	32^{a}	115^{a}	74^{a}	4^{a}	455^{a,p,n}
	1984	93^{a}	4^{a}	223^{a}	249^{a}	4^{a}	4^{a}	279^{a,n}
Perennial grass	1983	334^{a}	1162^{b}	1055^{a}	692^{b}	499^{a}	526^{a}	276^{a,p}
	1984	591^{a}	1008^{a}	670^{a}	1391^{b}	1034^{a}	285^{b}	371^{p}
Forbs and other grasses	1983	1048^{a}	109^{b}	120^{a}	280^{a}	243^{a}	823^{b}	260^{a}
	1984	274^{a}	427^{a}	132^{a}	89^{a}	18^{a}	433^{b}	81
		Western wheatgrass-blue grama site						
Annual grass	1983	274^{a}	11^{b}	180^{a}	172^{a}	95^{a}	5^{a}	657^{a,p,n}
	1984	592^{a}	679^{a}	542^{a}	358^{b}	295^{a}	106^{b}	753p,n
Perennial grass	1983	623^{a}	1088^{b}	654^{a}	759^{a}	723^{a}	606^{a}	376^{a,p,n}
	1984	177^{a}	243^{a}	263^{a}	279^{a}	294^{a}	469^{a}	301^{a,n}
Forbs and other grasses	1983	56^{a}	40^{a}	92^{a}	91^{a}	328^{a}	121^{b}	2^{n}
	1984	66^{a}	230^{a}	121^{a}	212^{a}	355^{a}	615^{b}	26^{n}

[1]Within years and herbicides, rates with unlike superscripts are significantly different ($P<0.10$).
[2]Control yields with letters ^{a} (atrazine), ^{p} (propham) or ^{n} (pronamide) indicate a significant difference between the control and average yield (high and low rate) of the abbreviated herbicide ($P<0.10$).

Table 2. Percent crude protein (CP), phosphorus and total nonstructural carbohydrate (TNC) content of crested wheatgrass, Russian wildrye and western wheatgrass-blue grama herbage in herbicide-treated plots and controls, 1983, 1984[1,2]

		Herbicide and rate (kg/ha)						
		Atrazine		Propham		Pronamide		
Species and nutrient	Year	0.6	1.1	3.4	6.7	0.6	0.8	Control[2]
		(Percent)						
		Crested wheatgrass						
CP	1983	8.1^{a}	12.9^{b}	6.6^{a}	8.3^{a}	7.6^{a}	7.3^{a}	6.3^{a}
	1984	17.7^{b}	12.9^{a}	11.7^{a}	9.2^{a}	14.1^{a}	14.4^{a}	10.8^{a}
Phosphorus	1983	0.17^{a}	0.24^{b}	0.19^{a}	0.20^{a}	0.23^{a}	0.22^{a}	0.18^{a}
	1984	0.21^{a}	0.20^{a}	0.17^{a}	0.18^{a}	0.23^{a}	0.21^{a}	0.19^{a}
TNC	1983	47.6^{a}	41.0^{b}	45.4^{a}	46.3^{a}	45.2^{a}	45.4^{a}	47.0^{a}
	1984	38.4^{b}	40.4^{a}	44.4^{a}	44.5^{a}	41.4^{a}	44.7^{a}	42.8^{a}
		Russian wildrye						
CP	1983	12.4^{a}	13.1^{b}	10.2^{a}	12.2^{a}	8.8	9.4^{a}	7.9^{a}
	1984	20.8^{b}	18.9^{b}	15.4^{a}	16.0^{a}	14.5^{a}	15.1^{a}	17.6^{a}
Phosphorus	1983	0.19^{b}	0.18^{a}	0.16^{a}	0.18^{a}	0.16^{a}	0.17^{a}	0.15a
	1984	0.19^{a}	0.18^{b}	0.19^{a}	0.18^{b}	0.22^{a}	0.21^{a}	0.23^{a}
TNC	1983	34.6^{b}	34.9^{a}	36.4^{a}	35.6^{a}	35.9^{a}	35.3^{a}	39.0^{a}
	1984	37.3^{a}	36.8^{a}	38.6^{a}	39.3^{a}	35.6^{a}	35.9^{a}	37.4^{a}
		Western wheatgrass-blue grama						
CP	1983	9.2^{a}	10.8^{b}	9.2^{a}	10.2^{b}	8.9^{a}	9.7^{a}	8.6^{a}
	1984	14.6^{a}	15.7^{a}	14.0^{a}	14.2^{a}	12.3^{a}	14.7^{a}	14.2^{a}
Phosphorus	1983	0.16^{b}	0.21^{a}	0.20^{a}	0.21^{a}	0.18^{a}	0.21^{a}	0.21^{a}
	1984	0.23^{a}	0.23^{a}	0.23^{a}	0.23^{a}	0.23^{a}	0.24^{a}	0.24^{a}
TNC	1983	47.2^{a}	44.9^{a}	$46.^{a}$	45.1^{a}	45.4^{a}	44.7^{a}	47.6^{a}
	1984	44.0^{a}	42.6^{a}	47.3^{a}	44.9^{a}	44.9^{a}	41.8^{a}	45.6^{a}

[1]Treatment and control means (rows) with unlike are significantly different ($P<0.10$).
[2]Pubescent wheatgrass data are not given because of inadequate plant material in several replications.

ing perennial range grasses when used in a nonselective program of chemical fallow (Eckert and Evans 1967; Evans et al. 1967, 1969) and for selective weed control in existing pure stands of perennial grasses (McCarty et al. 1967, Cockreham 1976, Morrow et al. 1977, Eckert 1979). Eckert (1979) reported that atrazine applied at 0.56 kg/ha damaged the vegetative or reproductive parts of resident crested wheatgrass plants. Furthermore, density of crested wheatgrass seedings and established plants was greatest on treated plots 2–3 years after application (Eckert 1979). In our study, atrazine applied at 1.1 kg/ha was more effective than the 0.6 kg/ha rate at the crested wheatgrass site. By the second year posttreatment, atrazine was less effective than pronamide in controlling annual bromes.

Percent CP of crested wheatgrass was significantly higher in the 1.1 kg/ha atrazine treatment than in the control in 1983 as well as in the 0.6 kg/ha treatment in 1984 ($P<0.10$; Table 2). Eckert (1979) reported that CP of crested wheatgrass was significantly increased from 12.0% on the control to 16.2% with atrazine application. He concluded that triazine residues and CP in herbage indicated that crested wheatgrass on the atrazine-treated plots would be safe, nutritious forage for grazing animals (Eckert 1979).

The percent phosphorus in the 1983 samples for the higher atrazine rate was also greater than the control. Total nonstructural carbohydrate content in the atrazine treatment (higher rate) was less than the control in 1983 and at the lower rate in 1984.

Pubescent Wheatgrass Site

Annual bromegrass yields in the pubescent wheatgrass stands averaged 97% less in the herbicide-treated plots compared to the control plots in 1983 (Table 1). In 1984, however, the yields from the atrazine- and propham-treated plots were not different from the control ($P>0.10$). Also, the yields of pubescent wheatgrass (dominant perennial grass) in 1983 were about 600% higher in the atrazine and pronamide treatments compared to the control (Table 1). Again by 1984, there were no differences between any of the herbicide treatments and the control ($P>0.10$). Also no significant differences between rates of any of the herbicides were measured in either year and the yield of the forbs and other grasses class was only greater than the control in the pronamide treatment during 1983 ($P>0.10$; Table 1). The data for forage quality of this species are not presented because of inadequate plant material in the replications.

Russian Wildrye Site

Annual bromegrass yields in Russian wildrye stands averaged 84 and 66% less than those of the control in the herbicide treatments in 1983 and 1984, respectively. The yields were significantly less for all 3 herbicides both years with the exception of propham in 1984 ($P<0.10$; Table 1). Rate of herbicide had no effect on bromegrass yield at this site either year.

Compared to the control, the average yields of Russian wildrye, the dominant perennial grass, were significantly greater in the atrazine treatment in 1983 and in the propham treatment both years ($P<0.10$; Table 1). Russian wildrye yields in the pronamide treatment were not significantly different from the control either year ($P>0.10$). Rate effects were inconsistent with greater yields at the high application rate of atrazine (1983) and propham (1984) but significantly greater yields at the low rate of propham (1983) and pronamide (1984; $P<0.10$). In 1983, forbs and other grasses yields were significantly greater only in the atrazine-treated plots compared to the control ($P>0.10$; Table 1).

Crude protein of Russian wildrye was greater in the higher-rate atrazine treatment in 1983 and at both rates in 1984 than in the control ($P<0.10$; Table 2). Crude protein of herbage from all study sites and treatments was generally higher in 1984 than in 1983. This, however, was probably a function of maturity as samples were collected about 2 weeks earlier in 1984 than in 1983. Total nonstructural carbohydrates in the atrazine treatment (lower rate) were less than in the control in 1983, but no differences were observed in 1984 (Table 2).

Western Wheatgrass-Blue Grama Site

Annual bromegrass yields on the native, western wheatgrass-blue grama site were 81 and 43% less in the herbicide treatments compared to the control in 1983 and 1984, respectively (Table 1). These yields were significantly less than the control for all 3 herbicides in 1983 and propham and pronamide in 1984 ($P<0.10$). The higher rate of atrazine resulted in less bromegrass than the lower rate in 1983, but the difference disappeared by the second year posttreatment. A significant rate effect was present in the propham and pronamide treatments in 1984 with the higher rates resulting in less bromegrass ($P<0.10$).

The 3 herbicide treatments had an average perennial grass yield 197% greater than the control in 1983. Yields in the pronamide treatment were still significantly higher in 1984 but were not different in the propham treatment and were less in the atrazine treatment than in the control ($P<0.10$; Table 1). The higher rates of atrazine and pronamide resulted in greater perennial grass yields than their low-rate treatment in 1983 and 1984, respectively. Houston (1977) applied atrazine at 2 kg/ha for 3 consecutive years on shortgrass range in northeastern Colorado and found that atrazine controlled all annual plant species but also greatly reduced frequency of occurrence of cool-season perennial grasses such as western wheatgrass and needle-and-thread. In our study, perennial grass yields increased substantially in each grass stand the first year following atrazine application, but yields were usually not significantly different from the control thereafter.

The yields of forbs and other grasses were significantly greater in the pronamide-treated plots compared to the control in both years ($P<0.10$; Table 1). There were no differences in yields between the atrazine and propham treatments and the control. However, percent phosphorus in the lower-rate atrazine treatment (1983) was less than in the control. In the crested wheatgrass and Russian wildrye samples, phosphorus tended to be higher in the herbicide treatments than in the controls the first posttreatment year.

Crude protein in the western wheatgrass-blue grama composite samples from the higher rate atrazine-treated plots (1983) was significantly higher than in the control ($P<0.10$; Table 2). This was also true in the propham treatment. The mechanism by which triazine compounds influence plant protein, nitrate-N, and yield are not well understood (Houston and vanderSluijs 1975), but triazines appear to affect a great many plant reactions. Triazine-treated plants have shown increased total-N and nitrate-N and increased nitrate reductase activity (Reis et al. 1967). On a renovated big sagebrush (*Artemisia tridentata* Nutt.) site in northeast California, Kay (1971) found that a 1.1 kg/ha application of atrazine effectively removed downy brome in intermediate wheatgrass and thereby increased forage yields and plant protein over a 4-year period. Houston and vanderSluijs (1973, 1975) later found that 3 S-triazine herbicides (atrazine, simazine, and cyanazine {[4-chloro-6-(ethylamino)-1,3,5-triazin-2-yl]amino]-2-methylpropanenitrile} applied annually at 1.1 and 3.4 kg/ha to shortgrass range in north central Colorado consistently increased protein concentration in range herbage for 3 years.

Yields of annual bromegrasses averaged over the 3 herbicides were 90 and 47% less than those of the control in 1983 and 1984, respectively. Averaged over all 4 study sites, bromegrass yields were 88 and 50, 88 and 8, and 94 and 84% less than the control in the atrazine, propham, and pronamide treatments in 1983 and 1984, respectively.

Conclusions

Atrazine, propham, and pronamide were comparable the first year after application in controlling annual bromegrasses. Pronamide, however, provided substantially better control the second year posttreatment than the other 2 herbicides. Our data suggest though that yields of crested wheatgrass may be reduced with pronamide. Considering differences in rate of application and an assumed constant cost for application, atrazine applied at 0.6 kg/ha was the most cost effective herbicide for decreasing the competiveness of annual bromegrasses and increasing the quantity of perennial grasses.

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