Renovation of Sparse Stands of Crested Wheatgrass

RICHARD E. ECKERT, JR.

Abstract

Atrazine at 0.56 kg/ha and simazine at 1.12 kg/ha were evaluated for renovating sparse stands (0.9 to 1.5 m between plants) of resident crested wheatgrass. The study was repeated for 3 years for both weed control and seeding of crested wheatgrass. Both herbicides reduced yield and reproductive potential of downy brome and tumble mustard in the fallow year. Neither herbicide significantly damaged the vegetative or reproductive parts of resident crested wheatgrass plants. Atrazine residues in the soil in the fall of the fallow year and spring of the seeding year were below the toxic level for crested wheatgrass seedling. Simazine residues were above the toxic level. Both herbicides increased seed production of resident crested wheatgrass plants and neither adversely affected seed test weight and germination, or root and shoot growth of seedlings from seed of these plants. Weed competition during the seedling year was reduced by herbicide treatment. Density of crested wheatgrass seedlings and established plants was greatest on treated plots in 2 of 3 years. Based on low triazine residues and increased crude protein, resident crested wheatgrass on treated areas would be excellent forage during the fallow year. High levels of NO_3- N, *trans*-aconitate, and K, but low Mg suggest that grass tetany could be a problem if lush herbage on treated areas was grazed during the spring period.

Many hectares of depleted rangeland have been improved by mechanical or chemical control of weeds and seeding of perennial grasses. Seeding failures are usually dominated by annual grasses and forbs. Such stands can be seeded to perennial grasses by the atrazine-fallow technique (Eckert and Evans 1967; Eckert et al. 1974) or by the paraquat direct-seed method (Evans et al. 1967). Partial stands of perennial grasses with annuals in the interspaces also need improvement to maximize site productivity. Where perennial grasses are of sufficient density to dominate the site, control of annuals increased the vigor, competitive ability, and productivity of the perennials (Morrow et al. 1977). When the perennial grass stand is sparse and the site is dominated by annual species, the density of perennial grasses must be increased. Natural revegetation is very slow because annuals can fully occupy a site and form a closed community (Robertson and Pearse 1945). Some weed control, therefore, is necessary to reduce competition for successful revegetation (Stewart and Hull 1949). Also, maintenance of the resident perennial stand is desirable as a forage source during the treatment period or as a seed source for revegetation.

The author is range scientist, U.S. Dep. Agr., Sci. and Educ. Admin., Agricultural Research, Renewable Resources Center, University of Nevada, Reno. 920 Valley Road, Reno, NV 89512.

The work represents a cooperative investigation of the U.S. Dep. Agr., Sci. Educ. Admin., Agr. Res., and the Agr. Exp. Sta., Univ. of Nevada, Reno. Journal Series No. 399.

Manuscript received August 21, 1978.

Objectives of this study were to: (1) evaluate two triazine herbicides and the rate needed for maximum reduction in yield of weeds with minimum residual soil activity and damage to resident perennials; (2) determine the effects of these herbicides on seed quantity and quality and herbage quality of resident perennials; and (3) measure the effects of herbicide treatments on density of seedlings and established plants of crested wheatgrass in seeding trials.

Methods

The study was conducted at six locations in northern Nevada. Site characteristics were presented in previous publications (Eckert and Evans 1967; Evans et al. 1970). Atrazine [2-chloro-4-(ethylamino)-6-(isopropylamino)-*s*-triazine] and simazine [2-chloro-4, 6-bis (ethylamino)-*s*-triazine] were applied in a herbicide screening trial in the fall, 1970. Rates of 0.28, 0.56, and 1.12 kg/ha of these herbicides, and a combination of each at 0.56 kg/ha, were evaluated. On the basis of reduction in weed yield and minimal damage to crested wheatgrass, the 0.56 kg/ha atrazine and the 1.12 kg/ha simazine treatments were selected for further study and these treatments were repeated on new plots in 1971 and 1972. These treatments were made on sparse stands (0.9 to 1.5 m between plants) of crested wheatgrass (*Agropyron desertorum*) with downy brome (*Bromus tectorum*) and tumble mustard (*Sisymbrium altissimum*) in the interspaces. Herbicides were applied in 93.5 L/ha water with a backpack sprayer to 3.6 by 19.5-m plots in October. Treatments were replicated three times in a randomized block design. Stands treated had not been grazed for at least 5 years.

Treatments were evaluated by six parameters in each of 3 fallow years after one herbicide application: triazine residues in the soil in the spring and fall, triazine residues on crested wheatgrass herbage, weed yield, herbicide damage to crested wheatgrass, quantity and quality of crested wheatgrass seed, and reproductive potential of weed species. Soil samples were collected at depths of 0 to 2.5, 2.5 to 5, 5 to 7.5, 7.5 to 15, and 15 to 30 cm in the spring and from 0 to 10 cm at 2.5 cm increments, in the fall for triazine analysis as described by Mattson et al. (1970). Yield of mature downy brome and tumble mustard was determined by clipping three 0.4-m^2 samples per replication. Herbicide damage to the vegetative (chlorosis and stunting) and reproductive (reduced number of reproductive culms) parts of crested wheatgrass was visually estimated on a 0 to 5 scale in June and August, respectively. The number of reproductive culms and total seed produced were determined on five crested wheatgrass plants per treatment with similar basal areas on three sites. Test weight (gm/100 seeds), germination percentage, and root and shoot growth of seedling after 14 days were used to assess seed quality. The reproductive potential of annual species was estimated at the end of the fallow year (Young et al. 1969). This estimate was made from 10, 64 cm^2 samples of the surface 2.5 cm of soil per treatment. These samples were placed in the greenhouse, watered, and the number of germinating seedlings of downy brome and tumble mustard was counted.

At the end of the fallow year, Nordan crested wheatgrass was broadcast seeded at the rate of 13.4 kg/ha on three, 0.4 m^2 subplots in each treatment. The soil surface was disturbed with a hoe, the seed scattered, and the soil again stirred to cover the seed. Depressions about 5 cm deep were made in the surface to simulate microrelief that might be created by an anchor chain or a rangeland drill.

In April of the seedling year, soil samples were collected from the surface 10 cm, at 2.5 cm increments, for triazine residue analysis. The density of crested wheatgrass seedlings and symptoms of herbicide injury (leaf chlorosis and death) were determined on seeded plots early in the spring and again in June when annual species were mature. Yield of annuals was obtained at this time on three, 0.4 m^2 subplots adjacent to the seedling-count plots on areas with weed growth similar to that on the seedling plots. Density of established crested wheatgrass plants was determined 1 year after seedling counts.

Various forage quality characteristics of crested wheatgrass were also evaluated. Not all analyses, however, were made in all years. Herbage was collected in July and analyzed for triazine residues (Geigy Chem. Corp. 1965). The incidence of grass tetany near one of the study sites prompted an evaluation of factors associated with this metabolic disorder of cattle (Grunes et al. 1967). At various times during spring growth in the fallow year of 1971, herbage was collected and analyzed for total nitrogen; NO_3-N by the nitrate electrode method (Paul and Carlson 1968); *trans*-aconitic acid (Burau 1969); and the cations K and Mg by flame photometry and atomic adsorption spectroscopy, respectively.

Results and Discussion

Fallow Year

Precipitation from time of herbicide application in the fall until April of the fallow year ranged from 15 to 22 cm over the 3-year period. Atrazine and simazine residue levels in the soil were similar among years and among sandy loam, loam, and silt loam soil textures. Most of the triazine residues from both treatments were in the surface 2.5 cm soil sample and were usually higher on the simazine treatment than on the atrazine treatment (Table 1). Very little residue of either herbicide was detected deeper than 7.5 cm and no residue was detected below 15 cm. All residue levels of atrazine (0.17 to 0.36 ppm) and of simazine (0.77 to 1.22 ppm) in the soil significantly reduced downy brome yield in all years compared with the control (Table 1). Although simazine more effectively reduced downy brome yield, differences between herbicides were not significant. Percent reduction in downy brome yield was greater in 1970-71 (92%) and 1972-73 (94%), the wetter years, than in 1971-72 (82%). Yield of tumble mustard was small and variable in all years.

Herbicide treatments also significantly reduced the reproductive potential of downy brome in each year (Table 1). Averaged over years, reduction in number of caryopses (seeds) was from 29,600/m^2 without treatment to 5,800/m^2 with herbicide treatment. The result was fewer weed seeds in treated plots to germinate the following year, thus fewer plants to compete with crested wheatgrass seedlings. The reduction in reproductive potential was greater in the wetter years, 1970-71 (84%) and 1972-73 (86%), than in 1971-72 (70%). Young et al. (1969) pointed out that, in years of favorable precipitation, more downy brome seeds germinate and can be controlled by soil-active herbicides than in unfavorable years. Conversely, fewer seeds germinate in unfavorable years, are not controlled by herbicides, and remain viable in the soil.

A significant reduction in the reproductive potential of tumble mustard was obtained in 1971 and 1972 on the herbicide treatments. The number of tumble mustard seeds in 1971 was reduced from 5,500/m^2 on the control to 2,600/m^2 on treated plots. The reduction in 1972 was from 2,900/m^2 on the control to 1,600/m^2 after treatment. Both herbicides gave similar reductions in those years. These data, however, may not represent the true treatment effects since seeds produced on the plots could move off the plot and seeds produced around the study area could move into the plot as these plants tumbled across the soil surface.

Herbicide damage to resident crested wheatgrass plants was variable. Some leaf chlorosis and reduction in number of reproductive culms were noted in all 3 years of study on plots treated with atrazine at 0.56 kg/ha. Simazine at 1.12 kg/ha caused minimal leaf chlorosis and no reproductive damage.

Quantity and quality of crested wheatgrass seed collected at the end of the fallow year are shown in Table 2. Herbicide treatments did not increase the number of seedheads produced by individual grass plants in any year. However, the greatest number of seedheads occurred on sites with high productive potential. Herbicide treatments significantly increased seed yield per plant in all years. Based on a maximum of 1.5 m between crested wheatgrass plants, seed yield on herbicide-treated plots over 3 years ranged from about 9 to 26 kg/ha.

Table 1. Triazine residue (ppm) in April, downy brome yield (kg/ha) in June, and downy brome seed (no./m^2) in September of 3 fallow years after one application of 0.56 kg/ha atrazine or 1.12 kg/ha simazine in the fall of 1970, 1971, or 1972.[1]

Year and treatment	Precipitation (cm) (Oct.–June)	Triazine residue 0–2.5	2.5–5	5–7.5	Downy brome Yield	Seed
1970	1970–71			1971		
Control	29	<0.04	<0.04	<0.04	881 a[2]	29,000 a
Atrazine		0.28	0.13	0.07	120 b	4,400 b
Simazine		1.22	0.37	0.18	27 b	4,900 b
1971	1971–72			1972		
Control	24	<0.04	<0.04	<0.04	522 a	28,000 a
Atrazine		0.36	0.17	0.10	121 b	7,900 b
Simazine		0.92	0.43	0.08	72 b	9,200 b
1972	1972–73			1973		
Control	28	<0.04	<0.04	<0.04	879 a	31,200 a
Atrazine		0.17	0.07	0.07	76 b	4,300 b
Simazine		0.77	0.32	0.22	24 b	4,300 b

[1] Triazine residue data are the means of three locations. Other data are the means of six locations.
[2] Within-year treatment means for downy brome yield or downy brome seed followed by different letters are significantly different at the 0.05 probability level as determined by Duncan's multiple range test.

Table 2. Effects of 0.56 kg/ha atrazine or 1.12 kg/ha simazine on seedheads (no./plant), a total seed weight (gm/plant), test weight (mg/100 seeds), germination (%), and root and shoot length (cm) of seedlings from crested wheatgrass seed collected in summer of 3 fallow years[1].

	Seedheads			Seed weight			Test weight			Germination			Root			Shoot		
Treatment	1971	1972	1973	1971	1972	1973	1971	1972	1973	1971	1972	1973	1971	1972	1973	1971	1972	1973
Control	46[2]	82	100	1.4 b[3]	2.5 b	3.0 b	25	24	20 b	86.4 b	82.3	76.4	3.2	2.7	2.3	5.3	7.1	6.6b
Atrazine	55	88	126	2.2 a	4.3 a	8.7 a	25	26	24 a	90.9 a	78.2	76.8	3.1	2.6	2.4	5.5	7.0	7.1a
Simazine	54	89	135	2.9 a	5.0 a	7.1 a	26	25	25 a	90.3 a	80.2	76.2	3.1	2.6	2.4	5.5	6.6	7.4a

[1] Data are the means of three locations in each year.
[2] Means without letters indicate no significant difference among treatments.
[3] Within-year treatment means for each characteristic followed by different letters are significantly different at the 0.05 level of probability as determined by Duncan's multiple range test.

Responses to treatments were similar among locations in 1971. In 1972 and 1973, seed yield on the check at different locations was similar, but seed yield on herbicide treated plots was greater on the high potential sites than on the low potential sites.

Average test weight of crested wheatgrass seeds in 1971 and 1972 was not significantly different among treatments. In 1973, however, test weights of seed on both herbicide treatments were significantly greater than on the control. This response was due to a low test weight on the control not to a high test weight on treated plots. Test weights were similar among locations in all years. Germination of crested wheatgrass seed produced in 1971 on the atrazine and simazine treatments was significantly greater than on the control. In other years germination was similar among treatments. Root length of 14-day-old seedlings was similar among treatments and locations in all years. Shoot length of 14-day-old seedlings from the 1971 and 1972 seed crop was similar among treatments. Seedlings from 1973 seed, however, had significantly longer shoots on the atrazine and simazine treatments than on the control. Shoot length was similar among locations. In summary, the quantity and quality of crested wheatgrass seed were not always improved by herbicide treatments in all years at all locations. In no instance, however, was herbicide treatment detrimental.

Triazine residues in the soil in the fall of the fallow year were lower after application of 0.56 kg/ha atrazine than following application of 1.12 kg/ha simazine. The highest residues, regardless of herbicide, were found in the 0 to 2.5 cm and 2.5 to 5 cm soil depths. Atrazine residues for the 3 years ranged from <0.04 to 0.12 ppm at the 0 to 2.5 cm depth and from 0.04 to 0.09 ppm at the 2.5 to 5 cm depth. In contrast, simazine residues were greater and ranged from 0.14 to 0.24 ppm at the 0 to 2.5 cm depth and from 0.11 to 0.16 ppm at the 2.5 to 5 cm depth. Residue levels at 5 to 10 cm depth did not exceed 0.06 and 0.08 ppm from the atrazine and simazine treatments, respectively. Residue levels, particularly on the simazine treatment, approached or exceeded 0.13 ppm, the approximate toxic level for crested wheatgrass seedlings, as suggested by Eckert et al. (1972). Therefore in areas with an environment conducive to fall germination of seeded grasses, triazine damage to seedlings may occur. Under those conditions, seeding treatments should be delayed until the weather is too cold for germination. Seeding could also be delayed until spring in areas where spring planting is successful.

Seedling Year

Average precipitation for the 3-year study from time of seeding in the fall until initial seedling counts in April ranged from 15 to 19 cm. From time of seeding until final seedling counts in June, precipitation ranged from 20 to 28 cm (Table 3). The wettest year at all sites was 1972-73.

Triazine residues were found at all soil depths sampled (Table 3). Atrazine residues were below the suggested toxic level for crested wheatgrass seedlings at all depths in all years. Simazine residues approached or exceeded the suggested toxic level for crested wheatgrass seedlings at the 0 to 7.5 cm depth in 1972, and the 0 to 5 cm depth in 1973, and at the 0 to 10 cm depth in 1974.

Table 3. Triazine residue (ppm) in April, yield of downy brome and tumble mustard (kg/ha) in June, and crested wheatgrass seedling density (no./m²) in April and June of the seedling year after one application of 0.56 kg/ha atrazine or 1.12 kg/ha simazine in the fall of 1970, 1971, or 1972. The density (no./m²) of established crested wheatgrass plants was determined 1 year after seedling counts.[1]

	Precipitation (cm)	Triazine residue				Weed yield		Crested wheatgrass		
						Downy	Tumble	Seedlings		Established
Year and treatment	(Oct.–June)	0–2.5	2.5–5	5–7.5	7.5–10	brome	mustard	April	June	plants
1970	1971–72					1972				1973
Control	8	<0.04	<0.04	<0.04	<0.04	278 a[2]	20 b	79 b	11 b	1 b
Atrazine		0.08	<0.04	0.06	<0.04	91 b	122 a	115 a	48 a	23 a
Simazine		0.30	0.19	0.14	0.08	53 b	84 a	102 ab	20 b	16 a
1971	1972–73					1973				1973
Control	28	<0.04	<0.04	<0.04	<0.04	398 a	57 b	13 b	2 b	0
Atrazine		0.06	0.06	<0.04	<0.04	241 b	133 a	24 a	9 a	0
Simazine		0.16	0.11	0.09	0.05	180 b	108 a	27 a	11 a	0
1972	1973–74					1974				1975
Control	20	<0.04	<0.04	<0.04	<0.04	157 a	21 b	33 b	2 b	1b
Atrazine		0.05	<0.04	<0.04	<0.04	144 a	183 a	88 a	24 a	8 a
Simazine		0.12	0.18	0.14	0.16	86 b	184 a	81 a	19 a	9a

[1] All data are the means of six locations.
[2] Within-year treatment means for weed yield, seeding density, and established plants followed by different letters are significantly different at the 0.05 probability level as determined by Duncan's multiple range test.

Downy brome yield was significantly less on herbicide-treated plots than on the control in 1972 and 1973. In 1974, yield on the control and atrazine treatment was similar and significantly greater than on the simazine treatment. The highest downy brome yield on herbicide plots occurred in 1973. This was probably due to more downy brome seeds in the soil at the end of 1972 fallow year on treated plots (Table 1) and high precipitation. Average yield of tumble mustard was significantly greater each year on treated plots than on the control (Table 3). Tumble mustard is not as competitive as is downy brome. It is suppressed by downy brome on untreated areas but develops rapidly when competition is reduced.

The density of crested wheatgrass seedlings on seeded plots was significantly greater on the atrazine treated plots than on control plots in all years and on both sample dates (Table 3). The simazine treatment increased seedling density only in 1973 and 1974, and in those 2 years both herbicide treatments gave similar results.

Herbicide damage to crested wheatgrass seedlings was noted on both sample dates in all years. Damage from the simazine treatment was more severe than from the atrazine treatment. More damage was noted on sites with loam and silt loam A horizons than on sites with a sandy loam A horizon. Seedling mortality from the early to the late sample date was severe (80%) only in 1972 on the simazine-treated plots on the heavier textured soils. Density of crested wheatgrass at the end of the seedling year on both herbicide treatments was sufficient to give a fully stocked stand of perennial grass.

Average precipitation from the end of the seedling year until the density of established crested wheatgrass plants was determined is shown in Table 3 for 1972-73 and 1973-74. Precipitation for 1974-75 averaged 26 cm. No established plants occurred in 1974 (Table 3). This failure may be due to the high reproductive potential of downy brome at the end of the 1972 fallow year and more competition from downy brome during the 1973 seedling year. Very few seedlings established on untreated plots in 1973 and 1975. On herbicide-treated plots, more seedlings established on sandy loam soils than on silty soils. This response may be related to herbicide residue or to crusting of silty soils after disturbance to form a massive, vesicular A horizon that restricts seedling emergence (Eckert et al. 1977; Wood et al. 1977). The stand of established plants on plots treated with herbicides in 1973 was double to triple that in 1975.

Herbage Quality

Atrazine residues on crested wheatgrass herbage collected in July ranged from 0.04 to 0.29 ppm and simazine residues ranged from 0.04 to 1.09 ppm. These triazine levels are well below the 4 ppm tolerance level established for these herbicides for grazing animals (Federal Register 1976).

Houston and Van der Sluijs (1973) and Kay (1971) found that triazine herbicides increased the crude protein content of range grasses. In the present study, crude protein of crested wheatgrass was significantly increased from 12.0% on the control to 16.2% with atrazine application and to 18.4% following simazine treatment. At most locations, the increase due to simazine was greater than the increase due to atrazine. The influence of both treatments carried through the growing season. For example, crude protein on six dates from 3/5 to 6/15 ranged from 17.0 to 11.7% on the control and from 26.4 to 18.6% on atrazine-treated plots.

Triazine residues and crude protein in herbage indicated that crested wheatgrass on the atrazine and simazine treated plots would be safe, nutritious forage for grazing animals. Two antiquality factors, however, should be considered. The NO_3-N content of crested wheatgrass herbage from early March to late May at five locations ranged from 106 to 481 ppm and averaged 220 ppm on the control compared with a range of 272 to 1,104 ppm and an average of 872 ppm on atrazine-treated plots. At one location, 3,005 ppm NO_3-N occurred. Therefore, crested wheatgrass herbage from the atrazine treatment on all sites but one was below the toxicity level of about 2,000 ppm suggested by Bradley et al. (1940) and Tucker et al. (1961). Jensen et al. (1971), however, indicated that oat hay with from 697 to 1,385 ppm NO_3-N should be fed with caution. Thus, herbage from all but one location on any of the sample dates would be in the potentially dangerous category.

Atrazine treatment significantly increased the *trans*-aconitate content of herbage on the early (1.38%) and late (1.40%) May sample dates to above the 1.0% level that is potentially toxic (Stout et al. 1967). The Mg content of herbage was above the minimum requirement for grazing cattle of 0.20 to 0.25% only at two of six locations. Even at those locations the Mg level fell below the minimum requirement for cattle by the middle of May. Low Mg was accompanied by an increase in K from 1.60 to 1.91% due to treatment. Herbage from the atrazine treatment was low in Mg but high in K, N, and *trans*-aconitate. These characteristics suggest the possibility of grass tetany from treated forage. The incidence could be reduced by delaying grazing until crested wheatgrass approached maturity or by grazing livestock with a low Mg requirement, such as nonlactating animals.

Application of Results

Atrazine at 0.56 kg/ha would be the treatment of choice for renovation of sparse stands of crested wheatgrass because: (1) weed control was similar to that with higher rates of herbicide in the screening study; (2) damage to resident crested wheatgrass plants was minimal; (3) herbicide residues in the soil in the fall of the fallow year and spring of the seedling year were below the toxic level for crested wheatgrass seedlings; and (4) good seedling stands and manageable stands of established plants were obtained in most years.

In a renovation procedure weed control creates a temporary void in the plant community. Young et al. (1969) pointed out the necessity of filling the void with perennial grass plants at the low point in the reproductive capacity of weed species. In this study, crested wheatgrass was introduced into the void by broadcasting seed and stirring the soil with a hoe to cover the seed and create a rough surface microrelief. Several methods of seeding could be used in practical application. If the area is grazed during the fallow year, a seed source must be supplied and planted. This could be done by drilling with a standard rangeland drill with depth bands or with a grain drill to prevent excessive uprooting of resident crested wheatgrass plants. Seed could also be broadcast and an anchor chain used to scarify the soil, cover the seed, and create a rough surface microtopography. If the area is not grazed, the existing seed crop could be dispersed and planted by an anchor chain. Supplemental seed could be broadcast prior to chaining in years when the resident seed crop was not adequate. Dispersal and planting of seed by grazing livestock at seed-rip time is not recommended. Uniform distributions and covering of seed by livestock trampling could not be accomplished in the 1-year period available for planting and establishing a perennial grass stand before weeds again dominate the site.

Literature Cited

Bradley, W.R., H.F. Eppson, and A.O. Beath. 1940. Livestock poisoning by oat hay and other plants containing nitrate. Wyo. Agr. Exp. Sta. Bull. 241. 23 p.

Burau, R.G. 1969. Polarographic estimation of aconitates in plant materials. Agr. and Food Chem. 17:1332-1334.

Eckert, R.E. Jr., J.E. Asher, M.D. Christensen, and R.A. Evans. 1974. Evaluation of the atrazine-fallow technique for weed control and seedling establishment. J. Range Manage. 27:288-292.

Eckert, R.E., Jr., G.J. Klomp, R.A. Evans, and J.A. Young. 1972. Establishment of perennial wheatgrasses in relation to atrazine residue in the seedbed. J. Range Manage. 25:219-224.

Eckert, R.E. Jr., F.F. Peterson, M.K. Wood, and W.H. Blackburn. 1977. Properties, occurrence, and management of soils with vesicular surface horizons. Final report. Contract 52500-CT5(N) Denver Service Center, Bureau of Land Management, Denver, Colo. 116 p.

Evans, R.A., R.E. Eckert, Jr., and B.L. Kay. 1967. Wheatgrass establishment with paraquat and tillage on downy brome ranges. Weeds 15:50-55.

Evans, R.A., H.R. Holbo, R.E. Eckert, Jr., and J.A. Young. 1970. Functional environment of downy brome communities in relation to weed control and revegetation. Weed Sci. 18:154-162.

Federal Register. 1976. Code of Federal Regulations. Title 40, Protection of environment Part 180.220. Atrazine: Tolerances for residue.

Geigy Chemical Corp. 1965. The determination of chlorotriazine residues in plant material, animal tissues, and water using the ultraviolet method. Analytical Bull. No. 7. Agr. Analytical Chem. Analytical Dep. Ciba-Geigy Chemical Corp. Greensboro, N.C.

Grunes, D.L., P.R. Stout, and J.R. Brownell. 1970. Grass tetany of ruminants. Adv. Agron. 22:331-334.

Houston, W.R., and D.H. van der Sluijs. 1973. Increasing crude protein content of forage with atrazine on shortgrass range. Production Res. Rep. No. 153, Agr. Res. Serv. U.S. Dep. Agr. Washington, D.C. 10 p.

Jensen, E.H., R.A. Young, and M.J. Sharp. 1971. Nitrate accumulation by oats. Nevada Agr. Exp. Sta. R 80. 7 p.

Kay, B.L. 1971. Atrazine and simazine increase yield and quality of range forage. Weed Sci. 19:370-372.

Mattson, A.M., R.A. Kahrs, and R.I. Murphy. 1970. Quantitative determination of triazine herbicides in soil by chemical analysis. Residue Rev. 32:371-390.

Morrow, L.A., C.R. Fenster, and M.K. McCarty. 1977. Control of downy brome on Nebraska rangeland. J. Range Manage. 30:293-296.

Paul, J.L. and R.M. Carlson. 1968. Nitrate determination in plant extract by the nitrate electrode. Agr. and Food Chem. 16:766-788.

Robertson, J.H., and C.K. Pearse. 1945. Artificial reseeding and the closed community. Northwest Sci. 19:58-66.

Stewart, G., and A.C. Hull. 1949. Cheatgrass (*Bromus tectorum* L.) an ecological intruder in southern Idaho. Ecology 30:58-74.

Stout, P.R., J.R. Brownell, and R.G. Burau. 1967. Occurrences of *trans*-aconitate in range forage species. Agron. J. 59:21-24.

Tucker, J.M., D.R. Cordy, L.J. Berry, W.H. Harvey, and T.C. Fuller. 1961. Nitrate poisoning in livestock. California Agr. Exp. Sta. Ext. Serv. Circ. 506. 12 p.

Wood, M.K., W.H. Blackburn, R.E. Eckert, Jr., and F.F. Peterson. 1977. Interrelations of physical properties of coppice dune and vesicular dune interspace soils with grass seedling emergence. J. Range Manage. 31:189-192.

Young, J.A. R.A. Evans, and R.E. Eckert, Jr. 1969. Population dynamics of downy brome. Weed Sci. 17:20-26.