RESEARCH

Creeping bentgrass seedling tolerance to herbicides and paclobutrazol

Some herbicides and a plant growth regulator were not harmful when applied to creeping bentgrass seedlings four weeks after emergence.

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Creeping bentgrass (*Agrostis palustris*) has increased in popularity as a fairway turf in the transition zone climate of the mid-Atlantic region. However, with their large seed bank, annual bluegrass (*Poa annua* ssp. *annua*) and other weeds often outcompete creeping bentgrass seedlings during late-summer or early-autumn establishment. Most of the herbicides available for controlling these weeds have not been tested on creeping bentgrass seedlings.

Herbicides versus creeping bentgrass

Ethofumesate (Prograss) can effectively control annual bluegrass post-emergence (1,5), and chlorsulfuron (Corsair) has been shown to have post-emergence activity on annual bluegrass without injuring mature creeping bentgrass (7,11). Bensulide (Bensumec, PreSan and others), prodiamine (Barricade) and other pre-emergence herbicides have been effective for controlling annual bluegrass in mature turf situations (2,3,4,8). Siduron (Tupersan) is primarily used to control crabgrass (*Digitaria* spp.), but it can reduce annual bluegrass 19% to 33% at rates ranging from 10 to 15 pounds a.i./acre (11.2-16.8 kilograms a.i./hectare) (9). No research has examined the tolerance of creeping bentgrass seedlings to any of these herbicides.

The plant growth regulator paclobutrazol (Trimmit) can enhance the competitive ability of mature creeping bentgrass over annual bluegrass (10). No study, however, has evaluated the effects of paclobutrazol on creeping bentgrass seedlings. Because herbicides and paclobutrazol may be injurious to young creeping bentgrass seedlings, their application following seedling emergence could conflict with renovation and overseeding operations. Furthermore, herbicide residues that persist in the soil over winter could interfere with successful spring reseeding if large turf areas were damaged or killed during winter as a result of ice cover, crown hydration, desiccation, disease or other factors.

KEY points

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- **Until now, herbicides used to control weeds** in creeping bentgrass have been tested on mature turf but not on creeping bentgrass seedlings.
- **Five common herbicides** and a plant growth regulator were tested on creeping bentgrass seedlings at two and four weeks after emergence after a fall seeding.
- **In the spring, each site was treated** and renovated to determine whether chemical residue in the soil would adversely affect seedling establishment.

Research

We conducted three studies from autumn to spring 1998-2002 to assess tolerance of creeping bentgrass seedlings to five herbicides and paclobutrazol and their overwintering residues in the soil. The primary objectives of this investigation were to assess:

- tolerance of creeping bentgrass seedlings to five herbicides and paclobutrazol applied at various times after seedling emergence
- creeping bentgrass establishment rate in response to treatment with herbicides and paclobutrazol
- influence of potential chemical residues on establishment of creeping bentgrass seedlings in plots treated in the autumn and reseeded in the spring

Materials and methods

Field studies were initiated on mature stands of fairway-height creeping bentgrass turf at the University of Maryland Turfgrass Research Facilities. Three separate creeping bentgrass sites were treated with Roundup (glyphosate) from Aug. 20 to Sept. 14 in 1998, 2000 and 2001. The sites then were vertical-cut in three to five directions and seeded with a drop-seeder at approximately 1.1 pounds seed/1,000 square feet (53.7 kilograms/hectare) with Crenshaw on Sept. 21, 1998, and with L-93 on Sept. 18, 2000, and Sept. 7, 2001.

All seeded sites were syringed frequently, and most seedlings emerged within six to eight days. After seedling emergence, the sites were irrigated as needed to avoid drought stress. At the time of seeding, 1 pound nitrogen/1,000 square feet (48.8 kilograms/hectare) from a starter fertilizer was applied. An additional 1 pound nitrogen/1,000 square feet (48.8 kilograms/hectare) was applied about three weeks after seedling emergence. Beginning two to three weeks after seedling emergence, the areas were mowed three times per week at a height of about 0.75 inch (1.9 centimeters).

Chemicals

The chemicals evaluated and their formulations are: bensulide (Bensumec 4L), chlorsulfuron (Corsair 75DF), ethofumesate (Prograss 1. 5EC), siduron (LescoSan 3.1G in 1998, and Tupersan 50WP in 2000 and 2001), prodiamine (Barricade 65DG) and paclobutrazol (Trimmit 2SC). Rates and application dates of the chemicals are shown in the tables. All rates were based on label and local-use recommendations. The prodiamine rate of 0.32 pound a.i./acre (0.36 kilograms/hectare) was chosen because previous studies had shown that it was as effective as higher rates for controlling annual bluegrass in Maryland (4).

Treatments were applied two, four or seven weeks after seedlings had emerged. Seedlings were in the three-leaf to two-tiller stage when each study was initiated. The test areas were irrigated within 24 hours of each application.

Chemical residue

To determine whether residues in the soil

from herbicides and paclobutrazol applied in the autumn affected seedling emergence in the spring, we treated the test sites with glyphosate between May 2 and May 23 of each year. Each site was vertical-cut and seeded as described above with either Crenshaw or L-93 creeping bentgrass between May 1 and May 10 in each year. Nitrogen fertilizer and mowing practices were performed as described above for the autumn seeding.

Evaluating cover and quality

Seedling injury was assessed using creeping bentgrass cover and overall turfgrass quality ratings (data not shown). The percentage of creeping bentgrass cover was assessed visually using a linear scale of 0% to 100%, where 0 = no creeping bentgrass and 100 = entire plot covered with creeping bentgrass. Overall turfgrass quality was assessed visually on a 0 to 10 scale, where 0 = entire plot area brown or dead, 7.5 = minimum acceptable quality for a golf course fairway and 10 = optimal greenness and density.

In the spring overseeding study, only the ratings for percentage of creeping bentgrass cover were used to measure the effects of potentially adverse soil residues on seedling establishment. Safe treatments caused little or no reduction in creeping bentgrass cover or quality. Plots treated with *marginally safe* chemicals suffered adverse effects but eventually achieved ratings similar to plots treated with safe chemicals.

Results and discussion

Autumn seedling tolerance, 1998-1999

Applications two weeks after emergence. Cover and quality (data not shown) were used to assess the effects of the chemicals on seedling tolerance. When the chemicals were applied two weeks after seedling emergence in 1998, bensulide and siduron did not reduce cover between Nov. 12 and Dec. 23 (Table 1). During the same period, ethofumesate reduced cover by 16-26% and paclobutrazol by 8-12%; chlorsulfuron was extremely phytotoxic and reduced cover to 78-84% of the cover on untreated plots. Cover ratings increased between Feb. 9, 1998, and April 8, 1999, but the same trends were evident. By April 8, plots treated with ethofumesate (93% cover) and chlorsulfuron (25% cover) still had cover ratings that were less than those observed in the control (98% cover).

Quality ratings for treatments applied two weeks after seedling emergence reflected cover ratings (data not shown).

Applications four weeks after emergence. Seedling injury was much less severe when the chemicals were applied four weeks after seedling emergence in 1998. Only chlorsulfuron reduced cover among the treatments when plots were rated between Nov. 12, 1998, and March 17, 1999 (Table 1).

Turf quality was reduced by ethofumesate on one date in both December and January, but thereafter the quality of ethofumesate-treated plots was equivalent to the control. Chlorsulfuron-treated plots exhibited reduced quality on all dates from Nov. 12, 1998, to March 17, 1999, but ratings were equivalent to the control by April 8.

Autumn seedling tolerance, 2000

In 2000, the chemicals were applied either two or four weeks after seedling emergence. The bensulide rate was increased from 7.5 to 12.5 pounds a.i./acre (8.4-14.0 kilograms/hectare), and the siduron rate was increased from 6.0 to 8.0 pounds a.i./acre (6.7-8.9 kilograms/hectare). Chlorsulfuron was not used because it was too phytotoxic. Paclobutrazol was not evaluated in 2000.

Applications two weeks after emergence. Ethofumesate applied two weeks after seedling emergence greatly reduced cover within two weeks (Oct. 19); these plots never achieved cover equivalent to the control (Table 2).

CRENSHAW COVER: 1998-1999

Timing/ Treatment*	Rate Pounds a.i./acre	Rate Kilograms a.i./hectare	Cover (%)† 1998 Nov. 12	1998 Dec. 23	1999 Feb. 9	1999 Mar. 17	1999 Apr. 8
2 WASE							
Bensulide	7.5	8.4	90 ab	95 ab	94 a	97 ab	97 a
Ethofumesate	0.75	0.84	68 d	80 c	80 d	90 d	93 b
Siduron	6.0	6.7	90 abc	96 a	95 a	97 abc	99 a
Chlorsulfuron	0.12	0.13	10 e	18 d	14 e	26 e	25 c
Paclobutrazol	0.12	0.13	82 c	88 bc	86 cd	92 bcd	98 a
4 WASE							
Bensulide	7.5	8.4	94 a	97 a	97 a	98 a	99 a
Ethofumesate	0.75	0.84	91 ab	91 ab	93 ab	95 a-d	98 a
Siduron	6.0	6.7	94 a	98 a	98 a	98 a	99 a
Chlorsulfuron	0.12	0.13	84 bc	81 c	87 bc	92 cd	96 a
Paclobutrazol	0.12	0.13	94 a	96 a	96 a	97 ab	99 a
7 WASE							
Ethofumesate	0.75	0.84	—‡	97 a	97 a	97 ab	99 a
Prodiamine	0.32	0.36	—	96 a	96 a	98 a	99 a
Untreated	—		94 a	96 a	96 a	97 abc	98 a

*Application timings were as follows: two weeks after seedling emergence (2 WASE) on 12 Oct.; 4 WASE on 28 Oct.; and 7 WASE on Nov. 17, 1998.
†Percentage of creeping bentgrass cover was assessed on a linear scale of 0% to100%, where 0 = bare ground and 100 = complete cover. Means in a column followed by the same letter are not significantly different from each other.
‡Treatment not applied until Nov 17, 1998.

Table 1. Percentage of cover of Crenshaw creeping bentgrass seedlings treated with five herbicides and paclobutrazol at three timings, 1998-1999.

L-93 COVER: 2000-2001

Timing/ Treatment*	Rate: Pounds a.i./acre	Rate: Kilograms a.i./hectare	Cover (%)† 2000: Oct. 19	2000: Nov. 3	2000: Nov. 25	2001: Feb. 27	2001: Apr. 23
2 WASE							
Bensulide	12.5	14.0	83 b	86 b	97 a	96 b	89 d
Ethofumesate	0.75	0.84	29 c	44 c	47 b	64 c	64 e
Siduron	8.0	8.9	96 a	94 a	100 a	100 a	98 a
Prodiamine	0.32	0.36	96 a	90 ab	100 a	97 ab	91 bcd
4 WASE							
Bensulide	12.5	14.0	—‡	86 b	100 a	100 a	98 ab
Ethofumesate	0.75	0.84	—	85 b	100 a	97 ab	90 cd
Siduron	8.0	8.9	—	91 ab	97 a	99 ab	97 abc
Prodiamine	0.32	0.36	—	94 a	100 a	99 ab	95 a-d
Untreated	—		94 a	94 a	98 a	100 a	98 ab

*Application timings were: two weeks after seedling emergence (2 WASE) on Oct. 6 and 4 WASE on Oct. 23, 2000.
†Percentage of creeping bentgrass cover was assessed on a 0% to 100% linear scale, where 0 = bare ground and 100 = complete cover. Means in a column followed by the same letter are not significantly different from each other.
‡Treatment not applied until Oct. 23, 2000.

Table 2. Percentage of cover of L-93 creeping bentgrass seedlings treated with four herbicides and paclobutrazol at two timings, 2000-2001.

L-93 COVER: 2001-2002

Treatment*	Rate: Pounds a.i./acre	Rate: Kilograms a.i./hectare	Cover (%)† 2001: Oct. 19	2001: Nov. 3
4 WASE				
Bensulide	7.5	8.4	92 abc	98 a
Bensulide	12.5	14.0	91 abc	98 a
Siduron	6.0	6.7	87 c	98 a
Siduron	8.0	8.9	94 ab	100 a
Ethofumesate	0.75	0.84	91 abc	98 a
Ethofumesate	0.75 + 0.75	0.84 + 0.84	89 bc	98 a
Prodiamine	0.32	0.36	95 a	98 a
Paclobutrazol	0.12	0.13	92 abc	98 a
Untreated	—		93 abc	98 a

*Treatments were applied four weeks after seedling emergence (4 WASE) on Oct. 12; sequential ethofumesate treatment was applied Nov. 5, 2001.
†Percentage of creeping bentgrass cover was assessed on a linear scale of 0% to 100%, where 0 = bare ground and 100 = complete cover. Means in a column followed by the same letter are not significantly different from each other.

Table 3. Percentage of cover of L-93 creeping bentgrass seedlings treated with four herbicides and paclobutrazol in one timing, 2001-2002.

When bensulide was applied two weeks after seedling emergence, cover was less than that of the control on two dates (Oct. 19 and Nov. 3), but plots appeared to recover. By Feb. 27, and as late as the final rating (April 23), cover had declined in bensulide-treated plots, and cover was 9% lower than the control. Siduron- and prodiamine-treated plots had cover ratings equivalent to the control on all rating dates.

Applications four weeks after seedling emergence. When bensulide and ethofumesate were applied four weeks after seedling emergence, cover was initially 8-9% lower than the control (Table 2). These plots achieved complete cover by Nov. 24, but cover ratings for ethofumesate-treated plots declined by April 23. Siduron- and prodiamine-treated plots had cover equivalent to the control on all rating dates.

Turf quality of bensulide and ethofumesate-treated plots was initially reduced but was equivalent to the control by Nov. 24, 2000 (data not shown). On the final rating date (April 23), however, the quality of ethofumesate-treated creeping bentgrass had declined and was inferior to the control.

Autumn seedling tolerance, 2001

Because only siduron and bensulide (7.5 pounds a.i./acre [8.4 kilograms/hectare] in 1998) were safe to apply two weeks after seedling emergence in the first two study years, in 2001 treatments were applied only four weeks after seedling emergence. Two rates of three herbicides and one rate of paclobutrazol and prodiamine were re-evaluated in the final year.

None of the treatments reduced cover when compared to the control in 2001, and by Nov. 16, all treated plots had 98-100% cover (Table 3). Two weeks after treatment (Oct. 26), siduron (6.0 pounds a.i./acre [6.7 kilograms/hectare]) and ethofumesate (both rates) had reduced creeping bentgrass quality (data not shown). Turfgrass quality was not reduced by a second treatment with ethofumesate on Nov. 5. Paclobutrazol-treated plots had poor quality in November.

Data collected between Dec. 6, 2001, and April 22, 2002, showed that none of the chemicals had a long-term adverse effect on creeping bentgrass quality.

Effects of residual chemicals in the soil

In the spring following the autumn application of chemicals, each study site was treated with glyphosate and renovated to determine whether residue in the soil from

the chemicals applied in the autumn would have any adverse effects on seedling emergence and establishment. In this portion of the study, only creeping bentgrass cover ratings were used to measure establishment.

1999. The 1998-1999 site was reseeded on May 6, 1999. On May 20, only plots treated with prodiamine (on Nov. 17, 1998, seven weeks after seedling emergence) showed reduced seedling emergence, and therefore reduced cover, when compared to all other treatments (Table 4). The adverse effects of residual prodiamine in the soil were evident on all rating dates, and on the final rating date (June 17) cover was 19% lower than cover for the control (Figure 1).

Photo courtesy of John Kaminski

Figure 1. The overwintering soil residuals of prodiamine and bensulide (12.5 pounds a.i./acre [1.4 grams/square meter]) unacceptably reduced spring establishment of creeping bentgrass seedlings.

Overseeded plots treated with chlorsulfuron (four weeks after seedling emergence; Oct. 28, 1998) also showed reduced cover on May 20 and June 3, when compared to plots treated with several other herbicides. However, on the final rating date (June 17), all treated plots (except those treated with prodiamine) had cover ratings equivalent to the control.

2001. In 2001, the site was reseeded on May 1. On May 15, plots treated with prodiamine (two and four weeks after seedling emergence) had greatly reduced seedling emergence and reduced creeping bentgrass cover (Table 4). Bensulide (12.5 pounds a.i./acre [14.0 kilograms/hectare]) applied Oct. 23, 2000, reduced cover more than the

SOIL RESIDUAL EFFECTS: 1999, 2001

Timing/ Treatment	Rate		Cover (%)†						
			Crenshaw, 1999			L-93, 2001‡			
	Pounds a.i./acre	Kilograms a.i./hectare	May 20	June 3	June 17	May 15	May 29	June 12	June 19
2 WASE									
Bensulide	7.5	8.4	27 de	78 ab	95 a	NE§	NE	NE	NE
Bensulide	12.5	14.0	NE	NE	NE	27 d	57 c	84 cd	96 ab
Ethofumesate	0.75	0.84	47 a	87 a	96 a	55 a	84 a	97 a	100 a
Siduron	6.0	6.7	35 a-e	83 ab	96 a	NE	NE	NE	NE
Siduron	8.0	8.9	NE	NE	NE	44 bc	66 bc	90 bc	98 a
Chlorsulfuron	0.12	0.13	47 a	86 a	95 a	NE	NE	NE	NE
Prodiamine	0.32	0.36	NE	NE	NE	7 ef	10 e	36 e	65 c
Paclobutrazol	0.12	0.13	43 ab	86 a	99 a	NE	NE	NE	NE
4 WASE									
Bensulide	7.5	8.4	31 b-e	83 ab	97 a	NE	NE	NE	NE
Bensulide	12.5	14.0	NE	NE	NE	15 e	40 d	80 d	91 b
Ethofumesate	0.75	0.84	39 a-d	83 ab	97 a	51 ab	69 b	94 ab	100 a
Siduron	6.0	6.7	28 c-e	82 ab	97 a	NE	NE	NE	NE
Siduron	8.0	8.9	NE	NE	NE	33 cd	57 c	92 ab	98 a
Chlorsulfuron	0.12	0.13	24 e	73 b	93 a	NE	NE	NE	NE
Prodiamine	0.32	0.36	NE	NE	NE	3 f	7 e	22 f	48 d
Paclobutrazol	0.12	0.13	42 abc	87 a	99 a	NE	NE	NE	NE
7 WASE									
Ethofumesate	0.75	0.84	38 a-e	85 a	97a	NE	NE	NE	NE
Prodiamine	0.32	0.36	8 f	46 c	79 b	NE	NE	NE	NE
Untreated	—		34 a-e	86 a	98 a	50 ab	65 bc	91 ab	98 a

*Percentage of creeping bentgrass cover was assessed on a linear scale of 0% to 100%, where 0 = bare ground and 100 = complete cover. Means in a column followed by the same letter are not significantly different from each other.
†Site was treated with glyphosate April 23, 1999 and disk-seeded May 6, 1999. Application timings were: two weeks after seedling emergence (2 WASE) on Oct. 12; and 4 WASE on Oct. 28; and 7 WASE on Nov. 17,1998.
‡Site was treated with glyphosate April 23, 2001 and disk-seeded May 1, 2001. Application timings were: 2 WASE on Oct. 6; 4 WASE on Oct. 23, 2000.
§NE, Treatment not evaluated.

Table 4. Soil residual effect of five herbicides and paclobutrazol applied in the autumn of 1998 (Crenshaw) or 2000 (L-93) on creeping bentgrass cover in spring 1999 or 2001.

same treatment applied Oct. 6, 2000. Plots treated with siduron (8.0 pounds a.i./acre [8.9 kilograms/hectare]) on Oct. 23, but not Oct. 6, exhibited reduced cover.

Ethofumesate did not adversely affect creeping bentgrass seedling emergence. By June 19, only plots treated with prodiamine (both timings) and bensulide (applied Oct. 23) had cover ratings inferior to the control.

2002. In 2002, the site was reseeded on May 10. From May 31 to the final rating date, July 18, prodiamine-treated plots had less cover than all other chemically treated plots. Plots treated with the high rate of bensulide (12.5 pounds a.i./acre [14.0 kilograms/hectare]) had reduced cover on June 6 and did not achieve cover levels equivalent to the control by the end of the study. Paclobutrazol and both rates of siduron and ethofumesate did not adversely influence cover (Table 5).

Conclusions and future research

L-93 and Crenshaw exhibited similar effects from each herbicide and paclobutrazol treatment.

We found that siduron (6.0 and 8.0 pounds a.i./acre [6.7 and 8.9 kilograms/hectare]) and bensulide (7.5 pounds a.i./acre [8.4 kilograms/hectare]) were safe to apply to creeping bentgrass seedlings two weeks after seedling emergence.

When applied four weeks after seedling emergence, bensulide (12.5 pounds a.i./acre [14.0 kilograms/hectare]), prodiamine and paclobutrazol were not harmful to creeping bentgrass seedlings.

Ethofumesate (0.75 pound a.i./acre [0.84 kilograms/hectare]) reduced cover and quality when applied four weeks after seedling emergence, but a second autumn application in 2001 did not cause additional injury. Furthermore, residual ethofumesate in the soil did not adversely affect reseeding. Therefore, where competition between annual bluegrass and creeping bentgrass seedlings is severe, it may be prudent to consider using ethofumesate to improve the competitiveness of the creeping bentgrass despite the possibility of injury.

Applying bensulide (7.5 pounds a.i./acre [8.4 kilograms/hectare]) or siduron two weeks after seedling emergence, or bensulide (12.5 pounds a.i./acre [14.0 kilograms/ hectare]) or prodiamine (0.32 pound a.i./acre [0.36 kilograms/hectare]) four weeks after seedling emergence also may reduce annual bluegrass competition with creeping bentgrass seedlings.

The risks of residual prodiamine in the soil, however, are considerable. If autumn creeping bentgrass establishment fails, residual prodiamine would likely prevent a successful spring renovation. Overwintering soil residue from bensulide (12.5 pounds a.i./acre [14.0 kilograms/hectare]) also reduced creeping bentgrass establishment, but not nearly as much as prodiamine.

Creeping bentgrass seedlings were not harmed by applications of paclobutrazol four weeks after seedling emergence. It is not known whether paclobutrazol would help or hinder seedling establishment of creeping bentgrass in competition with annual bluegrass. Future study would involve using these chemicals at sites with a mix of annual bluegrass and creeping bentgrass seedlings.

SOIL RESIDUAL EFFECTS: 2002

Timing/ Treatment*	Rate		Cover (%)†			
	Pounds a.i./acre	Kilograms a.i./hectare	May 31	June 6	June 24	July 18
4 WASE						
Bensulide	7.5	8.4	21 a	31 ab	89 a	99 a
Bensulide	12.5	14.0	13 ab	17 bc	70 b	88 b
Siduron	6.0	6.7	25 a	34 ab	87 a	98 a
Siduron	8.0	14.0	19 a	36 ab	89 a	99 a
Ethofumesate	0.75	0.84	22 a	45 a	92 a	100 a
Ethofumesate	0.75 + 0.75	0.84 + 0.84	21 a	43 a	94 a	100 a
Prodiamine	0.32	0.36	2 b	3 c	20 c	53 c
Paclobutrazol	0.12	0.13	18 a	33 ab	89 a	99 a
Untreated	—		24 a	48 a	94 a	99 a

*Treatments were applied on Oct. 12, 2001; sequential ethofumesate treatment was applied Nov. 5, and the site was over seeded May 10, 2002.
†Percentage of bentgrass cover was assessed on a 0% to 100% linear scale, where 0 = bare ground and 100 = complete bentgrass cover. Means in a column followed by the same letter are not significantly different from each other.

Table 5. Soil residual effects of four herbicides and paclobutrazol applied four weeks after seedling emergence on Oct. 12, 2001, on L-93 creeping bentgrass cover in spring 2002.

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