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Root Growth, Seedhead Production, and Quality of Annual Bluegrass as Affected by Mefiuidide and a Wetting Agent[1]

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ABSTRACT

Annual bluegrass *[Poa annua* ssp. *reptans* (Hauskins) I imm.| often comprises a large portion of golf course greens, yet its shallow root system and extensive seedhead production limit its turf quality. The purpose of this investigation was to determine if annual bluegrass seedheads could be suppressed and rooting enhanced by the plant growth regulator mefiuidide |/V-(2,4-dimethyl-5-|[(trifluoromethyl)sulfonyl)amino| phenyl)acetamide) and the wetting agent Aqua-Gro (polyoxyethylene esters and ether of cyclic acid and alkylated phenols, silicone anti-foam emulsion). Chemicals were applied prior to seedhead emergence during 1983 and 1984 to annual bluegrass grown in a rhizotron in fine quartz sand. Root elongation of mefluidide-treated annual bluegrass was superior to the control for 2 to 4 weeks following Spring 1983 application. Maximum rooting depth of mefluidide-treated turf was significantly greater than that of Aqua-Gro-treated or untreated turf during May 1983. Aqua-Gro applied at either 4.2 or 8.4 L ha ' generally did not affect rooting. In 1983, mefiuidide (0.07 or 0.14 kg ha ') prevented seedhead emergence throughout the entire seedhead production period (approximately 8 weeks) when applied under environmental conditions favoring uptake. Leaf tip yellowing occurred for 3 to 4 weeks following mefiuidide application. Mefluidide-treated turf, however, exhibited quality superior to untreated turf for approximately 6 weeks following discoloration. Aqua-Gro provided little seedhead suppression and reduced quality for about 10 days following application. In 1984, environmental conditions were not conducive to chemical uptake so 1983 results were not corroborated. Mefiuidide appears promising as an annual bluegrass management tool; however, more information is needed to determine the influence of environmental conditions on mefiuidide uptake and its ability to suppress seedheads and enhance rooting at low rates.

***Additional index words:* *Poa annua* L., Growth retardant. Growth regulator. Wetting agent.**

ANNUAL bluegrass *{Poa annua* L.) often comprises a large portion of the turfgrass sward on golf courses in cool humid climates and has been characterized as having an inherently shallow and poorly developed root system (9,19,20). Rhizotron studies by Kucharski and Karnok (9) revealed that the root growth of creeping bentgrass *(Agrostis palustris* Huds.) was threefold greater than that of annual bluegrass throughout much of the growing season. Koski (8) monitored the root growth of five cool-season turfgrasses and found that, except for the first 20 weeks of establishment, annual bluegrass was consistently the most shallow-rooted.

It has been suggested that annual bluegrass has erroneously gained a reputation of being shallow-rooted based on growth observations made under compacted conditions since annual bluegrass is successful at colonizing highly compacted turf areas where more desirable turfgrasses cannot persist (1). Regardless of the reason for the shallow root system, annual bluegrass does exhibit restricted rooting under typical golf course conditions, which often limits its stress tolerance and turfgrass quality.

In addition to its shallow root system, extensive spring seedhead production is a major factor limiting the quality of annual bluegrass turf. Annual bluegrass is a prolific seed producer, with virtually every mature tiller producing an inflorescence (12). There is reason to believe that the restricted rooting of annual bluegrass may be due at least in part to the monopolization of assimilates by developing seedheads during the spring season (9,12). Reduced root growth following flowering and seed production has been noted in other grasses (13,17).

The plant growth regulator mefiuidide [N-(2,4-dimethyl-5-|[(trifluoromethyl) sulfonyl] amino} phenyl) acetamide] and the wetting agent Aqua-Gro (polyoxyethylene esters and ether of cyclic acid and alkylated phenols, silicone anti-foam emulsion; Aquatrols Corp. of America, Pennsaukin, NJ) are capable of suppressing seedhead formation in annual bluegrass (6,14). The objective of this research was to determine if chemical seedhead suppression using mefiuidide or Aqua-Gro would result in a higher quality turf with a better developed root system than untreated annual bluegrass.

MATERIALS AND METHODS[3]

Rooting studies were conducted at the Ohio State University Turfgrass Rhizotron, Columbus, OH (7). Fifteen observation cells (60 by 60 by 90 cm deep) were used for the study. Each cell consisted of three 1.9-cm-thick plywood walls and a viewing panel of 9.5-mm-thick plate glass (60 by 90 cm) set at an angle of 20° from vertical. Cells were filled by adding washed, fine quartz sand in 20-L increments. The sand was leveled by hand and packed between each increment using a wooden tamping tool to assure uniform bulk density throughout each cell. Bulk densities among cells averaged 1.45 ± 0.09 g cm^{-1}.

Seed of a perennial ecotype of annual bluegrass *[Poa annua* ssp. *reptans* (Hauskins) Timm.] was used to establish the rhizotron cells on 18 Aug. 1982. Because the seed was unprocessed and contained inert matter, it was not possible to calculate an exact seeding rate. However, the establishment rate was sufficient to provide a full turf cover over the rhizotron cells within 8 weeks.

The turf was fertilized weekly during establishment and throughout the growing season, using Hoagland's solution (5) to supply 9 kg N, 2.6 kg P, and 12 kg K ha ' $week^1$. The turf was mowed three times weekly with a reel mower at a height of 19 mm. Irrigation was applied only to alleviate severe moisture stress. Fungicides were applied on a preventative basis at recommended rates and included: benomyl [Methyl l-(butylcarbamoyl)-2-benzimidazolecarbamate]; chlorothalonil (tetrachloroisophthalonitrile); iprodione [3-(3,5-dichlorophenyl)-N-(l-methylethyl)-2,4-dioxo-l-imidazolidinecarboxamide); mercury chloride; and triadimefon [1-

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[3] **Trade** and company names are included for the benefit of readers and do not imply endorsement by the authors or The Ohio Slate University.

(4-chlorophenoxy)-3,3-dimethyl-1 -(1H-1.2.4-triazol-1 -y 1)-2-butanone]. The insecticides dylox [dimethyl (2.2,2-trichloro-1-hydroxyethyl) phosphonate] and diazinon *[0,0-dielhyl O-*(2-isopropyl-4-methyl-6-pyrimidinyl) phosphorothioate] were applied at recommended rates as needed to control sod webworm *(Pediasia trisecta* Wlk.). black turfgrass ataenius *(Ataenius spretulus* Haldeman) and ants *(Lasius alienus* Foerster). No herbicides were used during the course of the study.

Chemical treatments were applied to rhizotron turf on 31 Mar. 1983 and 10 Apr. 1984 when inflorescences could be felt in the leaf sheath but had not yet emerged. Mefluididc was applied at 0.07 and 0.14 kg a. i. ha 'in both years. Aqua-Gro was applied at 4.2 and 8.4 L ha 'in 1983. As a result of 1983 findings, Aqua-Gro treatments were discontinued in 1984 and an additional rate of mefluididc (0.21 kg a.i. ha ') was evaluated. Plots were whole cells with treatments arranged in a completely randomized design, with three replications per treatment. All treatments were applied using a CO^-powered backpack sprayer at 276 kPa pressure delivering 600 L ha '.

Rooting Parameters

Rooting parameters monitored regularly throughout the study included root elongation rate and maximum rooting depth. Root color and root thickness were noted when appropriate. All parameters were monitored by exposing the root system to long-wave ultraviolet light (366 nm). Exposure to ultraviolet light induced a fluorescence that made the roots more easily seen than when using visible light.

Ultraviolet fluorescence photography was used to record root elongation on a weekly basis from March through November, and biweekly from December through February during the study. Roots were exposed to ultraviolet light while photographed using a tripod-mounted 35-mm camera equipped with a yellow (Y2) filter. Kodak Panatomic X black and white film (ISO 32) (Eastman Kodak Co.. Rochester. NY) was used with a 1.4 f-stop setting and a 1 -min exposure. This film is fine grained and provided good contrast between the white roots and the dark brown sand background. Negatives were mounted and stored for later root elongation determinations.

Root elongation rates were calculated from projected negatives using a method similar to that described by Reicosky et al. (15). Negatives were projected onto a vertical frosted glass surface using a standard slide projector. Transparent acetate sheets were attached to the screen so that the projected images could be traced onto the sheets using colored pens. A different color pen was used for each projected negative to represent the amount of root elongation since the previous observation date. A total of seven dates (negatives) could be recorded on each acetate sheet. The total rooting area of each cell recorded in this manner was 26.6 cm wide and 21.5 cm deep.

The color-coded pen tracings were then measured with a LASICO Model XD electric opisometer (Los Angeles Scientific Instrument Co., Los Angeles. CA). This procedure allowed quantification of root elongation in each cell for the observation period. By noting the number of roots traced per observation date, a mean root elongation rate (mm of growth root ' week ') was calculated for each cell. Maximum rooting depth was determined at least twice monthly for each root system, and was defined as the depth to which at least 10 fluorescing roots had penetrated.

Aerial Quality Parameters

Counts of seedheads were made weekly throughout the spring seedhead development period. Counts were made prior to mowing, usually 2 days following the previous mowing. Both partial and entire inflorescences were counted when determining seedhead number. A 100-cm frame was placed randomly on each plot, and the total number of inflorescences within the frame were counted.

Weekly visual quality ratings were made during the growing season using a scale of 1 to 9, with 1 representing brown, low quality turf and 9 representing dark green, high quality turf. Turfgrass quality is a composite of several characteristics, including uniformity, density, texture, and color. For annual blucgrass turf, the presence of seedheads also greatly affects turfgrass quality. All of these factors were considered when making quality ratings.

Data Analysis

All aerial quality and rooting parameters were subjected to a standard analysis of variance technique (ANOVA) using the Statistical Analysis System (16). Seedhead density data were transformed prior to the ANOVA using the log transformation, log,,, (seedheads 100 cm~ + 1). This was necessary because the sample variances were positively correlated with their means (10). Fischer's LSD test or Duncan's Multiple Range test were employed as needed for mean separation when the ANOVA F-test indicated that the treatment effect was significant.

RESULTS AND DISCUSSION

Root Elongation Rates

1983 Treatments

Mean root elongation rates did not vary significantly among cells when observed on 30 March, prior to treatment application (Table 1). Root elongation of Aqua-Gro-treated and untreated annual bluegrass decreased 14 and 39%, respectively, during heavy seedhead development (13 April-11 May). The root elongation rate of annual bluegrass treated with Aqua-Gro did not differ statistically from the control for any weekly observation period from April through June. Mefluidide-treated annual bluegrass (0.07 and 0.14 kg ha"') exhibited greater root elongation than untreated plants for 2 and 4 weeks following application, respectively.

Root elongation during May in response to mefluidide (mean of both rates) was 1.5 and two times greater than root elongation for Aqua-Gro or the control, respectively. Substantial variability in root elongation within treatments, however, precluded the detection of statistically significant differences among treatments during May. This variation may have been due to differential root age, genotypic variation within plots, or a combination of the two factors.

On 9 and 10 July, drought stress combined with maximum daily air temperatures of 32°C resulted in the death of annual bluegrass on several of the rhizotron plots. Damage to injured plots was localized at the front of the cell where the sand rooting media was most shallow (due to the slant of the observation glass). Severe damage occurred on Aqua-Gro-treated and untreated cells, with the zone of dead turf extending about 7 cm back into the plots. Mefluidide-treated turf suffered little damage, with injury extending less than 1 cm into the plots. Differential stress tolerance among treatments was further reflected in root elongation rates during July and August (Table 1).

Root growth of injured, untreated turf declined from 5 mm root 'week ' on 6 July to less than 1 mm root '

Table 1. Effect of chemical treatments on the average weekly root elongation rate of annual bluegrass, 30 Mar. through 31 Aug. 1983.

Chemical†	Application rate	March	April				May				June					July				August				
		30	6	13	20	27	4	11	18	25	1	8	15	22	29	6	13	20	27	3	10	17	24	31
		mm of growth root^{-1} wk^{-1}																						
Mefluidide	0.07 kg a.i. ha^{-1}	7.5a‡	10.3a	10.6a	8.1ab	7.4ab	8.7a	7.4a	7.1a	7.8a	6.8a	6.5a	6.7a	6.2a	5.4a	6.9a	7.3a	6.3ab	6.5ab	5.9ab	8.5a	7.6ab	7.2a	7.9a
	0.14 kg a.i. ha^{-1}	7.8a	10.3a	10.3a	9.3a	8.3a	8.7a	10.2a	8.9a	7.5ab	7.2a	6.6a	6.3a	5.5a	5.3a	5.7b	7.5a	8.4a	7.1a	8.3a	9.3a	9.8a	10.3a	8.9a
Aqua-Gro	4.2 L ha^{-1}	6.2a	6.4b	6.5ab	5.9b	4.8b	5.5a	5.7a	5.9a	6.1abc	5.9a	6.1a	5.0a	4.5a	4.5a	5.4b	5.2b	4.3bc	3.6ab	3.8bc	5.9ab	6.1bc	6.6a	6.4a
	8.4 L ha^{-1}	5.8a	5.9b	6.3ab	5.5b	5.1ab	4.7a	5.3a	6.1a	5.3bc	5.2a	4.9a	4.7a	4.7a	4.9a	5.7b	5.3b	4.2bc	3.0b	1.7c	4.1bc	4.5c	7.8a	7.3a
Untreated control		6.0a	5.6b	5.6b	5.0b	4.6b	4.0a	3.4a	4.0a	4.8c	6.6a	5.2a	5.2a	4.4a	4.2a	5.0b	3.6c	3.6c	3.0b	0.4c	0.5c	6.0bc	8.6a	8.6a
CV (%)		12	8	29	24	28	40	57	28	19	26	20	21	24	17	9	10	21	43	50	35	24	25	26

† Treatments applied 31 Mar. 1983. ‡ Values within columns followed by the same letter do not differ significantly at $P = 0.05$ according to Fischer's LSD.

week^{-1} during the first week of August. Root elongation of injured, Aqua-Gro-treated turf declined from an average of 5.6 to 2.8 mm root^{-1} week^{-1} during the same period. New annual bluegrass seedlings emerged from the soil seed reservoir during the first week of August and exhibited root elongation rates ranging from 6 to 8.6 mm root^{-1} week^{-1} through the end of August. These seedlings rapidly colonized the dead areas, in the absence of further drought stress, and provided complete turf cover by 30 September.

The average root elongation rate of mefluidide-treated turf did not decline during July and early August as did that of stress injured plants in untreated and Aqua-Gro-treated plots. Evidently, mefluidide-treated plants were better able to withstand early July heat and drought stress because of improved rooting that occurred earlier during April. Mefluidide applied at 0.07 or 0.14 kg ha^{-1} resulted in root growth superior to that of stress injured, untreated plants for 5 and 6 weeks, respectively, from 6 Julv through 17 August (Table 1).

Root elongation of mefluidide- and Aqua-Gro-treated turf did not vary significantly among treatments from September 1983 through March 1984 (data not presented). Root elongation rates during January averaged 2.6 mm root^{-1} week^{-1} despite maximum daily soil temperatures at a 15-cm depth averaging 0.2°C. The ability of turfgrass roots to maintain growth at soil temperatures near freezing or below has been observed previously (8,18).

Root growth increased dramatically during the final 2 weeks of February 1984 in response to unseasonably warm temperatures (data not presented). Mean maximum daily air and soil temperatures at 15 cm during February were 8.2 and 5.4°C, respectively. These temperatures were 5.7 and 3.8°C above normal, respectively, based on a 20-yr average. Noticeable annual bluegrass greenup was observed by 13 February. Mean root elongation, regardless of the Spring 1983 treatment, was 8.9 mm root^{-1} week^{-1} in February, and increased to 15.5 mm root^{-1} week^{-1} during March.

1984 Treatments

The root elongation rate of annual bluegrass during 1984 did not vary among cells prior to mefluidide application on 10 April (Table 2). Unlike 1983, mefluidide treatment in 1984 at 0.07 or 0.14 kg ha^{-1} did not result in greater root elongation rates than for untreated plants immediately following application. These results were attributed to the unfavorable environmental conditions previously discussed. Root growth of turf treated with mefluidide at 0.21 kg ha^{-1}, however, was superior to rooting in response to all other treatments during the final 3 weeks of April. Root elongation of plants in response to the high (0.21 kg ha^{-1}) mefluidide rate was consistently greater than that of the two lower rates throughout May and June. Differences in root elongation among treatments, however, were statistically significant only on 23 May, 30 May, and 27 June. As in 1983, inherent variability of rooting within treatments made establishment of statistical significance difficult. Root elongation did not vary among treatments during July and August (data not presented).

Maximum Rooting Depth

1983 Treatments

Maximum rooting depth for all annual bluegrass root systems ranged from 50 to 57 mm on 30 March, prior to chemical application (Table 3). The average maximum rooting depth of untreated and Aqua-Gro-treated plants declined from 64 and 60 mm, respectively, on 13 April, to 47 mm for both Aqua-Gro-treated and untreated turf on 11 May. This decline coincided with heavy seedhead production. During the same period, the average maximum rooting depth of mefluidide-treated turf increased from 57 to 68 mm. Mefluidide-

Table 2. Effect of mefluidide rate on the average weekly root elongation rate of annual bluegrass, 4 Apr. to 27 June 1984.

Mefluidide rate	April				May					June			
	4	12	18	25	2	9	16	23	30	6	13	20	27
kg a.i. ha^{-1}	mm of growth root^{-1} week^{-1}												
0	13.0a‡	13.4b	15.2b	7.7b	6.2a	5.5a	6.1a	5.5b	5.3b	5.2b	8.7a	8.7a	8.1b
0.07	14.9a	14.1b	13.7b	7.9b	7.1a	6.5a	6.1a	5.9b	6.5b	7.9ab	8.9a	7.0a	6.6b
0.14	12.5a	10.5b	14.0b	8.0b	5.4a	6.0a	6.3a	6.8b	6.2b	7.3b	6.9a	7.1a	8.3b
0.21	14.8a	20.0a	22.5a	14.8a	12.3a	11.7a	11.3a	12.1a	10.6a	10.7a	11.5a	12.1a	12.8a
CV (%)	18	18	18	30	48	38	33	29	22	23	40	40	25

† Treatments applied 10 Apr. 1984. ‡ Values within columns followed by the same letter do not differ significantly at $P = 0.05$ according to Fischer's LSD.

Table 3. Effect of chemical and application rate on the maximum rooting depth of annual bluegrass, 30 Mar. to 31 Aug. 1983.

Chemical†	Application rate	March	April		May		June		July				August			
		30	13	27	11	25	8	22	6	13	20	27	3	10	17	31
		rooting depth (mm)														
Mefluidide	0.07 kg a.i. ha⁻¹	54a‡	60a	65a	70a	76b	80a	80a	74a	74a	73a	71a	70a	71a	70a	76a
Mefluidide	0.14 kg a.i. ha⁻¹	50a	54a	59a	65a	68a	75a	82a	75a	75a	73a	71a	70a	73a	67a	75a
Aqua-Gro	4.2 L ha⁻¹	52a	58a	51a	45b	52b	60a	66a	69a	60a	54b	34b	27b	38b	49b	63a
Aqua-Gro	8.4 L ha⁻¹	57a	62a	56a	48b	55b	64a	71a	72a	63a	56ab	39b	32b	43b	54ab	69a
Untreated control		56a	64a	57a	47a	53b	63a	68a	68a	59a	52b	35b	13b	22b	45b	69a
CV (%)		13	11	10	12	13	12	9	11	12	15	18	21	22	16	10

† Treatments applied 31 Mar. 1983.
‡ Values within columns followed by the same letter do not differ significantly at $P = 0.05$ according to Fischer's LSD.

treated turf exhibited significantly greater rooting depth than either untreated or Aqua-Gro-treated turf during May. This suggests that inhibition of seedhead development using mefluidide prevented the decline in rooting depth observed with other treatments.

Severe drought and heat stress on 9 and 10 July resulted in root mortality and root dieback in untreated and Aqua-Gro-treated turf during July and August (Table 3). The maximum rooting depth of untreated and Aqua-Gro-treated turf declined from 68 and 71 mm, respectively, on 6 July, to 13 and 30 mm, respectively, on 3 August. The root systems of mefluidide-treated turf maintained a depth of 67 to 75 mm from 6 July through 17 August. As with root elongation, effective seedhead suppression and improved rooting during spring provided improved stress tolerance during early July. Rooting depth of untreated (13mm) and Aqua-Gro-treated (27-32 mm) turf on 3 August increased to 69 and 66 mm on 31 August, respectively. This increased rooting depth was attributed to new seedling growth from annual bluegrass seed present in the soil.

The root color of injured, untreated, and Aqua-Gro-treated annual bluegrass changed from predominantly white before early July stress to completely brown within 7 days following stress injury. This was the only time during the study when root color varied notably among treatments. Rhizotron soil temperature at 15 cm during the first 2 weeks of July averaged 28.5°C. Bogart (2) reported that the roots of annual bluegrass begin to turn brown as soil temperatures rose above 27°C, indicating a reduction in normal root function.

Maximum rooting depth did not vary significantly among treatments from September 1983 through March 1984 (data not presented). Rooting depth, averaged for all treatments, declined from 82 mm during September 1983 to a minimum of 40 mm during December and January 1984. The peak rooting depth of 82 mm observed during September agrees closely with the maximum annual bluegrass rooting depth of approximately 86 mm observed in Ohio rhizotron studies during October reported by Kucharski and Karnok (9). During 1984, maximum rooting depth averaged for all treatments increased rapidly from 40 mm during January to 81 mm during March as a result of uncharacteristically high maximum daily air temperatures during February (8.2°C average maximum).

Substantial visual changes in root morphology were noted for all root systems during February. Root turnover (i.e., formation of new roots in association with senescence of older roots) was at a maximum during late February and early March. New roots produced

Table 4. Effect of chemical and application rate on annual bluegrass seedhead density, 1983 and 1984.

Application rate	1983									
	April					May				June
	1	10	15	22	29	6	14	20	27	3
	seedheads 100 cm⁻¹									
Mefluidide†										
0.07 kg a.i. ha⁻¹	9a‡	10b	23b	22b	17d	8b	7b	7b	13a	1a
0.14 kg a.i. ha⁻¹	9a	8b	15b	14b	2e	0c	1c	3c	7a	2a
Aqua-Gro										
4.2 L ha⁻¹	10a	30a	45a	54a	57b	31a	20a	16a	9a	5a
8.4 L ha⁻¹	10a	35a	49a	40a	39a	19a	13a	14a	10a	1a
Untreated control	10a	33a	50a	59a	83a	23a	15ab	12ab	9a	4a

Application rate	1984										
	April		May					June			
	seedheads 100 cm⁻²										
Mefluidide											
0.07 kg a.i. ha⁻¹	5a‡	10b	18a	24b	17b	8b	4a	6a	11b	5b	0a
0.14 kg a.i. ha⁻¹	5a	6b	19a	21b	19b	9b	6a	11a	6c	3bc	0a
0.21 kg a.i. ha⁻¹	7a	10b	23a	25b	14b	12b	6a	9a	8bc	2c	0a
Untreated control	10a	22a	30a	42a	45a	20a	11a	10a	23a	9a	0a

† Treatments applied 31 Mar. 1983 and 10 Apr. 1984.
‡ Means within dates followed by different letters are significantly different according to Duncan's Multiple Range test (0.05). Duncan's Multiple Range is based on the analysis using transformed [log $_{10}$ (seedheads 100 cm^{-2} + 1)] data.

Table 5. Effect of chemical and application rate on annual bluegrass quality, April through June 1983.

Chemical†	Application rate	April				May				June		
		10	13	22	29	6	14	20	27	3	10	24
		turfgrass quality‡										
Mefluidide	0.07 kg a.i. ha^{-1}	5.7bc§	5.2b	5.5b	6.7a	8.3a	7.3b	7.3b	8.2a	8.2a	7.5ab	8.8a
	0.14 kg a.i. ha^{-1}	5.0c	4.5b	4.7c	3.5c	8.3a	8.5a	8.2a	8.5a	8.7a	7.8a	8.3a
Aqua-Gro	4.2 L ha^{-1}	6.3b	6.7a	6.7a	4.8b	6.5c	6.0c	6.3c	7.2b	7.0b	6.3bc	8.0a
	8.4 L ha^{-1}	6.5b	6.7a	6.7a	6.0a	7.3b	6.5c	6.3c	7.0b	7.3b	6.7a	8.3a
Untreated control		7.5a	7.5a	6.8a	4.5b	6.0d	6.0c	6.0c	6.8b	6.5b	5.2c	7.5a

† Treatments applied 31 Mar. 1983.
‡ 1 = brown, low quality turf; 9 = dark green, ideal turf.
§ Values within columns followed by the same letter do not differ significantly at $P = 0.05$ according to Fischer's LSD.

during February were localized primarily in the upper 5 cm of the profile, fluoresced brightly, and were notably thicker than older roots remaining from 1983. Older roots fluoresced weakly, were spindly in appearance, and were evenly distributed throughout the profile. These older roots ceased all growth and turned brown within 4 weeks following the onset of new root initiation.

1984 Treatments

The rooting depth of annual bluegrass in response to the 10 April mefluidide application did not vary among treatments during 1984 (data not presented). The decline in rooting depth of untreated plants observed during spring seedhead development in 1983 was not evident during 1984. Mean rooting depth remained constant for all treated plants during May 1984 (121 mm) even though considerable seedhead emergence was occurring. Mefluidide-treated turf averaged 15 seedheads 100 cm^{-2} during May 1984, which was not extensive enough to inhibit the rooting depth of mefluidide-treated turf. The average seedhead density of untreated turf for 8 weeks following initial seedhead emergence was 26 seedheads 100 cm^{-2} during 1984 compared to 36 seedheads 100 cm^{-2} during 1983. It is possible that an average of 26 seedheads 100 cm^{-2} was below the threshold seedhead density required to adversely affect the rooting depth of untreated turf.

Rooting depth, averaged for all treatments, decreased from 123 mm on 31 May to 93 mm on 13 June (data not presented). This decline in rooting depth was associated with an increase in the average maximum daily air temperature from 23°C during the final 2 weeks of May to 32°C during the first 2 weeks of June. Maximum rooting depth did not differ statistically among treatments from 13 June through 5 September. Rooting depth, averaged for all treatments, during June, July, and August was 86, 77, and 75 mm, respectively.

Seedhead Density

The seedhead density of untreated turf in 1983 peaked at 83 seedheads 100 cm^{-2} on 29 April, 4 weeks after initial seedhead emergence (Table 4). Mefluidide applied at both 0.07 and 0.14 kg ha^{-1} reduced seedhead density compared to the control for a period of 5 and 7 weeks, respectively, following application. The wetting agent Aqua-Gro at either 4.2 or 8.4 L ha^{-1} was ineffective in preventing seedhead development except during peak seedhead emergence on 29 April. On this date, Aqua-Gro-treated turf had fewer seedheads than the control, but more than turf treated with either rate of mefluidide. Seedhead production began to decrease during early May. Thus, as existing inflorescences were removed via mowing, seedhead density decreased and did not vary among treatments after 20 May.

During extensive seedhead emergence (10 Apr.-6 May 1983), mean seedhead density (averaged for both application rates) was suppressed 76 and 20% by mefluidide and Aqua-Gro, respectively. Petrovic et al. (14) evaluated similar rates of mefluidide and Aqua-Gro for seedhead suppression and observed average reductions of 66 and 21%, respectively, during the period of peak seedhead emergence. After evaluating 1983 results, Aqua-Gro was excluded from the 1984 study and a 0.21 kg ha^{-1} rate of mefluidide was added to determine if a higher rate would improve seedhead suppression without substantially increasing discoloration.

In 1984, maximum seedhead density of untreated turf occurred 4 weeks after the onset of seedhead emergence (Table 4). All rates of mefluidide reduced seedhead density for 6 of 9 weeks following seedhead emergence on 15 April. Seedhead reduction averaged over all rates of mefluidide, however, was only 50% for the period of 24 April through 19 June 1984. This level of seedhead suppression was substantially lower than expected based on 1983 data and previous observations (4,6). The relatively poor seedhead suppression during 1984 was probably a result of suboptimal mefluidide uptake and translocation due to adverse environmental conditions. McWhorter and Wills (11). working with soybean {*Glycine max* (L.) Merr.] and Johnsongrass [*Sorghum halepense* (L.) Pers.], found that as air temperature decreased from 32 to 22°C, mefluidide absorption decreased two- to threefold, and translocation decreased four- to eightfold. In this study, skies were cloudy and the temperature was 10°C when 1984 mefluidide treatments were applied. Thus, the combination of low application rates and undesirable environmental conditions probably resulted in suboptimal mefluidide uptake and reduced inhibition of seedhead emergence.

Turfgrass Quality

The effect of mefluidide and Aqua-Gro on annual bluegrass quality from April through June 1983 is summarized in Table 5. The quality of turf treated with mefluidide at 0.07 or 0.14 kg ha^{-1} was significantly reduced when compared to that of the control for 3 and 4 weeks, respectively, following application.

Table 6. Effect of mefluidide on annual bluegrass quality, 17 apr. to 18 July 1984.

Mefluidide rate†	April		May					June		July	
	17	24	1	8	15	23	29	5	19	3	18
kg a.i. ha⁻¹	turfgrass quality‡										
0	5.8a§	5.5a	5.5b	4.7a	4.2d	5.3a	6.2b	6.2a	6.5a	6.8b	7.5a
0.07	6.0a	5.3a	6.5a	5.0a	5.0c	5.8a	6.8ab	6.8a	6.2a	6.7b	7.3a
0.14	5.8a	4.5a	5.7ab	5.5a	5.8b	5.8a	6.5b	6.7a	6.2a	6.7b	7.0a
0.21	5.2a	4.3a	4.5c	5.7a	6.5a	6.7a	7.3a	7.0a	6.8a	7.8a	7.8a

† Treatments applied 10 Apr. 1984.
‡ 1 = brown, low quality turf; 9 = dark green, ideal turf.
§ Values within columns followed by the same letter do not differ significantly at $P = 0.05$ according to Fischer's LSD.

This was due to leaf tip yellowing associated with mefluidide treatment. Following this initial discoloration, turf treated with mefluidide at 0.07 and 0.14 kg ha ' was seedhead free and darker green than untreated turf for 7 and 6 weeks, respectively.

Aqua-Gro at both rates initially reduced turfgrass quality compared to untreated turf for about 10 days due to leaf tip discoloration. Aqua-Gro applied at 8.4 L ha ' resulted in turfgrass quality superior to untreated turf on 29 April, 6 May, and 10 June (Table 5) with little effect on quality for the remainder of the growing season. Annual bluegrass quality from July through November 1983 was not affected by spring application of mefluidide or Aqua-Gro (data not presented).

The turfgrass quality responses associated with mefluidide application in 1983 were not evident during 1984, presumably due to suboptimal mefluidide uptake (Table 6). Initial discoloration associated with mefluidide application was far less evident than in previous evaluations (3). This lack of discoloration is indirect evidence of decreased mefluidide uptake. No substantial differences in turfgrass quality were noted until 1 May when turf treated with mefluidide at 0.21 kg ha ' showed lower quality than all other treatments. Mefluidide application at all rates resulted in quality better than that of the untreated turf on 15 May due to the heavy seedhead cover of untreated turf. In general, the 0.21 kg ha ' rate of mefluidide was the only rate that caused a significant reduction in initial turfgrass quality (1 May) followed by an enhancement of quality later in the season (15 May, 29 May, and 3 July). No differences in quality were observed among treatments after 3 July.

CONCLUSIONS

Mefluidide appears to have merit as a management tool for improving annual bluegrass turf. When applied under environmental conditions conducive to uptake, rates as low as 0.07 kg ha ' provided very good seedhead inhibition and prevented the rooting decline observed in flowering annual bluegrass. A potential problem with mefluidide application is that temperatures are often cool and rainfall frequent during spring. Thus, the potential for suboptimal uptake may often be a concern. Application at 0.14 kg ha ' is suggested if environmental conditions are conducive to good uptake in order to reduce the potential for increased discoloration associated with higher mefluidide rates. Aqua-Gro did not show promise as an inhibitor of annual bluegrass seedheads in this study and generally had little effect on rooting.

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