A Chemical-Fallow Technique for Control of Downy Brome and Establishment of Perennial Grasses on Rangeland[1]

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Highlight

Downy brome was controlled with three soil-active herbicides: atrazine, EPTC, and IPC. Seedings were made 1 year after herbicide application. If fallow were effective during this year, soil moisture was conserved. Seeding in deep furrows resulted in superior seedling stands and greater 2nd and 3rd year production than did surface drilling. Performance of Amur intermediate wheatgrass was superior to Standard crested and Topar pubescent wheatgrasses.

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Downy brome or cheatgrass (*Bromus tectorum* L.) is established on many acres of rangeland in the big sagebrush (*Artemisia tridentata* Nutt.) type. When brush is killed and dominance of perennial grasses is low, downy brome will fully occupy a site and form a closed community (Robertson and Pearse, 1945). Undesirable characteristics of this species include variable yield, short green-feed period, and a fire hazard when dry. Conversion of downy brome to perennial grass without weed control usually has been unsuccessful (Hull and Stewart, 1948). Competition by downy brome for soil moisture and perhaps for soil nitrates and light in seedling stands of perennial grasses contributes to these failures. Effects of weed control and method of seeding on stand density, survival, and production of seeded species in downy brome stands need to be evaluated.

This paper describes a chemical-fallow technique for control of downy brome and associated weeds with perennial grasses seeded 1 year after herbicide application. Chemical fallow was used by Alley and Chamberlain (1962), and Bovey and Fenster (1964), in wheat production studies. Robocker et al. (1965), used chemical fallow in range seeding studies without success.

Chemical fallow is effective if: (1) after fall application, the herbicide remains active in the soil to control weed species in late winter or early spring, and (2) at the time seeded species germinate (usually 1.5 years after treatment) the herbicide has either broken down or leached or both, and toxicity to perennial seedlings is minimized. A desirable herbicide should control a broad spectrum of weeds and dissipate rapidly after weed control is accomplished.

Procedures

Investigations were initiated at one location in 1959 and at three locations in 1962. Characteristics of the four study sites are given in Table 1.

Two soil-active herbicides were

Table 1. Characteristics of the four study sites.

	Hallelujah Junction						Paradise Hill			Italian Canyon			Emigrant Pass		
	59-60	60-61	61-62	62-63	63-64	64-65	62-63	63-64	64-65	62-63	63-64	64-65	62-63	63-64	64-65
Precip. (in.)															
Annual	5.0	7.2	9.4	17.1	6.1	11.8	12.4	9.8	11.7	12.4	10.5	11.6	13.4	15.7	15.9
Oct.-May	5.0	3.9	7.6	15.5	5.5	6.6	8.8	8.3	9.8	8.2	6.6	7.9	8.4	12.9	13.1
Mar.-May	1.1	0.9	2.3	4.5	3.0	1.4	4.7	3.1	2.0	5.6	3.2	5.0	5.2	4.5	6.9
Description															
Location	N. Eastern Calif.						N. Central Nev.			Central Nev.			N. Eastern Nev.		
Soil classification[1]	Typic Argiustoll						Duric Mollic Haplargid						Entic Haplic Durustoll		
Soil depth (in.)	60						60			60			24		
Cause of downy brome dominance	Brushbeat and disc in 1959						Wildfire in 1940			Reseeding failure in 1960			Wildfire in 1956		
Broadleaf species	None						Tumble mustard			Russian thistle			Tumble mustard and annual borage		

[1] U. S. Department of Agriculture, 1960.

applied in December, 1959 at Hallelujah Junction. A 5% granular formulation of ethyl N,N-dipropylthiolcarbamate (EPTC) at rates of 1, 2, and 4 lb/acre was mixed with sand, hand sprinkled, and incorporated into the surface soil by raking. A 75% wettable powder of isopropyl N-phenylcarbamate (IPC) was applied at rates of 5 and 10 lb/acre in water at 32 gpa and 30 psi. Herbicides were applied preemergence to downy brome. Treatments were seeded in the fall of 1960, one year after herbicide application. Herbicide plot size was 20 by 20 ft. Experimental design was a four-replicated split-split-plot with herbicides the whole plot and methods of seeding and species the subplots.

Gypsum soil-moisture units were installed in the herbicide and check treatments. These units were placed at depths of 3, 12, 21, and 48 inches corresponding to the A_1, B_1, B_2, and C horizons. Weekly readings were made during the spring and summer of 1960 and 1961. Less frequent readings were taken at other times.

In the fall of 1962, 80% wettable powder of 2-chloro-4-ethylamino-6-isopropylamino-*s*-triazine (atrazine) was applied at 1 lb/acre in water at 26.4 gpa and 30 psi on the Emigrant Pass, Italian Canyon, and Paradise Hill study sites. Atrazine was applied preemergence or early postemergence to downy brome. Treatment plots were 24 x 100 ft. Each species and method-of-seeding treatment was replicated four times. Weed control and check treatments were analyzed as separate experiments. then combined and analyzed as a series of experiments (Cochran and Cox, 1957). Soil moisture in the check and atrazine treatments was determined by gypsum soil-moisture units buried at 3, 12, and 24 inches and at one location, 36 inches.

In the studies at Hallelujah Junction, Standard crested (*Agropyron desertorum* (Fisch.) Schult.), Amur intermediate (*A. intermedium* (Host) Beauv.) and Topar pubescent (*A. trichophorum* (Link) Richt.) wheatgrasses were evaluated. At the other locations Standard crested and Amur intermediate wheatgrasses were evaluated.

In all studies, two methods of seeding were used: drill into the surface soil and drill in the bottom of deep furrows. For brevity, these two methods will be termed surface and furrow, respectively. Furrows were made immediately before seeding. After settling over winter, they were approximately 5 inches deep, 5 inches wide at the bottom, and 10 inches wide at the top. Seeding depth was 0.5 to 0.75 inch for crested wheatgrass and 0.75 to 1 inch for intermediate and pubescent wheatgrasses. Seeding rate for all studies was two live, pure seeds per inch of row.

During the study an individual seeded plot varied from three to four rows wide and from 10 to 25 ft long. In 1960, row spacing was 12 inches. In 1963, spacing was increased to 18 inches to facilitate use of tractor-drawn furrowing and seeding equipment.

Downy brome control was evaluated by plant density, yield, or both, during the fallow year and during the seedling year of perennial species. Performance of seeded species was evaluated by plant density, height, and 1st-year survival during the seedling year; and by frequency of occurrence per linear foot of row, and yield in the 2nd and subsequent years. In the results, statistical significance is reported as $P < .05$.

Results

Hallelujah Junction

Fallow year - 1960.—The check and 1 and 2 lb/acre of EPTC gave similar responses. Results from EPTC at 4 lb/acre and from IPC at 5 and 10 lb/acre were also similar. Therefore, data from the check and from IPC at 10 lb/acre are compared in Table 2, as representative of each group.

A significant decrease in downy brome density due to treatment (Table 2) reduced soil moisture extraction during the fallow year. Soil moisture tension at the 12-inch depth on the check was below 1 bar until the last of May. By October, tensions increased to about 6 bars. During the same period, moisture tension on plots treated with IPC remained below 3 bars. At the 21-inch depth, moisture tension on the check was below 1 bar until the middle of July, then increased to a maximum of 5.5 bars by October. On treated plots tensions did not exceed 1 bar at

Table 2. Density of downy brome and seeded species during fallow and seedling years, and yield of perennial grasses for 4 years after establishment at Hallelujah Junction. Herbicide applied in the fall of 1959 and perennial grasses seeded in the fall of 1960.

Treatment	Density				Production — lb/acre			
	Plants/sq ft Downy brome		Plants/ft of row — 1961					
	1960	1961			1962	1963	1964	1965
			Intermediate wheatgrass					
Check	13.7	6.3	1.3	Surface Drill	634	424	106	454
			2.0	Furrow Drill	840	1128	189	778
			Pubescent wheatgrass					
			0.3	Surface Drill	274	354	148	324
			1.7	Furrow Drill	455	509	261	546
			Crested wheatgrass					
			0.2	Surface Drill	236	351	85	157
			0.8	Furrow Drill	443	657	109	201
			Intermediate wheatgrass					
IPC-10 1b/A	0.05	0.5	0.8	Surface Drill	1234	1097	161	673
			2.5	Furrow Drill	1283	1130	139	768
			Pubescent wheatgrass					
			0.4	Surface Drill	182	378	141	524
			1.4	Furrow Drill	1201	448	152	720
			Crested wheatgrass					
			0.2	Surface Drill	176	302	90	163
			0.4	Furrow Drill	740	674	73	180

the 21-inch depth. The soil profile was not wet to 48 inches during 1960 or 1961.

Seedling year of perennial grasses - 1961.—A significant reduction in downy brome competition in 1961 (Table 2) increased soil moisture available to perennial seedlings. Soil moisture at the 3-inch depth fluctuated with wet and dry periods. At the 12-inch depth, moisture tension on the check was 4 bars in April and increased rapidly to 13 bars by the first of May and to 15 bars by the end of May. On the treated plots, tension was below 1 bar until the middle of June, 11 bars by the end of June, and above 15 bars by the middle of July. Soil moisture at the 21-inch depth followed a similar trend, however, the time of peak extraction was about 2 weeks later than at the 12-inch depth. In addition, maximum tension was 12 bars on check plots and 6 bars on treated plots.

Reduced downy brome competition and more favorable soil moisture conditions on treated plots did not result in a significant increase in seedling density of perennial grasses in 1961 (Table 2). Three factors may have contributed to the lack of response: (1) downy brome density of 6.3 plants per ft^2 on the check was not extremely competitive; (2) residual herbicide may have killed some seedlings on the treated plots; and (3) approximately 2 inches of precipitation fell during the first few days of June when perennial seedlings on the check were under severe moisture stress. Following this precipitation, soil moisture tension at the 3-inch depth remained below 1 bar for at least 1 week and below 15 bars for about 2 weeks. A slight change in tension at the 12-inch depth indicated that moisture percolated almost to 12 inches.

In contrast to herbicide treatment, species and methods of seeding did result in significant variation in density and height of seedlings. For all treatments, average seedling density per foot of row was: intermediate wheatgrass—1.7; pubescent wheatgrass—1.1; and crested wheatgrass—0.3. Seeding in furrows resulted in about twice as many, and also in more vigorous seedlings than did surface seeding (1.3 plants 15.3 inches high and 0.7 plants 10.9 inches high, respectively).

Production in second and subsequent years after seeding.—Although use of herbicides did not result in more seedlings, field observations indicated that seedlings in treated plots were more vigorous than in the check. Second-year production in 1962 supported this observation (Table 2). Treated plots produced significantly more herbage than did the check. Average production of intermediate and crested wheatgrasses on treated plots was 1,258 and 458 lb/acre, respectively. On the check, respective yields were 737 and 340 lb/acre. Pubscent wheatgrass was intermediate in response. Intermediate wheatgrass produced more than did the other two species in all years except 1964.

The effect of furrows on productivity was evident in 1962 and 1963 (Table 2). In 1962, a comparison of species seeded in furrows and on the surface showed: intermediate wheat-

grass 1,062 and 934 lb/acre; pubescent wheatgrass 828 and 228 lb/acre; and crested wheatgrass 592 and 225 lb/acre, respectively. All species-seeding method comparisons, except for intermediate wheatgrass, were significantly different. In 1963, all combinations of species and methods of seeding except intermediate and pubescent wheatgrasses in the IPC treatment produced significantly more in furrows than by surface seeding. A gradual soil sloughing and filling of furrows may explain the lack of response after 1963.

Production in 1963, 1964, and 1965 showed no relation to original herbicide treatment (Table 2). In the very wet year of 1962-63, production on the check increased to the production level of the treated plots. In 1964, production of all species was low. Low total precipitation in 1963-64, together with heavy precipitation in March, April, and May of 1964, reduced growth of perennial species by increasing growth and competitive ability of downy brome. Production increased again in 1965 because total precipitation was adequate for growth of perennial species, and light spring precipitation resulted in a poor stand of downy brome.

The work at Hallelujah Junction in 1960 and 1961 was conducted during years of below normal precipitation and weak downy brome competition. With little competition, a thorough evaluation of herbicide effect on weed control, seedling establishment, and subsequent production was not possible. However, we were able to: (1) measure a fallow effect from soil-active herbicides; (2) evaluate the effectiveness of furrows on seedling establishment and subsequent production, and (3) increase our knowledge of species performance. Results from these studies formed a background from which to evaluate similar treatments and species under different climatic and edaphic conditions.

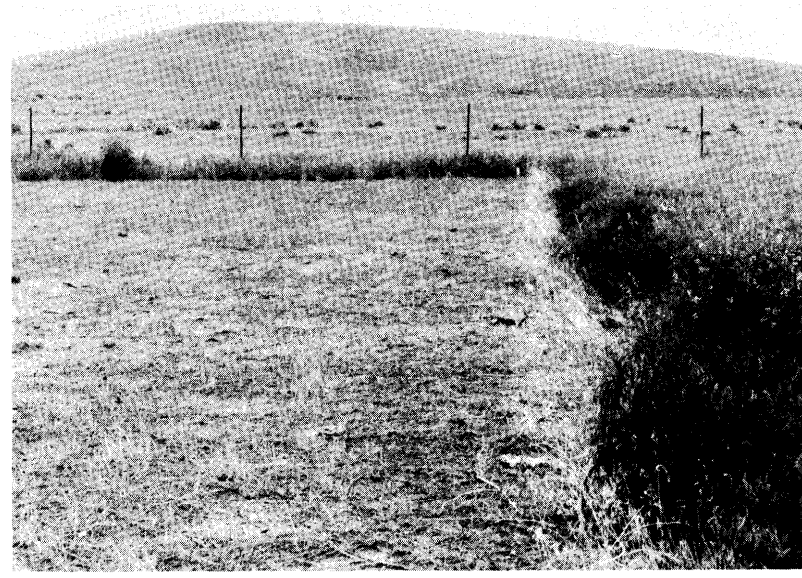

FIG. 1. An effective chemical fallow at Paradise Hill in 1963, created by atrazine at 1 lb/acre applied in the fall of 1962.

Paradise Hill, Italian Canyon, and Emigrant Pass

Fallow year - 1963.—At Paradise Hill, an effective chemical fallow was obtained in 1963 from atrazine applied at 1 lb/acre in the fall of 1962. Downy brome and tumble mustard (*Sisymbrium altissimum* L.) production on the check were 1646 and 106 lb/acre, respectively. On the fallow plots, these two species were virtually eliminated for 1 year (Fig. 1), and soil moisture was conserved. On the check, soil moisture tensions at the 12 and 24-inch depth were above 15 bars by June 1. On the fallow plots, soil moisture tensions at the same depths did not exceed 0.7 bar through October.

No fallow was obtained at Italian Canyon. Downy brome was reduced from 1,421 lb/acre on the check to 202 lb/acre with atrazine, however, Russian thistle (*Salsola kali* var. *tenuifolia* Tausch.) was not controlled. Production by this summer annual on the check was 86 lb/acre as compared to 690 lb/acre on the atrazine treatment. On the check treatment with a dense cover of downy brome, soil moisture tensions at the 12 and 24-inch depths were above 15 bars by July 1. On the atrazine treatment, with a dense cover of Russian thistle, soil moisture tensions reached 15 bars by August 1.

A fallow was obtained at Emigrant Pass. Downy brome and mustard production on the check plots was 1,421 and 192 lb/acre, respectively. On the fallow, production of downy brome was reduced to 307 lb/acre with no mustard. By October, soil moisture tensions at 12, 24, and 36 inches on the check reached a maximum of between 4 and 10 bars. On the fallow, maximum tensions were between 0.6 and 1 bar.

Seedling year of perennial grasses - 1964.—A second-year effect from chemical fallow in terms of soil moisture conservation was evident only at Paradise Hill. On the check, soil moisture tensions at 12 and 24 inches reached 15 bars between May 1 and June 1. Moisture tensions on the treated plots did not exceed 1.7 bars by July 1. Mustard, which was absent on the check produced 1,536 lb/acre on the

Table 3. Weed yield and density of seeded species during seedling year, 1964. Percent frequency (frequency in seeded rows) and yield of seeded species in 1965. Atrazine was applied in the fall of 1962 and plots seeded in the fall of 1963.

Location Weed control and seeding treatment	Weed yield 1964 lb/acre Downy-brome	Weed yield 1964 lb/acre Broadleaf	Intermediate wheatgrass 1964 Seedlings No./ft of row	Intermediate wheatgrass 1965 Percent frequency	Intermediate wheatgrass 1965 Yield lb/acre	Crested wheatgrass 1964 Seedlings No./ft of row	Crested wheatgrass 1965 Percent frequency	Crested wheatgrass 1965 Yield lb/acre
Paradise Hill								
Atrazine								
Surface drill—mustard control	307	325	1.5	95	692	0.3	20	92
Surface drill—no mustard control	336	1536	0.7	35	106	0.1	25	50
Furrow drill	24		2.0	90	1341	2.5	88	744
Check								
Surface drill	614		0.2	0	0	0.0	0	0
Furrow drill	998		3.2	80	369	1.0	62	95
Italian Canyon								
Atrazine								
Surface drill	490		0.0	0	0	0.0	0	0
Furrow drill—								
Russian thistle control	121	0	4.0	95	1084	2.0	70	422
Furrow drill—								
no Russian thistle control	47	718	2.1	45	28	0.3	45	272
Check								
Surface drill	384		0.1	0	0	0.1	0	0
Furrow drill	624		4.1	85	234	1.4	63	54
Emigrant Pass								
Atrazine								
Surface drill—no borage control	979	624	0.1	5	14	0.2	0	0
Furrow drill—no borage control	2093	432	0.2	25	65	0.4	13	24
Check								
Surface drill	2592	60	0.2	8	2	0.1	5	1
Furrow drill	1430	240	0.5	18	2	0.3	0	1

atrazine fallow. Use of furrows in the atrazine treatment further reduced downy brome from 336 to 24 lb/acre and eliminated mustard. Mustard appeared to be a potentially strong competitor on the atrazine surface-drill treatment. It was controlled with propylene glycol butyl ether esters of 2,4-D at 1 lb/acre applied in water at 10 gpa and 30 psi on May 20, 1963. With broadleaf control, an average of 0.8 more seedlings per foot of row of intermediate wheatgrass and 0.2 seedlings of crested wheatgrass survived the summer. Seedling density of perennial grasses was similar on the atrazine and check treatments (Table 3). Low seedling density on the atrazine treatment was attributed to some residual herbicide toxicity. In the atrazine treatment, seedling density of the two seeded species was similar, however, in the check seeding density of intermediate wheatgrass was significantly greater than crested wheatgrass. Seedling density of both species was also significantly greater in furrows than in surface seeding. In the check, intermediate wheatgrass benefited more from furrows than did crested wheatgrass. Survival on the atrazine and check were 64 and 36%, respectively. Survival in furrows was 64% compared to 14% by surface seeding. Survival of intermediate and crested wheatgrasses was 42 and 36%, respectively. Control of mustard in the atrazine surface-drill treatment increased survival of intermediate wheatgrass from 29 to 75%; of crested wheatgrass from 17 to 33%.

At Italian Canyon, downy brome averaged 490 lb/acre on the check during the seedling year. In the atrazine treatment, furrows significantly reduced downy brome competition from 490 to 47 lb/acre. However, Russian thistle, which was absent in the surface-drill plots, produced 718 lb/acre in furrows. Russian thistle, a potentially strong competitor in the atrazine-furrow treatment, was controlled with 2,4-D at 1 lb/acre applied on June 1, 1963. With broadleaf control, an average of 1.9 more seedlings of intermediate wheatgrass and 1.7 more seedlings of crested wheatgrass survived the summer. Seedling density was similar on the check and atrazine treatments. In the atrazine treatment, seedling density of seeded species was similar, but on the check, density of intermediate wheatgrass was significantly

greater than for crested wheatgrass. In both treatments, seedling density was significantly higher in furrows than when surface drilled. In the check, furrows were more beneficial to intermediate wheatgrass than to crested wheatgrass. First-year survival was 75 and 69%, respectively, on the atrazine and check treatments. Furrows resulted in 58% survival, while 32% of the plants survived in the surface-drill treatment. Survival of both intermediate and crested wheatgrasses was 34%. Control of Russian thistle in the atrazine-furrow treatment increased survival of intermediate wheatgrass from 44 to 79%, and of crested wheatgrass from 50 to 100%.

At Emigrant Pass, average downy brome production during the seedling year on the atrazine treatment was 979 lb/acre as compared to 2,592 lb/acre on the check. Here, as at the other two locations, a decrease in downy brome was accompanied by an increase in competition from annual broadleaf species. An annual borage produced more on the atrazine treatment than on the check and resulted in extreme competition from 1603 lb/acre of annual weeds. In contrast to the other two locations, use of furrows in the atrazine treatment resulted in a doubling of the cheatgrass competition from 979 to 2,093 lb/acre. Severe competition from downy brome and broadleaf weeds on the atrazine and check treatments resulted in poor seedling stands of both species. Average survival for the atrazine and check treatments was 22 and 11%, respectively. Survival in furrows was 29% compared to 9% when surface seeded. Survival of intermediate and crested wheatgrasses was 12 and 25%, respectively. Because of this seeding failure, results from Emigrant Pass will not be discussed further.

Seedling heights taken in August generally were indicative of treatment effectivenesss. When downy brome was controlled, average plant height was 10.1 inches, compared to 4.9 inches on the check. Control of broadleaf species did not increase plant height. Seedling heights in furrows averaged 8.0 inches compared with 6.2 inches in the surface-drill treatment.

Second year after seeding.— High-density stands were found in the weed control and furrow treatments (Table 3). In comparable treatments, frequencies of intermediate wheatgrass were higher than for crested wheatgrass. Use of furrows in the check treatment was especially beneficial for establishment of perennial grasses under very competitive conditions.

Seedling density and 2nd-year frequency indicate only the relative abundance of perennial species among treatments and locations. Second-year yield, however, indicates the effectiveness of a treatment to alter the environment and to increase site productivity.

At Paradise Hill, in the atrazine treatment, intermediate wheatgrass produced 1,341 lb/acre in furrows compared with 106 lb/acre when surface seeded (Table 3). Production of crested wheatgrass increased from 50 lb/acre on the surface plots to 744 lb/acre in furrows. Greater production in furrows can be attributed to less competition from downy brome and mustard, to better moisture relations, and, in some instances, to a greater density of perennials than on the surface-drill plots. Production of intermediate wheatgrass on surface-drill plots was increased from 106 to 692 lb/acre with mustard control. Crested wheatgrass did not respond to mustard control. Neither species produced any herbage on the check surface-drill treatment. Comparative yield in the check-furrow treatment was intermediate wheatgrass 369 lb/acre and crested wheatgrass 95 lb/acre.

At Italian Canyon, as at Paradise Hill, the atrazine treatment also increased productivity. However, success was dependent upon the use of furrows and broadleaf weed control. With furrows and Russian thistle control, intermediate wheatgrass produced 1,084 lb/acre while crested wheatgrass produced 422 lb/acre. Corresponding yield without broadleaf control was 28 and 272 lb/acre, respectively. Neither species produced a stand on the atrazine surface-drill or check surface-drill treatments. In the check-furrow treatment, yields of intermediate and crested wheatgrasses were 234 and 54 lb/acre, respectively.

Discussion

Benefits from an effective chemical fallow are twofold: (1) weed seed production is reduced or eliminated, and (2) soil moisture and perhaps soil nitrates are conserved.

The disadvantages of atrazine for weed control and chemical fallow are related to: (1) spectrum of weed control; (2) competition during the seedling year from uncontrolled grass and broadleaf species; and (3) residual toxicity.

The most competitive weed species encountered in this study were downy brome, mustard, an annual borage, and Russian thistle. Atrazine gave excellent control of the first three during the fallow year. In application of a fallow technique, the control spectrum of the herbicide should coincide with the weed species present. Control of annual grass is of primary importance, since most broadleaf species can be controlled with 2,4-D.

Although a fallow condition is maintained, seeds of grass and broadleaf weed species may germinate during the seedling year and offer severe competition to perennials. A dense stand of

downy brome in the atrazine treatment during the seedling year at Emigrant Pass resulted in a seeding failure. Residual seed in the soil and litter appears to be the source for downy brome reestablishment. The tumbling nature of mustard and Russian thistle suggest that the major reinvasion of these species was due to wind movement.

Atrazine at 1 lb/acre has not shown any selectivity between downy brome and seeded species. Therefore, under our conditions a 1-year waiting period between herbicide application and seeding is required. By this procedure degradation and leaching of atrazine in the soil was sufficient to prevent serious damage to perennial species during germination in the spring. A residual effect of atrazine is perhaps the most serious problem in use of this material since complete seeding failure may result. Before atrazine or any other soil-active herbicide can be recommended for a chemical fallow on rangeland, more information is needed on herbicide residues in the 8 to 12-inch precipitation zone.

Regardless of weed control or species seeded, drilling in furrows most always resulted in superior seedling stands and higher 2nd and 3rd year production when compared to drilling in the surface soil. Improved seedling stands in furrows can be attributed to better soil moisture relations and protected microenvironment (McGinnies, 1959).

Use of furrows in a chemical fallow may have additional values: (1) remove weed seeds from a band next to the seeded row and cover weed seeds adjacent to the furrows to a depth from which emergence is greatly reduced; and (2) remove soil with herbicide residue from the vicinity of the seeded row.

For the duration of the studies, Amur intermediate wheatgrass was superior to Standard crested wheatgrass. Superiority was in density of seedling stands and production in most treatments. Intermediate and pubescent wheatgrasses also have the ability to spread by rhizomes. Five-year-old plants of these two species at Hallelujah Junction have spread to occupy most of their individual plots. Two-year-old plants at Paradise Hill have started to spread vegetatively, particularly into the open spaces in the furrows. Where evaluated, Topar pubescent wheatgrass was inferior to intermediate wheatgrass, but superior to crested wheatgrass. The relative merits of crested, intermediate and pubescent wheatgrasses in a seeding program can be evaluated only over a period of environmental variation and under grazing management.

Conclusions

1. Atrazine applied at 1 lb/acre in the fall shows promise for chemical fallow and downy brome control followed by seeding perennial grasses 1 year after treatment.

2. Residual herbicide in the soil may be a potential problem in the use of soil-active materials for chemical fallow.

3. Control of broadleaf-weed species may be necessary to maintain a fallow.

4. Control of broadleaf-weed species in seedling stands was necessary for survival and for high productivity of perennial species.

5. With or without weed control, seeding in furrows resulted in superior seedling stands and higher production of perennial grasses than did drilling in the surface soil.

6. In most treatments, seedling stands and forage production of Amur intermediate wheatgrass were superior to Standard crested and Topar pubescent wheatgrasses.

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