Establishment of Perennial Wheatgrasses in Relation to Atrazine Residue in the Seedbed¹

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Highlight

Perennial wheatgrasses were seeded in fall, 1967 and 1968 on fallows created by atrazine at 1 lb./acre applied the previous fall or by mechanical means. Atrazine residue in the soil during seedling establishment (1.5 years after application) ranged from < 0.04 to 0.15, 0.09, 0.08, and 0.06 ppm, respectively, in the 0-1, 1-2, 2-3, and 3-4-inch soil samples. Residue was less than 0.04 ppm from 4 to 8 inches. Seedlings of perennial grasses were injured or killed by these residue levels. However, poor stands were obtained at only two of seven locations in 1969 with crested wheatgrass. Generally, stands of intermediate and pubescent wheatgrasses were superior to crested wheatgrass. Species response was also evaluated on fallows created by 0.5, 1.5, and 2.0 lb./acre atrazine.

An atrazine (2-chloro-4-(ethylamino)-6- (isopropylamino)-s-triazine) fallow shows promise for weed control and establishment of perennial grasses on downy brome (*Bromus tectorum*) infested rangelands in Nevada (Eckert and Evans, 1967; Evans et al., 1969). However, herbicide residue may be a problem in the use of atrazine for chemical fallow in arid regions (Burnside et al., 1963). We have minimized this problem by use of a technique which specifies a 1-year waiting period between application of atrazine at 1 lb./acre and fall seeding of perennial grasses. Therefore, emergence of seeded species occurs from 1 to 1.5 years after herbicide application. During this time, atrazine residue is dissipated by various

means. We have used 4-inch deep furrows to improve seedling microclimate (Evans et al., 1970) and to aid in removal of contaminated soil from the seedling environment. We have noted no atrazine damage in some years; in other years damage has been slight to severe. To evaluate the potential of an atrazine chemical fallow in the 8 to 12-inch precipitation zone, we must know: 1) the amount of herbicide residue in the seedbed during the period of seedling establishment; and 2) the response of perennial grass seedlings to various levels of atrazine residue.

Materials and Methods

We conducted the study on three sites for the period of fall, 1966, through spring, 1968; and on seven sites for the period of fall, 1967, through spring, 1969. All locations are in the big sagebrush (*Artemisia tridentata*) type, but now downy brome is dominant. At Cain Springs the treated area was 50 acres without replications. At all other locations plot size was 20 × 20 feet with four replications. Experi-

mental design was a split-plot with fallow treatments the main plots and species the subplots.

Atrazine and mechanical fallows were established on three sites in the 1966-68 series, and on two sites in the 1967-69 series. Atrazine at 1 lb./acre was applied in the fall of 1966 and 1967. In addition, at two locations in fall, 1967 atrazine was applied at 0.5, 1.5, and 2.0 lb./acre. Truck-mounted equipment was used on the 50-acre field. A back-pack sprayer was used on plots. Water at 11 gpa was the carrier in all studies. Mechanical treatment was made in June 1967 and June, 1968. A rangeland disc-plow was used on the 50-acre field. A moldboard plow or rototiller was used to cultivate small plots.

A sample of standing, dead litter was collected immediately after spraying at one location. A 0-1-inch soil sample was collected 27 days after spraying at two locations. The following spring (6 months after treatment) soil samples were collected by 1-inch increments to 6 inches at all sites. In spring, 1968 and 1969 (1.5 years after treatment) when perennial grasses were emerging, soil samples were collected at all locations by 1-inch increments to 8 inches from the bottom of seeded furrows. These samples were collected after leaching from winter and spring precipitation had ceased. Soil texture was loam at five locations, loam to silt loam at one location, silt loam at one location, and sandy loam to sandy clay loam at one location. Soil samples were air-dried for 2 days, screened, and stored at -20 F. until subsampled for bioassay and chemical analysis.

Perennial grasses were fall-seeded approximately 1 year after atrazine treatment and 6 months after mechanical treatment. Amur intermediate wheatgrass (*Agropyron intermedium*) was seeded in the

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atrazine and mechanical fallow treatments on the 50-acre field with a rangeland drill modified to make deep furrows.

Amur intermediate wheatgrass and Nordan crested wheatgrass (*Agropyron desertorum*) were seeded in 1967 on small plots. In 1968, Luna pubescent wheatgrass (*A. trichophorum*) was seeded in addition to those mentioned. All three species were seeded in furrows made with a shovel attachment mounted on a tool bar.

Seedling density of perennial grass was determined on six dates at Cain Springs in 1968. At other locations in 1968 and 1969, density data were collected on four dates before grasshoppers damaged the stands. We attempted to relate the density of intermediate wheatgrass seedlings to the level of atrazine residue in the soil. The density sample at all locations was chosen to include a uniform area with wheatgrass seedling. We excluded areas with ant hills, soil conditions which may have resulted in fast or slow infiltration and percolation of water, and microtopographic features which may have caused excess ponding or runoff of water. Soil for atrazine determination was collected adjacent to the seedling density sample. This method of sampling did not give a representative measure of seedling density of the entire treated plot, except at Cain Springs, but did give a valid measure of seedling response within the limits of residue encountered. Soil samples were not collected adjacent to the density samples for crested and pubescent wheatgrasses. However, since the same criteria were used to select the density sample area for these species as for intermediate wheatgrass, we believe that residue would be similar.

Percent frequency (occurrence per foot of row) data were collected in the summer of 1969 over the entire treated plot at all locations. These data indicate the kind of stand we could expect on fallow treatments on a field basis. Only well established plants were recorded. The

Table 1. Range in atrazine residue levels (ppm) on litter and in soil (inch intervals) after application of atrazine (1 lb./acre) in fall, 1967.

Time	Material	Depth	Atrazine
Fall			
Immediately after spraying	Standing, dry litter	—	144-246
27 days after spraying	Soil	0-1	6-14
Spring			
6 months after spraying	Soil	0-1	0.33-1.45
		1-2	0.12-1.34
		2-3	0.05-0.33
		3-4	< 0.04-0.25
		4-5	< 0.04-0.09
		5-6	< 0.04-0.08
1.5 years after spraying	Soil	0-1	< 0.04-0.15
		1-2	< 0.04-0.09
		2-3	< 0.04-0.08
		3-4	< 0.04-0.06
		4-5	< 0.04
		5-6	< 0.04
		6-7	< 0.04
		7-8	< 0.04

relative success of a stand in the 8 to 12-inch precipitation zone was based on the work of Hyder and Sneva (1954, 1963) and our experience. An excellent stand would have a frequency of greater than 70%; good stand—50 to 70%; fair stand—30 to 50%; and poor stand—10 to 30%.

Bioassays were conducted in 4 oz cups with Amur intermediate wheatgrass the test crop. Twenty seeds were planted in treated and control soils from each location and depth sampled. Seedlings were grown for 21 days, then rated for herbicide damage.

Soil samples were analyzed chemically by the method supplied by the Geigy Research Laboratory, Ardsley, N. Y. Atrazine was extracted from duplicate 100 g samples by refluxing with an acetonitrile-water mixture. Sample was evaporated to dryness, dissolved in carbon tetrachloride, and carried through an aluminum oxide cleanup column. Atrazine in the sample was hydrolyzed to hydroxyatrazine and dissolved in water. Absorbance was measured at 225, 240, and 255 m μ in a spectrophotometer.

Residue levels are reported in ppmw. Samples from three of four replications were analyzed. Replications selected were those with minimal, moderate, or severe damage to seedlings in bioassay and under field conditions.

Results and Discussion

Atrazine Residue

Atrazine residue on litter and in soil at intervals after spraying is presented in Table 1. The standing, dry litter of downy brome and broadleaf annuals can intercept some of the atrazine applied. Without immediate precipitation, atrazine on the litter is exposed to the environment and is subject to photochemical degradation and volatilization losses. With rainfall, atrazine on litter is washed to the soil surface. With heavy snowfall, litter is matted on the soil surface. In either case, atrazine on litter could become concentrated near the base of plants and results in uneven distribution of herbicide over the soil surface.

Little atrazine was found below 4 inches in spring, 1968, 6 months after spraying or in spring, 1969,

1.5 years after spraying at any location. This depth of leaching is of the same magnitude as reported by Birk and Roadhouse (1964). The depth of leaching in 1968–69 at Hallelujah Junction was greater than in 1967–68. The highest level of atrazine residue in the 4 to 5 and 5 to 6-inch samples was 0.09 and 0.08 ppm, respectively, in spring, 1968. Precipitation for the 6-month period after spraying was 5.8 inches. In spring, 1969 after 11.9 inches of precipitation, atrazine residue was 0.16 and 0.17 ppm, respectively, in the 4 to 5 and 5 to 6-inch samples. Under our precipitation pattern dissipation by leaching was not as important as under more mesic conditions (Fenster and Wicks, 1963; Rodgers, 1968; and Burnside et al., 1969). Atrazine residue remaining in the topsoil may be degraded more rapidly than if leached into the subsoil, due to more favorable conditions of temperature, moisture, and microorganism population (Roeth et al., 1969).

Herbicide residue at time of emergence of perennial grass seedlings at specific locations is discussed with the seedling density data.

Seedling Density, 1968

Seedling density of intermediate wheatgrass on the atrazine and mechanical fallows was compared at three locations (Fig. 1). At Cain Springs, significantly more seedlings were found on the atrazine fallow. The attrition in seedling density was similar under the two treatments and indicated no accelerated loss due to atrazine toxicity. The atrazine residue from eight samples ranged from < 0.04 to 0.13 ppm in the 0 to 1-inch depth, from < 0.04 to 0.10 ppm in the 1 to 2-inch depth, and from < 0.04 to 0.06 ppm in the 2 to 3-inch depth. Below 3 inches, atrazine residue was less than 0.04 ppm. Bioassay showed slight to moderate damage to intermediate wheatgrass seedlings grown in soil with 0.10 and 0.13 ppm atrazine. Under field conditions some seedling damage was noted;

FIG. 1. Seedling density of intermediate wheatgrass on atrazine and mechanical fallows at three locations in 1968.

however, no stand reduction was measured on sample sites with these residue levels. Precipitation during the fallow and seedling years was 11.6 and 6.9 inches, respectively.

At Orovada, seedling density of intermediate wheatgrass was similar on the atrazine and mechanical fallows (Fig. 1). Atrazine residue in three replications ranged from < 0.04 to 0.06 ppm in the 0 to 1-inch depth and from < 0.04 to 0.04 ppm in the 1 to 2-inch depth. Below 2 inches residue was less than 0.04 ppm. No damage was noted in bioassay, however, moderate to severe damage was noted under field conditions. Precipitation during the fallow and seedling years was 12.2 and 6.6 inches, respectively.

At Trap Butte significantly more seedlings were found on the mechanical fallow (Fig. 1). Atrazine residue by chemical analysis was less than 0.04 ppm at all depths. Bioassay also indicated no residue. However, seedlings in the field showed moderate to severe atrazine damage and stand reduction indicated atrazine damage. Precipitation for the fallow and seedling

years was 11.5 and 7.0 inches, respectively.

The response of crested wheatgrass was also compared on atrazine and mechanical fallows at Orovada and Trap Butte. At both locations, seedling density was significantly lower on the atrazine fallow. On May 28, seedling density at Orovada and 3.0 plants per foot of row (pfr) on the atrazine fallow compared to 5.1 pfr on the mechanical fallow. At Trap Butte, the atrazine fallow had 5.9 pfr compared to 13.0 pfr on the mechanical fallow. Although soil samples were not collected adjacent to the crested wheatgrass density sample, we concluded that atrazine residue was responsible for less seedling density in the atrazine fallow. This conclusion is based on the hypothesis that since all factors which contribute to a good seedling stand; i.e. weed control; soil moisture relations; control of planting depth; and lack of crusting; were more favorable on the atrazine fallow, the only factor which could result in a negative plant response was atrazine residue in the soil.

Table 2. Frequency (%) of three wheatgrass species on seven sites in summer, 1969. Atrazine (1 lb./acre) was applied in fall, 1967 and grasses seeded in fall, 1968. Precipitation data (inches) are for the 1967-68 fallow year and the 1968-69 seedling year.

Location	Frequency ¹			Precipitation	
	Crested wheatgrass	Intermediate wheatgrass	Pubescent wheatgrass	1968-68	1968-69
Orovada	19a x	42b x	49b x	6.6	13.6
Paradise Hill	19a x	49b xy	53b xy	6.9	16.0
Italian Canyon	30a x	42a x	42a x	7.6	11.0
Trap Butte	34a xy	68b yz	52ab xy	7.0	14.5
Emigrant Pass	46a y	60b xy	81c z	9.8	19.8
Hallelujah Junction	50a yz	87c z	64b y	6.9	17.3
Medell Flat	60a z	72a z	78a z	7.0	9.2

¹ Means are compared among locations and species. Means followed by the same letter (a through c) in horizontal sequence or by the same letters (x through z) in vertical sequence are not significantly different at the .05 probability level as determined by Duncan's Range Test.

Seedling Density, 1969

Seedling density of crested, intermediate, and pubescent wheatgrasses was compared on atrazine and mechanical fallows at two locations and on atrazine fallow only at five locations.

At Orovada, intermediate wheatgrass responded similarly on both fallow treatments. Average seedling density on May 29 was 3.0 pfr on the atrazine fallow and 3.4 pfr on the mechanical fallow. Atrazine residue ranged from <0.04 to 0.10 ppm in the 0 to 1-inch sample, from 0.04 to 0.09 ppm in the 1 to 2-inch sample, from <0.04 to 0.08 ppm in the 2 to 3-inch sample, and from <0.04 to 0.06 ppm in the 3 to 4-inch sample. Below 4 inches residue was less than 0.04 ppm. Bioassay of these soil samples showed moderate to severe damage of intermediate wheatgrass seedlings at residue levels of 0.06, 0.08, and 0.10 ppm atrazine.

Intermediate wheatgrass density at Hallelujah Junction was also similar on the two fallow treatments. Average seedling density on June 4 was 3.8 pfr on the atrazine fallow and 4.6 pfr on the mechanical fallow. Atrazine residue ranged from 0.04 to 0.08 ppm in the 0 to 1-inch sample, and was 0.04 ppm or less below 1 inch. Damage to intermediate wheatgrass seedlings

in bioassay with 0.08 ppm atrazine residue was very slight. A bioassay was also carried out with soil from one replication where an accidental overspray occurred. Damage to intermediate wheatgrass seedlings was severe with 0.19 ppm, moderate with 0.10 ppm, and slight with 0.06 to 0.08 ppm. Under field conditions an excellent stand of intermediate wheatgrass was obtained on replications without an overspray and where maximum atrazine residue was 0.08 ppm; however, some seedling damage was noted. On the replication with an overspray, no wheatgrass seedlings survived and atrazine residues were: 0 to 1 inch—0.19 ppm; 1 to 2 inches—0.10 ppm; 2 to 3 inches—0.08 ppm; 3 to 4 inches—0.07; and below 4 inches—0.06 ppm.

Seedling density of the three wheatgrass species on the last sampling date on five sites with only an atrazine fallow were not significantly different. Average densities were: crested wheatgrass—2.6 pfr; intermediate wheatgrass—3.1 pfr; and pubescent wheatgrass—3.6 pfr. Atrazine residue ranged from <0.04 to 0.15 ppm in the 0 to 1-inch sample; from <0.04 to 0.09 ppm in the 1 to 2-inch sample; from <0.04 ppm to 0.08 ppm in the 2 to 3-inch sample; from <0.04 ppm to 0.06 ppm in the 3 to 4-inch sample;

and less than 0.04 ppm below 4 inches. Damage to intermediate wheatgrass seedlings grown in bioassay was slight, but moderate damage was noted under field conditions.

Wheatgrass seedlings showed symptoms of atrazine damage under field conditions in 1968 and 1969. Levels of atrazine residue in both years were in the toxic range for oats (0.04 ppm) and for wheat (0.13 ppm) as determined by Talbert and Fletchall (1964). Responses of the three wheatgrass species in the field and of intermediate wheatgrass in bioassay indicate that the toxic level for these species is near the 0.13 ppm reported for wheat. However, under field conditions, seedling damage without mortality was noted at residue levels of 0.04 to 0.08 ppm. The degree of damage to intermediate wheatgrass seedlings in bioassay was not always the same as under field conditions. In several instances, bioassay indicated no toxic level of atrazine residue, but damage occurred in the field. This kind of response suggests a strong interaction between herbicide residue and environmental factors.

Seedling Frequency, 1969

Response to atrazine at 1 lb./acre

Wheatgrass frequency on plots fallowed with 1 lb./acre atrazine, and precipitation data are given in Table 2. In general, intermediate and pubescent wheatgrasses produced better stands than did crested wheatgrass on five of seven sites. On two sites response of the three species was similar. While seedling density data showed no difference among species, frequency data indicated that the larger seeded species produced a more uniform stand than did crested wheatgrass. An average of seven locations showed the frequency of crested wheatgrass (37%) was significantly less than the frequency of intermediate or pubescent wheatgrasses (both 60%). Fair, good, and excellent stands of intermediate and pubescent wheatgrasses

were obtained on sites with poor, fair, and good stands, respectively, of crested wheatgrass. Acceptable stands of all species were obtained on all sites except for crested wheatgrass at Orovada and Paradise Hill. Success of the larger seeded species, intermediate and pubescent wheatgrasses, over crested wheatgrass may be due to germination at lower temperature (Young et al., 1968) and to greater seedling vigor and more rapid elongation of roots to depths without toxic amounts of atrazine residue. Residue data from plots treated with 1 lb./acre atrazine (Table 1) indicated no toxic level of atrazine below four inches and in most cases very low levels below two inches at the time when perennial species germinate and are in the seedling stage.

Response to atrazine at 0.5, 1.0, 1.5, and 2 lb./acre and to mechanical fallow

The response of three wheatgrass species was also evaluated at two locations on fallows created by 0.5 (A-0.5), 1.0 (A-1.0), 1.5 (A-1.5), and 2.0 (A-2) lb./acre atrazine or by mechanical means (MF).

At Hallelujah Junction (Table 3), the frequency of intermediate wheatgrass was higher than for the other species on the A-1.0, A-1.5, A-2.0, and MF treatments. All species had similar frequencies on the A-0.5 treatment. All species showed a loss in stand frequency between the MF and A-1 treatments; however, the loss was significant only for crested wheatgrass. On a rating basis, all species produced good to excellent stands on the A-0.5 and MF treatments. The stand of intermediate wheatgrass also rated excellent on the A-1.0 treatment while other species rated good. On the A-1.5 and A-2.0 treatment, intermediate wheatgrass rated good while the other two species rated poor to fair. Intermediate wheatgrass produced an acceptable stand on all treatments. Pubescent and crested wheatgrass produced acceptable stands on all but the A-2 treatment.

Table 3. Frequency¹ (%) of three wheatgrass species at two locations in the summer of 1969 on five fallow treatments. Atrazine (lb./acre) was applied in fall, 1967 and grass seeded in fall, 1968.

Location and wheatgrass species	Fallow treatment				
	Atrazine rate				Mechanical
	2.0	1.5	1.0	0.5	
Hallelujah Junction					
Crested	25 a x	40ab x	50 b x	61bc x	82 c x
Intermediate	57 a y	62 a y	87 b y	83 b x	94 b y
Pubescent	34 a x	47ab x	64bc x	75 c x	73bc x
Orovada					
Crested	2 a x	4 a x	19ab x	45bc x	59 c x
Intermediate	16 a x	33ab z	42ab y	60 b x	56 b x
Pubescent	20 a x	18 a y	49ab y	72 b x	79 b x

¹Means within location are compared among species and treatments. Means followed by the same letter (a through c) in horizontal sequence or by the same letter (x through z) in vertical sequence are not significantly different at the .05 probability level as determined by Duncan's Range Test.

At Orovada (Table 3) stand frequency of the three species was similar on the A-2.0, A-0.5, and MF treatments. Frequency of intermediate wheatgrass was greater than for the other two species on the A-1.5 treatment, while both intermediate and pubescent wheatgrass produced better stands on the A-1.0 treatment than did crested wheatgrass. The loss in stand from the MF to the A-1.0 treatment was significant for crested wheatgrass and resulted in a change from a good stand to a poor stand. The loss in stand of the other two species from the MF to the A-1.0 treatment was not significant; however, the stand rating of intermediate changed from good to fair while the stand of pubescent wheatgrass changed from excellent to fair. Crested wheatgrass produced an acceptable stand only on the A-0.5 and MF treatment. Both intermediate and pubescent wheatgrasses produced acceptable stands on the A-1.0, A-0.5, and MF treatments.

Results obtained from 1966 to 1969 showed a carryover of atrazine in the soil after a period of 1.5 years. Seedlings of perennial wheatgrasses were injured or killed by this residue; however, poor stands were obtained at only two locations with crested wheatgrass. Crested wheatgrass is the most com-

monly seeded species on rangelands in the 8 to 12-inch precipitation zone. Therefore, we should give special consideration to obtain the best possible stand of this species with the atrazine-fallow technique. Our objectives are maximum weed control and minimum herbicide residue. Frequency data indicated that atrazine at 0.5 lb./acre resulted in stands of all species equal to stands obtained by mechanical fallow. Weed control with 0.5 lb./acre atrazine has been equal to 1.0 lb./acre in many instances but results have been erratic.² We suggest techniques that could be used to increase weed control with 0.5 lb./acre atrazine. Through coordination of herbicide application and grazing management, all standing litter could be removed by livestock prior to spraying. Herbicide would fall on soil rather than be intercepted and possibly degraded on the litter or concentrated when washed onto the soil. Application of atrazine late in the fall on moist, cool soil prior to expected precipitation would reduce the loss of herbicide from the soil surface and insure movement of herbicide into the soil. These techniques need to be verified by research.

²Unpublished data, Agricultural Research Service, USDA, Reno, Nevada.

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