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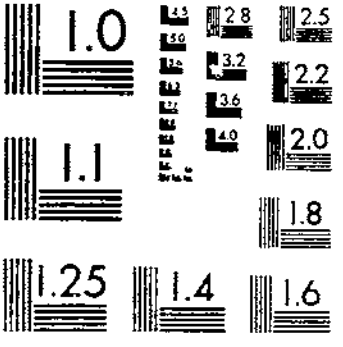
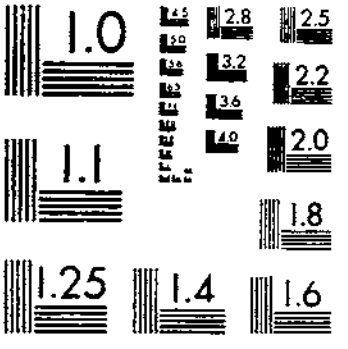


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



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Effect of Annual Applications of DIURON on SEED YIELDS of PERENNIAL GRASSES in Oregon

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Agricultural Research Service
UNITED STATES DEPARTMENT OF AGRICULTURE
in cooperation with
Oregon Agricultural Experiment Station

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EFFECT OF ANNUAL APPLICATIONS OF DIURON ON SEED YIELDS OF PERENNIAL GRASSES IN OREGON

By WILLIAM O. LEE, *research agronomist, Crops Research Division, Agricultural Research Service*

INTRODUCTION

Western Oregon is one of the major grass-seed producing areas of the United States (table 1). The climate, designated as a mild, subcoastal type characterized by moist, open winters, cool dry summers, and a long growing season is especially well suited to the production of high quality seed of many of the important cool season grass species.

The same climatic conditions that favor grass seed production also favor the growth and development of a wide array of winter annual grass and broadleaf weeds. Weeds that are especially troublesome in perennial grass seed crops include annual ryegrass (*Lolium multiflorum* Lam.), annual bluegrass (*Poa annua* L.), rattail fescue (*Festuca myuros* L.), soft chess, hairy chess, and ripgut brome (*Bromus* spp.), and dogfennel (*Anthemis cotula* L.). If not controlled, these weeds compete with the seed crops, cause drastic reductions in seed yield, and produce seeds that are difficult and sometimes impossible to remove from the crop seeds. Profitable seed production in western Oregon is dependent on satisfactory weed control.

TABLE 1.—*Comparison of Oregon's grass seed production with that of the entire United States, 1964*

Crop	Seed production		Percentage of United States production grown in Oregon
	Oregon	United States	
	Acres	*Acres*	
Chewings fescue	16,000	16,000	100
Creeping red fescue	8,500	8,600	99
Ryegrass:			
Annual and perennial	143,000	143,000	100
Bentgrass	26,000	26,600	98
Merion bluegrass	4,300	11,300	38
Other Kentucky bluegrass	9,000		
Orchardgrass	4,000	48,000	8
Alta tall fescue	10,500		6

Weed control by mechanical or hand methods is very difficult. The winter annual weeds germinate when the fall rains begin, grow during the wet winter months, and mature seed early in the spring. Cultivation during this period merely transplants the weeds. If hand labor is used, the weeds must be gathered up and hauled from the field to prevent re-establishment. A few specialty grass crops for which herbicidal methods of weed control have not been developed have been raised in western Oregon. Costs for hand labor to control weeds in these crops have ranged from about $200 to $1,200 per acre. Few grass seed crops can be raised profitably with such expenses.

For these reasons considerable emphasis has been placed on the development of chemical methods of weed control that will selectively remove winter annual weeds from grass seed crops without interfering with grass seed yields or with seed quality.

Much of the early work conducted in western Oregon on selective weed control in grass seed crops was done by Freed, Warren, and Leach, who reported in 1951 (*4*) [1] that 2,4-dichlorophenoxyacetic acid (2,4–D), 2, 4, 5–trichlorophenoxyacetic acid (2, 4, 5–T), and the alkanolamine salt of dinitro-*o*-*sec*-butylphenol (DNBP) could be used in grass seed crops for selective control of broadleaf weeds. At that time Freed and Bierman reported (*3*) that isopropyl *N*-phenylcarbamate (IPC) showed promise for control of winter annual grasses in established perennial grasses. In 1952, Freed, Bayer, and Furtick (*2*) published results comparing the application of isopropyl *N*-phenylcarbamate (IPC) and isopropyl *N*-(3-chlorophenyl) carbamate (CIPC) to Alta tall fescue, Chewings fescue, and creeping red fescue for selective grass control. They reported that both IPC and CIPC could be used to control annual grass weeds in perennial grass seed crops if certain precautions were followed.

In an experiment near Corvallis, Oregon in 1954, Furtick and Chilcote (*6*) found that under western Oregon conditions, 3-(3,4-dichlorophenyl)-1,1-dimethylurea (diuron) could be used to selectively remove both annual grasses and broadleaf weeds from established stands of Rainier creeping red fescue, Alta tall fescue, and Merion bluegrass without excessive crop injury. In 1956 these workers (*5*) reported that diuron also showed promise for winter annual weed control in seedling-year stands of creeping red fescue, Alta tall fescue, and Merion bluegrass.

In the early 1950's IPC and CIPC were recommended by the Oregon Agricultural Experiment Station for control of grass weeds in perennial grass seed fields. In 1956, diuron was recommended by this station for control of both annual grass and broadleaf weeds in certain grass seed crops. However, in addition to the crops on which diuron was recommended in 1956, there were several major grass species and numerous

[1] Italic numbers in parentheses refer to Literature Cited, p. 22.

varieties of species being grown in western Oregon on which diuron had never been tested. The application of diuron to grass breeding nurseries at Oregon State University showed that certain grasses exhibited varietal differences in tolerance to diuron. Thus, it was felt that additional work was needed before recommendations for use of diuron could be extended to include those species and varieties that had never been subjected to treatment with diruon.

The first part of this report consists of a description and evaluation of six experiments initiated at Corvallis, Oregon in 1957 to provide additional information on the tolerance of grass species and varieties to diuron. The objectives of these initial experiments were as follows:

1. To determine the relative tolerance of six major perennial grass species grown in western Oregon to diuron.

2. To determine whether or not different varieties of a given grass species differ in their tolerance to diuron.

3. To compare several rates of applying diuron on each species and each variety to establish tolerance limits within which weeds would be controlled but seed yields and quality would not be affected.

4. To determine whether or not several annual applications of diuron result in herbicide accumulations in the soil that may ultimately reach levels that are toxic to the grass plants.

The second part of this report consists of a description and evaluation of three additional studies conducted on soil samples from certain treated plots of the original six experiments. The purpose of these secondary tests was to determine whether or not several annual applications of diuron result in herbicide accumulations in the soil that are toxic to crop species that follow grass-seed crops in the rotation.

TOLERANCE STUDY

Materials and Methods

The six experiments included in the tolerance study were conducted at the Hyslop Agronomy Farm, about 5 miles northeast of Corvallis, Oregon. Soil and climatic conditions at this location are similar to conditions under which much of the grass seed is produced in western Oregon. The soils are not typical for perennial ryegrass, which is generally grown on heavier, poorly drained soil. The soil at this location is classified as a Willamette silt loam. Average annual precipitation is about 38 inches per year, most of it falling as rain during the period from October through April. Little rainfall occurs during the summer months.

Grasses used in these experiments were planted during May, 1957. The species and varieties were as follows:

Experiment 1—perennial ryegrass (*Lolium perenne* L.): Oregon perennial, S–23, and H–1. The H–1 is a long-lived annual variety rather than a true perennial.

Experiment 2—colonial bentgrass (*Agrostis tenuis* Sibth.): Highland and Astoria; creeping bentgrass (*Agrostis palustris* Huds): Penncross and Seaside.

Experiment 3—fescues: creeping red (*Festuca rubra* L.)—Pennlawn and Rainier; Chewings (*Festuca rubra* var. *commutata* Gaud.).

Experiment 4—tall fescue (*Festuca arundinacea* Schreb.): Alta, Goar, K–31, Ky–59gl–32, and New Zealand.

Experiment 5—Kentucky bluegrass (*Poa pratensis* L.): Merion, Common Kentucky, Delta, Park (95), Newport, Washington State strain (not released), and Troy.

Experiment 6—orchardgrass (*Dactylis glomerata* L.): Akaroa, Potomac, Danish commercial, S–37, domestic commercial, Latar, and S–143.

The ryegrass and bentgrass varieties were seeded in rows 6 inches apart and the other grasses were seeded in rows 36 inches apart. During the summers of 1957 and 1958 while the grasses were becoming established, weeds were controlled by cultivation between the 36-inch rows, by 2,4–D sprays, and by hand labor.

A split plot design was used for these experiments. For the creeping red fescue, tall fescue, orchardgrass, and bluegrass varieties, each main plot was 17 feet by 36 feet and included twelve rows of a single variety. Each main plot was divided into four subplots, each of which was 9 feet by 17 feet and included three rows of grass 17 feet long. For the ryegrass and bentgrass varieties, each main plot was 17 feet by 24 feet and each subplot was 6 feet by 17 feet and included 12 rows of grass. In all experiments each treatment was replicated four times.

Diuron was applied to each subplot at rates of 0, 2, 3, or 4 pounds per acre of active ingredient each year for 3 to 5 consecutive years. The 2-, 3-, and 4-pound rates of application are high enough to control most winter annual weeds in western Oregon. The treatments were started October 20, 1958, and subsequent applications were made each year between the 16th and 24th of October. Applications were made in 40 gallons of water per acre.

Beginning in July 1959 and continuing for the duration of the experiments, the center row of each subplot of grasses planted in 36-inch rows or a strip 39 inches wide in grasses planted in 6-inch widths was harvested as a seed-yield sample. The yield samples were bagged, dried, and threshed in a small plot thresher. The seed was cleaned with commercial cleaning equipment specially adapted for cleaning small lots of seed.

After harvest, most of the crop residue was removed from the plot areas with a flail-type forage harvester. The areas were then burned with a commercial propane weed burner to consume any crop residue left by the forage chopper and thereby control diseases.

Each September, before start of the fall rains, a tractor-mounted rotary tiller was run between the rows on all grasses planted in 36-inch rows. The tiller worked a strip 18 inches wide to a depth of about 2 inches. This tillage was to maintain the grasses in rows to facilitate treatment and harvest.

Results and Discussion

Perennial Ryegrass Varieties

The influence of three annual applications of diuron on the seed yields of several perennial ryegrass varieties is shown in table 2. The three ryegrass varieties compared in this experiment showed marked differences in their response to diuron. S–23 ryegrass showed considerable tolerance to diuron. The average seed yield of this variety for the three years in which yield determinations were made did not differ significantly from that of the untreated check at any rate of application. At the 2- and 3-pound rates, yields were somewhat higher than that of the untreated check although not significantly higher at the 5-percent level of probability. At the 4-pound rate rather severe injury and loss of stand occurred after the third treatment. Figures 1 and 2 show the differential response of H–1 and S–23 ryegrass varieties to diuron.

FIGURE 1.—Effect of one 1-pound-per-acre diuron application (Oct. 1958) on growth of perennial ryegrass varieties—April 1959 growth of H–1 ryegrass (left) and S–23 ryegrass (right).

FIGURE 2. Effect of one diuron application Oct. 1958 on growth of perennial ryegrass varieties (April 1959 growth shown). Foreground: H-1 ryegrass; left, 3 pounds per acre diuron; right, 4 pounds per acre diuron. Background: S-23 ryegrass; left, 3 pounds per acre diuron; right, untreated check.

Oregon perennial ryegrass and H-1 ryegrass were injured much more seriously by diuron than was S-23 ryegrass. With few exceptions, seed yields were lower, at all rates of application, than the yield of the untreated check. When the 3-year average yields of these two varieties are considered, diuron at all rates of application caused significant reductions in seed yield as compared to the untreated check.

A fourth diuron application was made in the fall of 1961. After this application, Oregon perennial ryegrass and H-1 ryegrass were eliminated from all treated plots and S-23 ryegrass was eliminated with the 4-pound rate of application. At the 2- and 3-pound rates of application, S-23 ryegrass also showed much more injury from the 1961 treatment than had appeared in earlier years. Injury that occurred following the fourth application of diuron may indicate an accumulation of diuron at toxic levels in the soil. In the summer of 1962, seed yields were not measured since the untreated checks were the only plots which produced seed in quantities sufficient to harvest. For this reason, the experiment was discontinued at this time.

These results indicate that while S-23 ryegrass showed considerable tolerance to diuron, the other varieties were severely injured. The possibility of damage to sensitive varieties and the limited safety margin on S-23 indicates a high degree of hazard in using diuron on perennial ryegrass.

TABLE 2.—*Perennial ryegrass seed yields after annual treatments with diuron at several rates*

Variety	Diuron application [1]	Seed yields in			Average seed yields, 1959–61
		1959	1960	1961	
	Lb./acre	*Lb./acre*	*Lb./acre*	*Lb./acre*	*Lb./acre*
Oregon perennial	0	1,447	711	567	908
	2	1,267	574	401	747*
	3	1,150	503	431	724*
	4	910	717	341	656*
S 23	0	775	537	340	553
	2	782	910	323	671
	3	803	745	396	648
	4	672	677	176	508
H-1	0	920	694	395	670
	2	921	184	0	368*
	3	309	0	0	103*
	4	71	0	0	24*

[1] Diuron applied: Oct. 21, 1958; Oct. 16, 1959; and Oct. 20, 1960.

*Yield significantly different from that of untreated check. LSD @ .05 within a variety = 125 lb. seed/acre.

Recognition of the fact that perennial ryegrass varieties differ in their response to diuron is very helpful in explaining the erratic control of perennial ryegrass in other grass species with diuron. Perennial ryegrass is frequently a weed problem where orchardgrass, tall fescue, creeping red fescue, and bluegrass are raised for seed on fields previously used for ryegrass seed production. In the past it has been very difficult to explain why diuron has controlled ryegrass under some conditions and failed completely in other instances. Results of this experiment make it possible to explain the differences in control of perennial ryegrass by diuron where different varieties have been grown and make it possible to predict the possiblity of selectively controlling perennial ryegrass in other grass species. Such information makes it possible to avoid problems that arise when other perennial grasses are planted for seed production on fields that have previously been used for producing S–23 perennial ryegrass seed.

Bentgrass Varieties

The effects of four annual applications of diuron on bentgrass varieties are shown in table 3. The use of diuron at rates up to 4 pounds per acre appear safe for Highland bentgrass—seed yields were equal to or greater than from the untreated check in nearly all instances. The average seed yield from soil treated at the 3-pound-per-acre rate was significantly higher than from the check.

The use of diuron at rates up to 4 pounds per acre is probably safe for Astoria bentgrass. However, the data show that yields will probably be slightly lower than from the untreated check. Use of diuron in Astoria bentgrass could be justified only if weeds with inseparable seeds were present, which would reduce the quality of the crop seed. In view of the limited tolerance of Astoria bentgrass to diuron, new varieties of colonial

TABLE 3.—*Colonial and creeping bentgrass seed yields after four annual treatments with diuron at several rates*

Variety	Diuron application [1]	Seed yields in—				Average seed yields, 1960–63
		1960	1961	1962	1963	
	Lb./acre	*Lb./acre*	*Lb./acre*	*Lb./acre*	*Lb./acre*	*Lb./acre*
Highland	0	335	214	401	251	300
	2	335	217	440	270	316
	3	380	227	455	311	343*
	4	384	190	416	258	312
Astoria	0	356	132	224	175	222
	2	270	108	219	129	182*
	3	335	127	237	162	215
	4	329	110	218	146	201
Seaside	0	248	111	195	104	165
	2	244	113	193	70	155
	3	166	103	45	56	93*
	4	155	85	83	24	87*
Penncross	0	240	120	136	55	138
	2	323	127	92	35	144
	3	207	78	33	0	80*
	4	198	52	0	33	71*

[1] Diuron applied: Oct. 16, 1959; Oct. 20, 1960; Oct. 19, 1961; and Oct. 24, 1962.

*Yield significantly different from that of untreated check. LSD @ .05 within a variety = 34 lb. seed/acre.

bentgrass should be evaluated to determine their tolerance to diuron before recommendations for use are made.

The use of diuron at 2 pounds per acre did not adversely affect seed yields of Seaside and Penncross bentgrass when applied for 3 and 2 years, respectively. However, when additional applications were made yield reduction occurred. At rates of 3 or 4 pounds per acre diuron appears to be too injurious to use on Seaside or Penncross bentgrass.

Creeping Red and Chewings Fescue Varieties

When the creeping red fescue varieties, Rainier or Pennlawn, or Chewings fescue were treated with diuron, a trend toward lower seed yields was noted (table 4). Average seed yield for all rates of application was generally below that of the untreated check. While the seed yields were not significantly lower than that of the check, they do suggest that injury was occurring. At the 2-pound rate the yields were about equal

TABLE 4.—*Creeping red and Chewings fescue seed yields after five annual treatments with diuron at several rates*

Variety	Diuron application [1]	Seed yields in—				Average seed yields, 1959–63 [3]
		1959	1960 [2]	1962	1963	
	Lb./acre	*Lb./acre*	*Lb./acre*	*Lb./acre*	*Lb./acre*	*Lb./acre*
Rainier	0	1,016	1,023	802	531	843
	2	923	942	821	595	820
	3	1,042	921	660	720	836
	4	996	838	640	458	733
Pennlawn	0	612	499	517	176	451
	2	612	556	394	287	462
	3	598	442	357	195	398
	4	634	376	157	137	326
Chewings	0	664	412	575	248	475
	2	551	550	462	281	461
	3	593	375	330	224	381
	4	536	328	212	148	306

[1] Diuron applied: Oct. 21, 1958; Oct. 16, 1959; Oct. 20, 1960; Oct. 19, 1961; and Oct. 24, 1962.

[2] Seed yield determinations not made in 1961. An accidental overtreatment with 2, 4–D in the spring of 1961 reduced seed yields.

[3] No evidence of significant differences in seed production at the .05 level of probability.

to those of the checks. However, at the 3- or 4-pound rates sizeable yield reductions occurred in most instances.

These results show that creeping red and Chewings fescue varieties have a limited tolerance to diuron. If the rate of application does not exceed 2 pounds per acre, diuron can be used in these grasses without noticeable injury and seed yields will probably approximate those of untreated areas. However, if higher rates of application are used, yield reductions may occur.

Tall Fescue Varieties

The influence of diuron upon the seed yields of five tall fescue varieties is shown in table 5. In most instances seed yields after treatment with diuron were as high as or higher than those on the untreated check. When the seed yields for 5 years were averaged, only Alta and Goar, treated at 4 pounds per acre, showed seed yields lower than that of the check. These yields were only a few pounds per acre lower than those on untreated plot and thus are of little consequence. Seed yields were significantly higher than that of the check where diuron was applied to KY–59gl–32 at 2 or 4 pounds per acre or to New Zealand at 2 or 3 pounds per acre.

The tall fescue varieties compared have considerable tolerance to diuron and exhibit a wide margin of safety. Since satisfactory weed control can usually be attained with rates of 2 to 3 pounds per acre, there is no need to apply diuron at higher rates. However, if it were applied at higher rates, due to faulty spray equipment or miscalculation, there would be little injury unless the rate of application exceeded the recommended rate by a sizeable margin.

Bluegrass Varieties

When diuron was applied to seven bluegrass varieties, striking seed yield increases occurred (table 6). When the seed yield data for 5 years were averaged, six of the seven bluegrass varieties showed significant seed yield increases at all rates of application. In the case of the seventh variety, seed yields were higher than that of the check for all rates of application, but the yield was significantly higher than that of the check only at the 2-pound rate.

The maximum seed yield of four of the seven varieties occurred at the 3-pound-per-acre rate, of one variety at the 4-pound rate, and of two varieties at the 2-pound rate of application. None of the bluegrass varieties included in this experiment showed any noticeable diuron injury during the duration of this experiment. The fact that most of the bluegrass varieties maintained a high level of seed production at the end of the experiment after application of as much as 20 pounds of diuron per

TABLE 5.—*Tall fescue seed yields after five annual treatments with diuron at several rates*

Variety	Diuron application [1]	Seed yields in—					Average seed yields, 1959–63
		1959	1960	1961	1962	1963	
	Lb./acre	*Lb./acre*	*Lb./acre*	*Lb./acre*	*Lb./acre*	*Lb./acre*	*Lb./acre*
Alta	0	1,314	961	741	795	689	900
	2	1,008	1,059	880	1,037	839	965
	3	1,097	1,037	882	923	864	961
	4	1,010	978	762	883	826	892
Goar	0	1,016	843	504	633	530	705
	2	1,087	824	526	700	603	748
	3	1,068	781	490	699	571	722
	4	1,031	772	450	564	600	683
K-31	0	1,145	1,268	1,075	723	697	982
	2	1,057	1,361	1,107	871	929	1,065
	3	1,086	1,254	1,007	711	740	959
	4	1,004	1,260	1,083	838	763	990
Ky-59 gl-32	0	1,019	1,379	852	689	570	902
	2	1,092	1,606	886	748	845	1,035*
	3	1,024	1,481	868	649	866	978
	4	1,197	1,552	850	841	899	1,068*
New Zealand	0	1,072	1,243	741	542	387	797
	2	1,261	1,506	1,015	825	620	1,045*
	3	1,201	1,175	1,012	715	631	947*
	4	894	1,042	990	692	561	836

[1] Diuron applied: Oct. 21, 1958; Oct. 16, 1959; Oct. 20, 1960; Oct. 19, 1961; and Oct. 24, 1962.

*Yield significantly different from that of the untreated check. LSD @ .05 within a variety = 85 lb. seed/acre.

acre over a 5-year period illustrates the wide tolerance of the bluegrass to diuron.

Figure 3 shows the need for herbicide applications in bluegrass seed fields.

Orchardgrass Varieties

The influence of diuron on the seed yields of seven orchardgrass varieties is shown in table 7. When the yield data for 5 years were averaged, six of the seven varieties showed seed yields significantly

TABLE 6.—*Bluegrass seed yields after five annual treatments with diuron at several rates*

Variety	Diuron application [1]	Seed yields in—					Average seed yields, 1959–63
		1959	1960	1961	1962	1963	
	Lb./acre	*Lb./acre*	*Lb./acre*	*Lb./acre*	*Lb./acre*	*Lb./acre*	*Lb./acre*
Merion	0	80	181	195	469	48	195
	2	69	452	218	450	100	258*
	3	68	539	429	418	115	314*
	4	54	523	298	488	123	297*
Kentucky	0	141	257	393	530	163	297
	2	152	481	483	715	280	422*
	3	166	596	487	609	159	504*
	4	132	737	402	523	180	395*
Delta	0	121	255	417	843	197	367
	2	91	540	596	1,015	328	514*
	3	119	631	553	1,070	314	537*
	4	76	675	590	953	284	516*
Park (95)	0	154	281	472	694	196	359
	2	144	624	548	918	208	488*
	3	132	568	654	997	270	524*
	4	178	713	586	859	171	501*
Newport	0	270	470	474	1,002	313	506
	2	238	1,027	615	1,431	489	760*
	3	209	1,038	635	1,275	428	717*
	4	176	1,034	541	1,182	395	666*
Washington State	0	164	251	302	194	56	193
	2	200	448	297	541	139	325*
	3	211	612	486	384	159	370*
	4	217	878	323	483	146	409*
Troy	0	119	402	326	617	244	342
	2	70	471	481	705	342	414*
	3	91	475	387	632	281	373
	4	96	543	419	552	255	373

[1] Diuron applied: Oct. 21, 1958; Oct. 16, 1959; Oct. 20, 1960; Oct. 19, 1961; and Oct. 24, 1962.

*Yield significantly different from that of the untreated check. LSD @ .05 within a variety = 49 lb. seed/acre.

FIG. 3. Effect of one diuron application Oct. 1958 on weed growth in Merion bluegrass Apr. 1959 growth shown. Left untreated check shows annual ryegrass; right diuron applied at rate of 3 pounds per acre.

higher than that of the untreated check at the 2-pound-per-acre rate of application. There was no indication that any rate of application reduced the yield as compared to that of the untreated check.

These results show that orchardgrass is also tolerant to diuron. While it is not as tolerant as bluegrass, the margin of safety is sufficient to indicate that this herbicide can be used at 2 to 3 pounds per acre on all varieties tested without undue injury or yield reduction.

TOXIC RESIDUE STUDY

Since diuron has been found to be an economical and effective herbicide for controlling winter annual weeds in certain perennial grass seed fields in western Oregon, this herbicide has gained widespread use in recent years. As shown in earlier sections of this bulletin, repeated annual applications did not adversely affect seed yields of tall fescue, orchardgrass, bluegrass, and colonial bentgrass varieties. The question arises, however, as to whether or not repeated annual applications result in soil

TABLE 7.—*Orchardgrass seed yields after five annual treatments with diuron at several rates*

Variety	Diuron application [1]	Seed yields in—					Average seed yields, 1959–63
		1959	1960	1961	1962	1963	
	Lb./acre	*Lb./acre*	*Lb./acre*	*Lb./acre*	*Lb./acre*	*Lb./acre*	*Lb./acre*
Akaroa	0	890	566	825	671	456	682
	2	832	550	760	706	492	668
	3	847	578	941	730	590	737
	4	684	551	817	770	549	674
Potomac	0	1,102	580	736	716	406	627
	2	1,080	696	963	1,077	664	896*
	3	1,082	491	826	864	616	776*
	4	905	443	721	792	488	670
Danish	0	795	528	687	763	512	657
	2	814	657	863	950	619	781*
	3	818	574	870	857	586	741*
	4	920	622	790	682	484	700
S–37	0	726	340	579	435	250	466
	2	902	513	640	399	391	569*
	3	811	578	581	343	360	535*
	4	808	466	542	347	383	509
Commercial	0	1,018	260	604	706	463	610
	2	959	272	664	873	675	689*
	3	917	243	619	679	522	596
	4	926	327	673	715	550	638
Latar	0	682	403	525	295	247	430
	2	716	444	654	382	431	525*
	3	666	335	541	430	325	459
	4	613	379	578	418	353	468
S–143	0	1,147	284	611	508	290	568
	2	1,052	483	840	688	550	723*
	3	1,050	476	880	504	494	681*
	4	1,069	480	839	504	435	665*

[1] Diuron applied: Oct. 21, 1958; Oct. 16, 1959; Oct. 20, 1960; Oct. 19, 1961; and Oct. 24, 1962.

*Yield significantly different from that of the untreated check. LSD @ .05 within a variety = 65 lb. seed/acre.

accumulations that may be injurious to crops following perennial grasses in the rotation.

Studies reported by Cowart (*1*) and by Hill, McGohen, Baker, Finnerty, and Bingeman (*7*) have shown that diuron is broken down quite rapidly by soil microorganisms when applied to soils at rates of 1 to 2 pounds per acre. These studies show that most of the herbicide disappeared within 4 to 8 months after treatment and that there was little tendency for carryover from one year to the next. They concluded that under conditions favorable for microbial activity the accumulation in the soil was of no practical significance.

The problem of diuron residues from repeated application at rates of 3 and 4 pounds per acre had not been studied, and there was the possibility of residual accumulation under Oregon's climatic conditions. Thus the following study was conducted.

Materials and Methods

During September of 1961, 1962, and 1963, soil samples were collected at several depths from plots used in the previously discussed experiments. On each sampling date one set of samples was drawn from an orchardgrass plot, one from a bluegrass plot, and one from a tall fescue plot. The samples were collected before the field was tilled each September and about 11 months after the last previous treatment. The 1961 sample had been subjected to three previous annual applications, the 1962 sample to four previous treatments, and the 1963 sample to five previous treatments. Sufficient soil was collected at each depth to fill a No. 10 can. The soil was taken into the greenhouse and a bioassay was conducted to determine whether or not diuron was present as a residue from previous treatments in concentrations toxic to plant growth. The test plants were: in 1961—spring barley and crimson clover; in 1962—spring barley, crimson clover, winter flax, and annual ryegrass; and in 1965—spring barley, winter flax, and annual ryegrass. The sampling depth varied from year to year.

Results and Discussion

The results of the bioassays conducted on samples collected in 1961 and 1962 are shown in tables 8 and 9. The effects of diuron residues on spring barley grown on soil samples collected at different depths in 1963 after five annual diuron applications are shown in figures 4 to 7. Winter flax and annual ryegrass are also present (in the untreated check and in those pots where injury was not severe) but are difficult to distinguish from the barley.

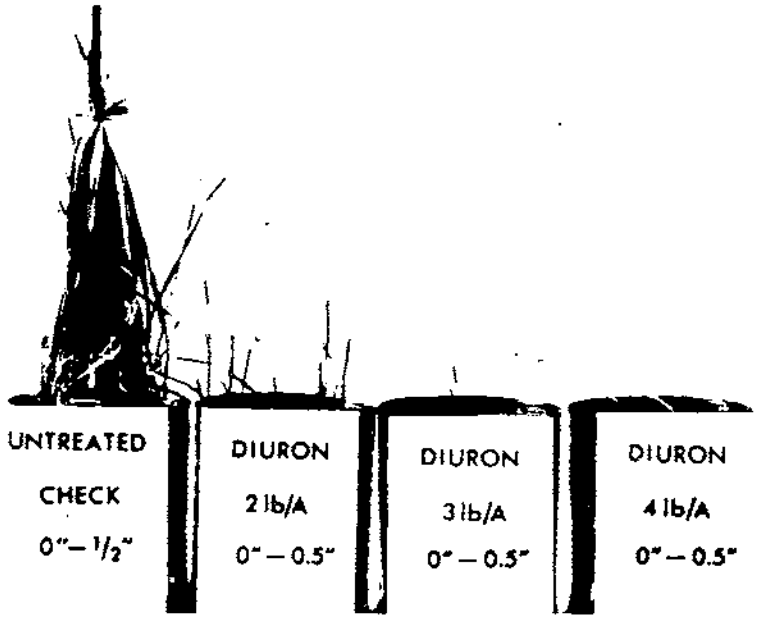

FIGURE 4. Test species grown on soil collected at the 0- to ½-inch depth. Diuron residues from all rates of application severely injured crop.

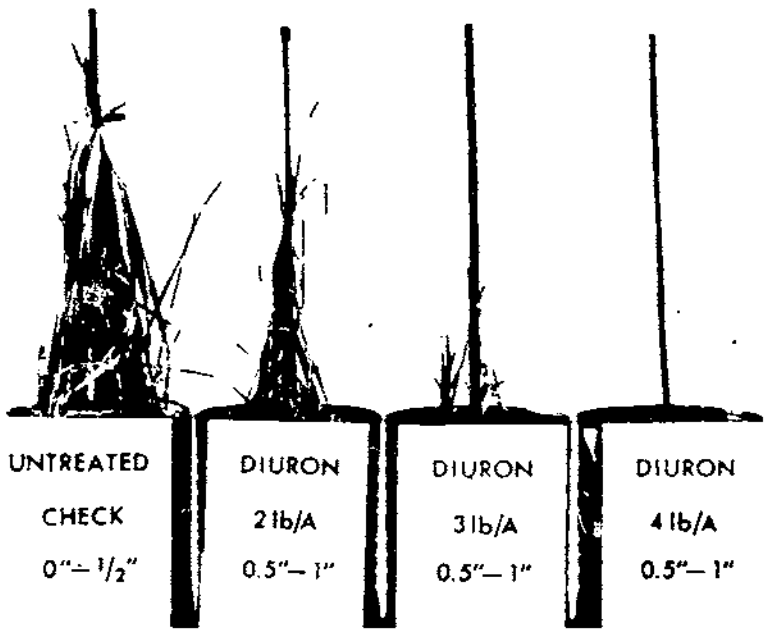

FIGURE 5. Test species grown on soil collected at the ½- to 1-inch depth. Diuron residues in this layer of soil appear less than those in the 0- to ½-inch layer (see fig. 4).

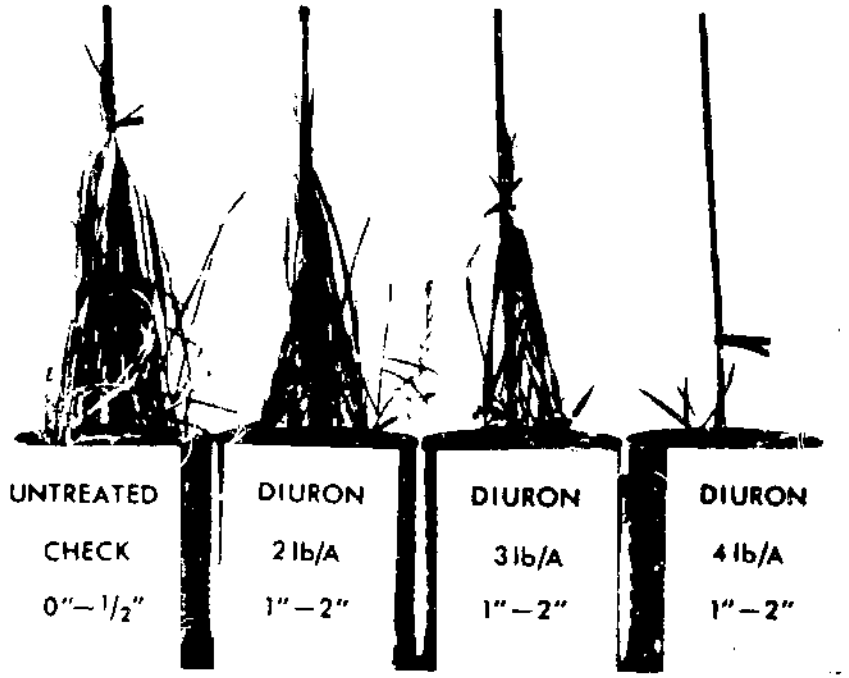

FIGURE 6. Test species grown on soil collected at the 1- to 2-inch depth. Only diuron residue from the 1-pound-per-acre rate of application severely injured crop.

1961 Bioassay

As shown in table 8, the number of barley plants that germinated and became established in the treated soil was not influenced by the rate of application of diuron or by the depth from which the soil on which they were grown was collected. However, the height of the plants was affected by both of these factors.

The height of barley was reduced when barley was grown on soil collected at the 0- to 2-inch level from a plot to which diuron had been applied at the rate of 3 or 4 pounds per acre. When the soil was collected at a depth of 2 to 4 or 4 to 8 inches, barley growth was not affected at any rate of diuron application. Thus, even though 42 inches of water had fallen between the time application began and the time the soil samples were collected, diuron was present at a concentration injurious to barley growth only when the barley was grown on soil from the 0- to 2-inch depth.

Crimson clover appears to be more sensitive to diuron than barley. When diuron was applied at 3 or 4 pounds per acre, crimson clover was eliminated from soil samples collected at the 0- to 2-inch level. At the

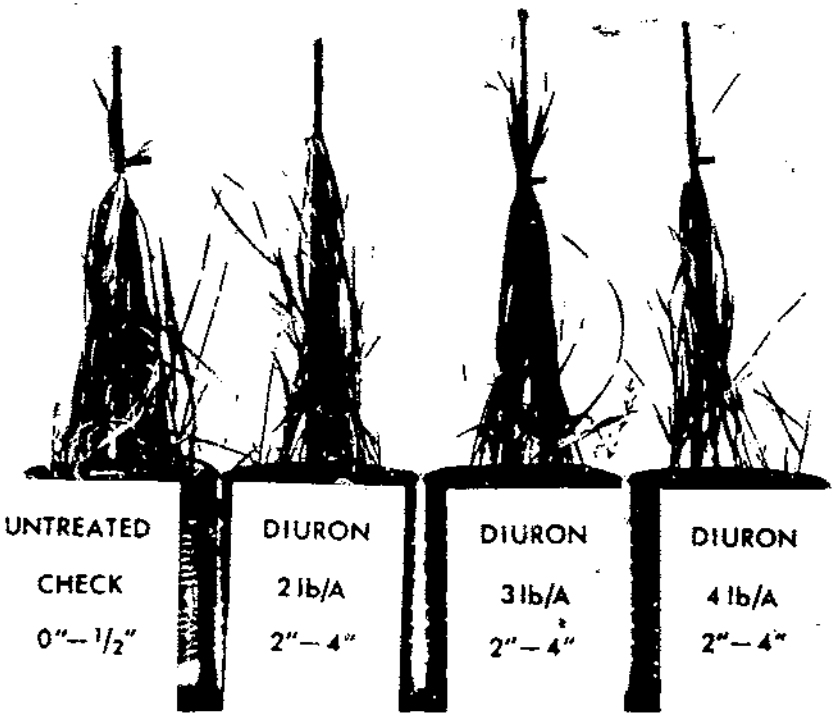

FIGURE 7.— Test species grown on soil collected at the 2- to 4-inch depth. Little indication of diuron residue, regardless of rate of application.

2-pound rate, some plants survived. The crimson clover survived on plots treated at these same rates when the soil on which it was grown was collected at the 2- to 4- or 4- to 8-inch levels.

When height of crimson clover is considered, a similar relation exists. Even though the crimson clover was eliminated from soil samples treated at the 3- and 4-pound-per-acre rates and collected at the 0- to 2-inch depth, plants growing in soil collected at 2- to 4- or 4- to 8-inch depths exhibited little injury from diuron. These data show that diuron residues were present at the soil surface in concentrations that were toxic to plant growth after three previous annual treatments with diuron at 3 or 4 pounds per acre.

1962 Bioassay

Results of the bioassay conducted on soil samples collected in 1962 are shown in table 9. Since it was found that most of the diuron remained at the 0- to 2-inch soil level in the 1961 samples, this 0- to 2-inch depth was divided into three levels in 1962 so that the area of accumulation within this upper 2-inch soil layer could be more precisely located.

TABLE 8.—*Number and height of plants [1] grown in soil previously treated with diuron [2]*

Depth of soil sample	Number of plants [3]		Height of plants	
	Barley	Crimson clover	Barley	Crimson clover
		NO DIURON		
Inches			*Inches*	*Inches*
0–2	8	6	13.1	4.9
2–4	9	7	15.7	5.2
4–8	8	6	15.9	4.7
		DIURON AT RATE OF 2 POUNDS/ACRE/YEAR		
0–2	8	5	14.5	3.7
2–4	9	8	15.6	5.2
4–8	8	6	15.1	4.2
		DIURON AT RATE OF 3 POUNDS/ACRE/YEAR		
0–2	9	0	10.2	0.0
2–4	8	6	15.3	5.2
4–8	8	5	13.8	4.3
		DIURON AT RATE OF 4 POUNDS/ACRE/YEAR		
0–2	6	0	6.4	0.0
2–4	8	6	15.3	5.2
4–8	8	5	13.8	4.3

[1] Average of three samples.

[2] Diuron applied: Oct. 21, 1958; Oct. 16, 1959; and Oct. 20, 1960. Soil samples collected Sept. 1961.

[3] Ten seeds of each test species planted.

Spring barley, crimson clover, winter flax, and annual ryegrass were planted in soil collected in 1962 whereas only spring barley and crimson clover were included in the earlier assay.

As in the earlier test, injury was most severe to plants grown on soil collected near the soil surface. All crops at all rates of application of diuron showed injury when grown on soil from the 0- to ½-inch level. Even at the 2-pound-per-acre rate, injury was severe to all test species

TABLE 9.—*Height of plants* [1] *grown on soil previously treated with diuron* [2] *as influenced by rate of application of diuron and depth from which soil was taken*

Depth of soil sample	Height of plants [3] grown on soil treated for 4 years with diuron at the annual rate of—			
	0 lb./acre	2 lb./acre	3 lb./acre	4 lb./acre
	Inches	*Inches*	*Inches*	*Inches*
HANNCHEN BARLEY				
0–0.5	17.9	16.1	1.1	0.0
0.5–1	16.5	16.3	9.8	1.3
1–2	16.1	16.9	15.5	3.9
2–4	15.1	16.4	15.7	16.9
4–8	14.4	13.7	14.5	15.5
ANNUAL RYEGRASS				
0–0.5	10.5	1.8	0.0	0.0
0.5–1	11.3	7.2	0.0	0.0
1–2	8.5	11.1	6.3	0.0
2–4	8.1	8.9	8.5	5.2
4–8	6.9	10.7	8.9	9.2
WINTER FLAX				
0–0.5	13.1	2.1	0.0	0.0
0.5–1	11.8	6.5	0.4	0.0
1–2	12.4	9.9	6.4	0.0
2–4	9.3	9.6	9.9	7.5
4–8	8.8	7.9	8.7	5.6
CRIMSON CLOVER				
0–0.5	4.1	0.0	0.0	0.0
0.5–1	3.6	0.9	0.0	0.0
1–2	3.3	0.4	1.9	0.0
2–4	3.3	3.8	4.1	0.4
4–8	3.9	4.5	3.3	2.6

[1] Average of three samples.

[2] Soil previously treated with diuron in October of 1958–61. Soil samples collected Sept. 1962.

[3] Average of the five tallest plants in each pot.

except barley, which showed only slight injury. At the 3- and 4-pound rates, all test species except barley were eliminated.

Injury was moderate to severe to plants grown on soil from the ½- to 1-inch depth. At the 2-pound rate of diuron application, barley escaped injury while all other species showed moderate injury. At the 3- and 4-pound rates, all species were severely injured or eliminated when grown on soil from this depth.

When grown on soil from the 1- to 2-inch depth, barley and ryegrass showed no injury at the 2-pound rate of diuron application, while flax and crimson clover showed moderate to severe injury. At the 3- and 4-pound rates, injury ranged from slight to severe with all test species.

On soil from the 2- to 4- and 4- to 8-inch depths, none of the test species showed injury at the 2- or 3-pound rate. Ryegrass and crimson clover showed some injury at the 4-pound rate.

These results show that diuron remains in the soil in concentrations toxic to plant growth for a considerable period of time after repeated annual applications. As the rate of application increases, the residue also increases. Even under the high rainfall of western Oregon, the herbicide residue was concentrated in the upper 2 inches of the soil surface, with the greatest accumulation at the 0- to ½-inch level.

The results from these studies point out the problem of toxic residues that may accumulate after several annual applications of diuron. Injury to subsequent crops may be avoided by:

1. Rotating available herbicides to prevent a harmful buildup of diuron in the soil.

2. Harrowing grass seed fields after burning to spread carbon and unburned crop residue (which inactivate diuron) so that weeds can be controlled with lower rates of application.

3. Avoiding the use of diuron in perennial grass seed fields when it is anticipated that the field may be plowed.

4. Plowing as deep as possible to distribute the herbicide residue throughout the soil profile, thereby diluting it.

5. Planting a crop exhibiting the same tolerance to diuron as the preceding seed crops, when this herbicide has been used.

SUMMARY AND CONCLUSIONS

Six experiments conducted in western Oregon compared the effect of several annual applications of diuron at rates of 0, 2, 3, and 4 pounds active ingredient upon the seed yields of several varieties of each of seven species of perennial grasses.

Under the soil and climatic conditions existing in western Oregon, the seven bluegrass varieties, seven orchardgrass varieties, and five tall

fescue varieties compared in this test showed considerable tolerance to five annual applications of diuron at rates of up to 4 pounds active ingredient per acre. On the basis of the wide safety margin exhibited by these species, it is probable that diuron could be used on additional varieties of these species without undue injury.

The colonial bentgrass, Highland, also showed considerable tolerance to diuron, but a second variety, Astoria, showed only moderate tolerance. Both creeping bentgrass varieties included in this study were severely injured by diuron at all rates of application.

The creeping red fescue and Chewings fescue varieties included in this study showed only fair tolerance to diuron. When 2 pounds per acre of diuron were applied to the soil, yields approximated that of the untreated check. At rates of 3 or 4 pounds per acre the yields were somewhat lower than that of the check.

While the ryegrass varieties showed differential tolerance to diuron, even the most tolerant variety showed severe injury after several repeated annual applications. Thus it is doubtful that diuron could be used for weed control in perennial ryegrass seed fields unless additional research produces a method of use safer than those evaluated here.

Bioassays of soils collected from plots following three, four, or five annual applications of diuron at 2, 3, or 4 pounds per acre showed that at all rates of application, diuron residue was present 11 months after the last previous application. Even though approximately 40 inches of water had fallen between the time of sampling and the last previous application, most of the diuron residue remained in the upper 2 inches of soil. The greatest accumulation was found at the 0- to ½-inch depth.

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