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Tolerance of Bentgrass to Amount, Frequency, and Timing of Ethofumesate Applications

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Abstract. **A creeping bentgrass (*Agrostis palustris* Huds. 'Penncross') green was treated with the herbicide ethofumesate at single and sequential applications during 2 years. A single ethofumesate application in September at 1.1, 1.7, or 2.2 kg a.i./ha slightly discolored bentgrass, but turfgrass quality was not significantly reduced. With October treatments, discoloration increased at 1.7 and 2.2 kg a.i./ha, but not at 1.1 kg. Ethofumesate treatments made in September and October resulted in less discoloration and reduced quality less than with applications made in October and November. Bentgrass treated in October and November was severely injured in 1 of 2 years, but turfgrass fully recovered by the following spring with no stand loss. Chemical names used: (±)-2-ethoxy-2,3-dihydro-3,3-dimethyl-5-benzofuranylmethanesulfonate(ethofumesate).**

Annual bluegrass (*Poa annua* L. var. *annua*) is a common weed that invades warm- and cool-season turfgrasses. This weed can be effectively controlled with several preemergence and postemergence herbicides (1, 2, 6–10), especially in warm-season turfgrasses.

Annual bluegrass control in creeping bentgrass, a cool-season turfgrass, has been more variable than in warm-season turfgrasses. For several years, *O,O-bis*(1-methylethyl) *S*-[2-[(phenylsulfonyl)amino]ethyl]phosphorodithioate (bensulide) was the primary preemergence herbicide used for annual bluegrass control in bentgrass greens. Bensulide did not provide consistent control of annual bluegrass (8), and injury to bentgrass varied from none (3) to severe (4). Researchers continually seek a herbicide that would consistently control this weed without injuring bentgrass.

In recent years, ethofumesate has been used for annual bluegrass control in creeping bentgrass (3) and perennial ryegrass [*Lolium perenne* (L.)] (2, 6, 7, 9, 10). General effectiveness of this chemical in terms of amount, frequency, and timing of application has been evaluated when ethofumesate was applied to dormant bermudagrass [*Cynodon dactylon* (L.) Pers.]. Ethofumesate applied at 1.1 kg a.i./ha in October and repeated in November provided full-season annual bluegrass control (9), but not in a later study (10). In contrast, when two applications were made at the same amount to overseeded perennial ryegrass, annual bluegrass was consistently controlled (2, 7). Overseeded perennial ryegrass may be more competitive to the annual bluegrass than dormant bermudagrass.

Two fall applications of ethofumesate at 1.1 kg a.i./ha controlled a higher percentage of annual bluegrass in a perennial ryegrass fairway in Maryland than in a 'Penncross' bentgrass green (6). Either the perennial ryegrass competed more with annual bluegrass than did bentgrass, or annual bluegrass competed more with bentgrass at the closer mowing. Even though the effectiveness of ethofumesate for annual bluegrass control has varied among turfgrass species, it appears that the herbicide has potential for controlling this weed in bentgrass greens.

There is little information on the effects of ethofumesate on the quality of bentgrass. In Tennessee, Callahan (5) reported that a single spring application of ethofumesate at 1.1 kg a.i./ha did not cause any stand loss within 5 weeks after treatment for 4 consecutive years. Lewis reported that in North Carolina (11, 12), fall-applied ethofumesate in three applications at 0.84 to 1.12 kg·ha^{-1} caused slight discoloration of bentgrass, but did not permanently injure grass that did not have a shallow root system. When ethofumesate was applied at 1.12 kg a.i./ha in September in Maryland and repeated in October, bentgrass was discolored in excess of the minimum acceptable level within 4 weeks after the final application, but the turfgrass fully recovered by mid-January (6). All of this ethofumesate-treated bentgrass was darker green than untreated turfgrass in January and throughout the winter.

Bentgrass response to ethofumesate while growing under stress conditions in the Georgia Piedmont is unknown. Therefore, an experiment was initiated to determine the phytotoxicity of ethofumesate on 'Penncross' creeping bentgrass as influenced by amount, frequency, and timing of application.

This experiment was conducted on an established 'Penncross' creeping bentgrass green in Athens, Ga. from Fall 1984 through Spring 1986. Ethofumesate was applied to the same plots each year as a broadcast spray in 375 liter of water/ha. The herbicide was applied in one or two applications (Table 1). Dates of treatment were 30 Sept. ± 1 day, 30 Oct. ± 5 days, and 28 Nov. ± 8 days.

The putting green root zone soil was an artificial mixture. The textural analysis of the mineral component of the soil was 95.1% sand, 0.3% silt, and 4.6% clay, and 1.8% organic matter. A soil test indicated that P was high (114 mg·kg^{-1}) and K was low (48 mg·kg^{-1}). Soil pH was 6.2. Bentgrass was fertilized with N at 200 kg·ha^{-1}·year.$^{-1}$

Actively growing bentgrass was mowed three times per week at a 4-mm cutting height and clippings were removed. Irrigation was applied as needed to prevent wilting and fungicides and insecticides to manage disease and insect problems.

The experimental design was a randomized complete block with three replications. Plot size was 1.5 × 3 m. Visual ratings for bentgrass injury and turf quality were made at 2- to 3-week intervals beginning 2 weeks after the initial ethofumesate treatment and continuing until mid-April. Turfgrass injury ratings were based on 0 = no injury and 100 = complete kill. On this scale, rating of 30 or higher would not be aesthetically acceptable. Turfgrass quality ratings were based on 1 = turfgrass brown or dead and 10 = a dark green, uniform, and dense, and the ratings are reported as percent of the nontreated check. Quality ratings <80% would be considered objectionable.

Statistical analysis using the general linear model procedure (13) was determined within and across years. Because of treatment × year interaction, data means are reported for each year and separated by LSD at the 0.05 level. Various post-hoc contrasts were hypothesized to compare a single herbicide application vs. two applications and to compare herbicide application at different dates.

Bentgrass injury from ethofumesate was related to amount and time of application (Table 1). A single herbicide application in September at either 1.1, 1.7, or 2.2 kg a.i./ha only slightly discolored bentgrass during the 2-year period (0% to 15%). When applications were delayed until October, injury

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Table 1. Effects of amount, frequency, and timing of ethofumesate applications on the level of injury to 'Penncross' creeping bentgrass.

Treatments[z]		Bentgrass injury on dates given (%)[y]								
		Treated 1984				Treated 1985				
Rates (kg a.i./ha)	Time applied (Month)	9 Nov.	20 Nov.	3 Dec.	7 Jan.	6 Dec.	6 Jan.	14 Feb.	17 Mar.	31 Mar.
Untreated	---	0	0	0	0	0	0	0	0	0
1.1	September	0	0	7	10	10	7	8	0	2
1.7	September	7	10	5	15	12	9	7	8	3
2.2	September	3	0	3	0	12	2	7	3	2
1.1	October	10	13	8	5	15	12	8	0	2
1.7	October	18	20	12	2	23	42	15	13	12
2.2	October	20	32	22	18	30	47	35	22	15
1.1+1.1	September and October	8	18	5	7	18	18	10	8	3
1.7+1.7	September and October	15	25	12	0	18	28	7	3	7
1.1+1.1	October and November	---	---	12	15	18	23	48	32	22
1.7+1.7	October and November	---	---	15	32	28	50	62	53	38
$LSD_{0.05}$		6	5	8	13	10	19	14	11	8

[z]Three replications of treatments were applied 30 Sept. ± 1 day, 30 Oct. ± 5 days, and 28 Nov. ± 8 days.
[y]Injury ratings were based on 0 = no injury and 100 = complete kill. Ratings of 30% or greater would not be aesthetically acceptable.

Table 2. Effects of amount, frequency, and timing of ethofumesate applications on the quality of 'Penncross' creeping bentgrass.

Treatment[z]		Bentgrass quality on dates given (% of nontreated check)[y]						
		Treated 1984			Treated 1985			
Rates (kg a.i./ha)	Time applied (Month)	7 Jan.	11 Mar.	11 Apr.	6 Jan.	17 Mar.	31 Mar.	14 Apr.
1.1	September	91	97	104	96	100	104	100
1.7	September	82	83	93	90	84	91	100
2.2	September	85	97	104	110	105	100	104
1.1	October	107	107	100	87	93	101	98
1.7	October	106	108	96	62	88	95	96
2.2	October	112	108	93	52	84	87	98
1.1+1.1	September and October	100	100	97	90	96	95	96
1.7+1.7	September and October	110	114	103	71	100	94	100
1.1+1.1	October and November	88	107	97	73	79	87	91
1.7+1.7	October and November	79	97	96	48	65	78	82
$LSD_{0.05}$		18	14	NS	19	19	14	NS

[z]Three replications of treatments were applied 30 Sept. ± 1 day, 30 Oct. ± 5 days, and 28 Nov. ± 8 days.
[y]Quality ratings were based on 1 = turf brown or dead to 10 = a dark green uniform, dense turf and presented on percent of nontreated check. Ratings lower than 80% would be objectionable.

was slight with 1.1 kg, and increased in severity with the 1.7 and 2.2 kg a.i./ha treatments. Bentgrass injury in 1985 was higher than in 1984 with ethofumesate at 1.7 or 2.2 kg a.i./ha. Even though bentgrass injury during 1984 from the higher herbicide amount was acceptable, injury following October treatment in 1985 with ethofumesate at 1.7 and 2.2 kg a.i./ha (>40%) was not. No bentgrass injury was observed in February and March from 1984 ethofumesate treatment nor from November treatments in 1985 (data not given).

With two applications of ethofumesate, the tolerance of bentgrass varied with time of application (Table 1). When 1.1 kg a.i./ha was applied each in September and October of 1984 and 1985, bentgrass was discolored only slightly (3% to 18%) during both years. However, when treatments were applied in Oct. and Nov. 1985, the degree of injury (>30%) was unacceptable on 14 Feb. and 17 Mar. 1986. The higher injury in 1985 than 1984 from October and November treatments with ethofumesate was probably related to temperature. The mean temperature for the 6 weeks following the final ethofumesate application in 1985 was 6.3°C colder than during the same period the previous year. Therefore, ethofumesate should not be applied to bentgrass in Georgia later than October. Lewis (12) also reported that bentgrass appeared to have less tolerance to ethofumesate when applied during the coldest part of the year. In our study, paired comparisons showed bengrass injury to be greater when treatments were made in October and November than in September and October.

Bentgrass showed severe injury in January and later when ethofumesate was applied in October and November at 1.7 kg a.i./ha (Table 1). The turfgrass fully recovered by March following the 1984 treatment (data not given), but had not recovered by late March following 1985 treatment. Bentgrass was injured only slightly when treated at the same concentration in September and October and the amount of leaf discoloration was acceptable.

The quality of bentgrass in January or later was not affected by a single September application of ethofumesate, regardless of amount applied in 1984 or 1985 (Table 2). Bentgrass responded similarly to ethofumesate applied in October 1984. However,with 1.7 or 2.2 kg a.i./ha in 1985, the quality of the turfgrass was 38% and 48% lower than nontreated turf, respectively, when ratings were made the following January. By mid-May, the turfgrass had recovered from all treatments (data not shown).

Bentgrass quality was not significantly affected either year by two applications of ethofumesate in September and October at 1.1 kg a.i./ha (Table 2), but two applications at 1.7 kg reduced the quality of bentgrass 29% in 1985 when compared with untreated turfgrass.

When multiple ethofumesate treatments at 1.1 kg a.i./ha were delayed until Oct. and Nov. 1984, the quality of turfgrass treated was reduced slightly but not significantly (12%) the following January (Table 2). However, when the herbicide was applied at the same amount and date in 1985, the turfgrass quality was significantly lower in January (27%) and mid-March (19%) when compared with untreated turfgrass. At 1.7 kg a.i./ha, the quality of bentgrass was lower when ethhofumesate was applied in October and November than in September and October in both years.

In some instances, bentgrass treated with ethofumesate during fall appeared darker green than untreated turfgrass in January both years (Table 2). This is supported by quality values that were >100. This phenomenon was also reported by Dernoeden and Turner in Maryland (6).

On the basis of this study, when two applications of ethofumesate are applied to a 'Penncross' bentgrass putting green in Georgia, treatments should be made in September and October. This is necessary to prevent excessive injury and to maintain the highest turfgrass quality. Injury to bentgrass increases either when the 1.1 kg a.i./ha treatment is delayed or when 1.7 kg is applied twice. In all instances, when bentgrass is injured from ethofumesate, regardless of amount and date applied, the turfgrass fully recovers during the following spring from the herbicide applied the previous fall.

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Preharvest Ethephon Sprays Reduce Superficial Scald of 'Granny Smith' Apples

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Abstract. **Various combinations of preharvest ethephon sprays were applied to 'Granny Smith' apples (*Malus domestica* Borkh). The fruit were harvested twice the first year with selective picking from the interior and exterior of the tree and three times the second year. Scald incidence was measured after storage at 0°C in air for 3 or 6 months plus 1 week at 20°. There was a correlation between scald after storage and fruit soluble solids concentration and firmness at harvest and with conjugated triene levels at harvest or after storage. Ethephon sprays reduced scald incidence between 20% to 75% depending on treatment and storage length.**

Superficial scald is a storage disorder of the peel of many apple cultivars. The etiology of the disorder is not fully understood, but the oxidation products of the sesquiterpene hydrocarbon α-farnesene have been implicated in its development (1, 7). Development of scald is inhibited by postharvest dips in diphenylamine (DPA) or 1,2-dihydro-6-ethoxy-2,2, 4-trimethylquinoline (ethoxyquin) (10). Huelin and Coggiola (8) proposed that DPA controlled superficial scald by preventing the oxidation of α-farnesene. As more countries prohibit the use of DPA and ethoxyquin, however, it becomes necessary to find alternative treatments to control scald.

It has long been known that early picking aggravates the problem of scald (2), although the amount of α-farnesene increases as the fruit ripens. Anet (1) showed that in fruits picked at different stages of maturity, the level of scald was closely related to the amounts of oxidation products of α-farnesene (conjugated trienes) in the peel of the fruit. Since (2-chloroethyl)phosphonic acid (ethephon) accelerates the ripening of fruits to which it is applied (4), we thought that application of ethephon might partly counteract the effect of early picking and thus inhibit scald development on stored fruit. Treatment with ethephon gave positive results in New Zealand (9), and we have tried it in Israel on the scald-susceptible cultivar Granny Smith. The primary objective of this work was to see if accelerating ripening of apples reduced their susceptibility to scald by affecting the oxidation of α-farnesene. The secondary objective was to determine whether ripeness characteristics and α-farnesene and conjugated trienes concentration measured at harvest were correlated with the scald that developed after storage.

Apples were harvested from a 12-year-old orchard that normally has scald-susceptible fruit. The first year one row was sprayed with 500 μl ethephon/liter 12 days before the first harvest. Fruits were harvested from this row and from control (unsprayed) trees two rows away. A second harvest, from unsprayed trees only, followed 1 week after the first. The apples were placed in air storage at 0°C and 85% RH.

In the second year a randomized block de-

Table 1. Effect of a preharvest ethephon spray on ripeness characteristics of 'Granny Smith' apples picked from the interior or exterior of the tree.[z]

Position	Harvest date	Ethephon	SSC (%)	Acidity (%)	Firmness (N)
Exterior	21 Oct.	–	12.1 b	0.61 ab	76 a
	21 Oct.	+	12.8 a	0.57 bc	73 bc
	28 Oct.	–	12.3 b	0.59 bc	69 d
Interior	21 Oct.	–	10.9 d	0.66 a	75 ab
	21 Oct.	+	11.3 c	0.53 c	72 c
	28 Oct.	–	11.2 c	0.57 bc	72 c

[z]Mean separation within columns by Duncan's new multiple range test, 5% level.

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